canada/yukon subsidiary
agreement on mineral resources

Program 3 Placer Mining

MATERIAL HANDLING TECHNOLOGY

Volume 1

Wright Engineers Ltd.

Canadä

Yukon

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Project No. 1401
June 16, 1986.

Department of Renewable Resources
Yukon [illegible]orial Government
P.O. Box [illegible]
Whitehorse, Yukon Territory
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Attention: Mr. J.A. Kuhn, M.Sc.
Project Officer

Dear Mr. Kuhn:

Re: Materials Handling Technology
Contract YEDA 07

In accordance with the statement of work for the above study, we are pleased to present ten copies of our report on materials handling methods for Yukon placer mining.

The report is in two volumes for ease of reference. The text is contained in Volume I and the drawings, photographs and calculation sheets in Volume II.

The study team has enjoyed working on this very interesting project and join me in acknowledging the high level of support and assistance we have been given by members of the Northern Affairs Program and the Territorial Government.

Yours very truly,

WRIGHT ENGINEERS LIMITED

J. Leader, P.Eng.
Project Manager.

JL/sd

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SECTION 1

INTRODUCTION

1.1 BACKGROUND

This study was commissioned by the Northern Affairs program of the Department of Indian Affairs and Northern Development (DIAND). The study was funded by the Canada/Yukon Economic Development Agreement (YEDA), as part of a series of research programs to assist the placer mining industry. The objective of this study was to examine all aspects of materials handling in the Yukon placer mining industry and recommend "Best Practical Technology" for all areas of materials handling.

1.2 TERMS OF REFERENCE

The terms of reference for this study were outlined in the Request for Proposal from the Northern Affairs Program (NAP). A summary is given below:

Objective

The objective of the study was to develop what was termed "Best Practical Technology" for all phases of materials handling. This was to serve as guidance to placer miners when determining the most cost effective methods for handling material in a mining operation. The study work was to include a thorough review of site reclamation with the objective of developing the most practical methods of stripping overburden and also investigate the practicality of integrating surface reclamation work concurrently with mining operations.

Scope of Work

The study was to develop a classification system, based on terrain characteristics, for the range of placer operations that exist now or will exist in the future. Materials handling methods were to be developed for each class of deposit for the following areas:

- Stripping vegetation cover and black muck overburden.
- Disposing of waste gravels.
- Mining and processing of pay gravels.
- Disposing of sluice tailings and settling pond sediments.
- Reclamation of mined areas, including recommendations on appropriate levels of reclamation and how these should form part of the operating licence.

The scope of work included a review of mining operations in other placer mining fields and methods of materials handling and site reclamation used in other allied industries (e.g. gravel quarries, china clay industry, etc.). This review was intended to bring forward alternative technology not currently used in the Yukon, but which could be incorporated into placer mines and lead to increased efficiency, reduced costs and improved reclamation.

As a second stage to the study, a report was required detailing a work plan for a "Demonstration Project". This report was to outlined both the philosophy of how to set up a demonstration project and recommend appropriate techniques to be tested.

1.3 STUDY EXECUTION

The study was officially awarded to Wright Engineers Limited (WEL) on September 25, 1985. WEL was the prime contractor for the study. Mrs. R. Debicki acted as a sub-consultant, providing local placer mining and geological knowledge. Norecol Environmental Consultants Limited acted as sub-consultants on site reclamation.

Immediately following award of the study, Mr. R.J. Leader (WEL), and Mrs. R. Debicki undertook a field trip to visit placer mining operations in the Klondike and Mayo districts of the Yukon. The purpose of this ten day trip was to observe the different aspects of placer mining and to supplement data already gathered by Mrs. Debicki on the methods of operation and the types of materials being handled. Samples of these materials were collected at a number of sites and analyzed for size distribution.

In order to understand the problems that occur when handling placer materials, the study team met with officials from the NAP and Yukon Territorial Government (YTG) and those placer miners who were still working at their properties. Subsequent to the field visit, the study team contacted placer miners who reside in the Vancouver area and discussed materials handling problems with them.

A site visit report outlining the study teams' observations was presented on November 1, 1985 to the Project Steering Committee. Included in the report were recommendations on a suitable system for site classification and suggestions on what alternative materials handling methods should be studied.

Following the site visit and production of the interim site visit report, the emphasis in the scope of work was redirected to allow the study to concentrate on developing alternative materials handling systems. In particular to develop pumping schemes to handle feed gravels and sluice tailings, as these were of particular interest to many placer miners as a means of reducing costs and helping in site reclamation.

The execution of the study included the following:

- Developing criteria for site classification system. Assigning existing operations and potential future mining areas to the classification system.
- Analyzing existing methods of operation and their costs. Determining the areas where alternative handling methods could be applied.

- Conducting a literature research on methods being used in other placer mining areas and other industries. Contacting operations that utilize pumping and conveying systems to move gravel type materials.

- Designing conceptual pumping and/or conveying systems and estimating the costs of using these methods. Providing example layouts of mining operations to show the effects that pumping and conveying of materials might have on the operation of these example placer mines.

- Assessing the effect that alterntaive methods might have on the reclamation of placer operations. Recommending appropriate levels of reclamation based on deposit location and end-use.

- Recommending alternative handling systems that should be tested as part of a field demonstration. Suggesting alternative methods of carrying out a field demonstration project and the expected costs.

This report closely follows the sequence of project execution.

In Section 2 the important findings of the study are summarized.

In Section 3 the site classification system is developed. The categories of material present at Yukon placer operations are also developed in Section 3.

In Section 4 the current methods used to handle the various materials at each type of deposit are described. The costs of equipment used in Yukon placer operations and the operating costs for moving different types of material are listed in Section 4.

Section 5 contains the results of researching materials handling methods used elsewhere. References are given to papers or articles written about methods used in other areas. Specific operations using alternative means of materials handling are included with costs, when available.

Section 6 describes the conceptual design for alternative handling systems, including lists of the types of equipment available commercially and the purchase costs. Examples of applying alternative handling techniques in different deposits are included.

As the comparative costs of using alternative versus traditional methods to move material will have a significant impact on their implementation. The costs for alternative systems have been compared to those developed in Section 4 for traditional methods.

Section 7 forms a summary of WEL's recommendations for the "Best Practical Technology" to move the different categories of material.

All aspects of reclamation are covered in Section 8. This includes an assessment of current reclamation techniques, techniques used elsewhere and the effect alternative handling systems might have on reclamation. The section concludes with a discussion on what might be the appropriate levels of reclamation for placer mines and advice on setting out guidelines for placer miners to follow.

1.4 ACKNOWLEGEMENTS

Wright Engineers Limited would like to gratefully acknowledge the assistance given during this study by members of DIAND, the Yukon Territorial Government and the Yukon placer mining community, all of whom gave freely of information and advice on the Yukon placer mining industry.

In particular, WEL would like to thank the following:

- Members of the placer mining section of the NAP and especially Mr. G.W. Gilbert who helped in obtaining information on current placer mining areas.

- Members of the committee of the KPMA and especially Mr. L. Bleiler and Mr. R. Johnson who provided cost information and advice on operating techniques used at placer mines and who critiqued WEL's conceptual pumping systems from an operations standpoint.

- Mr. G. Klein of Teck Corporation and Mr. A. Woodsend of Queenstake Resources Ltd. who provided site plans, operating information and cost data on company placer mining operations.

SECTION 2

SUMMARY

2.1 CLASSIFICATION OF DEPOSITS

A classification system was developed based on the most important physical charateristics that affect placer operations. The criteria for classifying the deposits included:

Width of valley bottom
Steepness of valley sides
Gradient of valley and stream
Gradient of bedrock/overburden interface

The four classes of deposits are:

Gulch
Narrow Valley and Low Bench
Broad Valley
High Bench

Low bench deposits are found in both narrow and broad valleys but size restrictions make them similar to narrow valleys. High bench deposits are set on plateaux above the valleys with ancient stream beds.

In Yukon the distribution of active operations 1983/84 between different classes was:

Gulch	23%
Narrow Valley	55%
Broad Valley	11%
High Bench	11%

New operations and discoveries are expected to be in the same proportions except high benches will decrease and broad valleys increase.

Materials present at placer deposits were divided into five categories:

A. Vegetative Cover
B. Black Muck
C. Waste Gravel
D. Pay Gravel
E. Tailings

Category E was sub-divided into:

1. Coarse oversize
2. Sluice tailings
3. Fine sediments

Materials handling systems were reviewed for each category.

2.2 MATERIALS HANDLING TECHNOLOGY

2.2.1 Current Techniques used in Yukon

Diesel equipment is being used at a majority of the operations in Yukon. In 87% of the operations, tracked or wheeled-loaders, dozers and backhoes are used and in another 5% scrapers are in operation. Only 3% of the operations used draglines and only one dredge is operating in Yukon.

There are a number of trends in materials handling:

- Operators are using mechanical rather than hydraulic methods to strip overburden.

- Equipment with greater mobility is being used for transportation, i.e. loaders and scrapers versus dozers.

- Mine operations are pre-sizing pay gravel prior to sluicing. 46% in 1985 versus 20% in 1979. Equipment ranges from static grizzlies to trommels and double decked screens.

- Settling ponds are becoming more common for sediment control and 78% of operations now have some form of pond system.

Movable recovery plants predominate in the narrower deposits, they range from plants moved on a daily basis to those moved two or three times a season. Fixed recovery plants are common at high bench deposits and in the broader valleys, with operators using larger mobile equipment such as scrapers to transport pay gravel to the plant.

The scale of Yukon placer operations generally increases from gulches to broad valleys and the wider the valley, the more the employees, the larger the machines, and the higher the production.

Typical types and sizes of machines are:

Gulch	Tracked loaders, Cat D6-D7 dozers, Cat 950 loaders
Narrow valley	Cat D8-D9 dozers, Cat 966-980 loaders, small scrapers
Broad valley	Cat D9 dozers, Cat 980-988 loaders, large self-loading scrapers
High bench	Cat 988 loaders, self-loading scrapers.

Mechanical methods of tailings disposal are predominant with wheel-loaders becoming more popular owing to the high wear and low output of tracked equipment in tailings removal.

2.2.2 Techniques used Elsewhere

In other northern placer mining fields such as Alaska and British Columbia, sluice box mining using diesel equipment predominates. A few operators are using unitized plants with trommel washers, slurry pumps, jigging banks and tailings cyclones, however, these are the exception.

Pre-sizing of gravel is done with trommel washers and multiple deck wet screens. Very few people are using pumping systems for gravel transport. Conveyors for handling plant feed are not common, but stacker conveyors are used regularly for removal of drained coarse material.

In the South Western U.S.A., conveyors are used for materials handling in the arid areas and some operators use pumps to move sized feed gravel. Recovery plants appear to be at permanent locations in many operations.

Placer mining operations overseas, especially in the Far-East and USSR, are usually larger in size. Diesel equipment is still used to move material but the main techniques are dredging and gravel-pump mining, with large horizontal or vertical gravel pumps used as methods of transporting pay gravel and tailings. In the USSR jet pumps are also used to transport gravel slurries from the pit to large unitized recovery plants.

In allied industries such as gravel quarries, china clay mines and dredging operations, the use of conveyors and gravel pumps is common. At quarries, conveyors predominate but gravel pumping systems are also used, particularly in the south eastern states. At china clay mines horizontal gravel pumps are commonly used to remove a clay-gravel mix. In common with dredging operations the production rates in these industries are higher than Yukon placer operations.

2.2.3 Recommended Technology

Suggested Materials Handling Methods

Each category of material was examined to see if alternative materials handling methods could be used to reduce the costs, increase the efficiency and improve the reclamation of placer operations.

The main areas where alternatives to mobile equipment are shown to have potential can be summarized as follows:

- Pumping of black muck in gulch and narrow valley deposits where no wood, trash or boulders are present in muck layer.
- Pumping or conveying of feed gravels in broad valleys and high bench deposits.
- Conveying of coarse oversize materials on high bench deposits.
- Pumping of pre-sized sluice tailings at all classes of deposits.

The types of equipment that were investigated included gravel pumps, cyclones, screening units and mobile conveyors.

Not all materials are amenable to the use of these systems and in many cases the existing methods of moving materials are the best (i.e. black muck with wood, trash and rock present).

Table 2-1 summarizes the suggested methods of materials handling by material category.

TABLE 2-1

SUGGESTED MATERIALS HANDLING METHODS

Material Category	Deposit Class	
A. Vegetative Cover	All	Use diesel equipment, especially tracked-dozers, to strip cover and dispose in old workings areas.
B. Black Muck	Gulches Narrow Valley	Strip coarse and frozen muck using dozers and push into old cuts. Monitor unfrozen fine muck and pump slurry to cover old tailings and waste gravels.
	Broad Valley High Benches	Strip frozen or dry muck using dozers. Transport long hauls by loaders and scrapers. If valley gradient steep enough use pumping system to dispose of fine muck over gravels.
C. Waste Gravel	Gulches Narrow Valleys	Use mobile equipment: short hauls loaders/dozers; long hauls scrapers.
	Broad Valleys High Benches	Same as above. For large volumes consider trucks. Conveyors could be considered for fixed loading and discharge points. Operations pre-concentrating gravel should consider pumping fines.
D. Pay Gravel	Gulches Narrow Valleys	Use diesel equipment to feed moveable plant, e.g. dozers, loaders or backhoes.
	Broad Valleys High Benches	Use more mobile equipment to feed static plant, i.e. scrapers, loaders. Consider using conveyors for dry feed or pre-sizing and pumping to sluice for wet or sticky feed.

TABLE 2-1

SUGGESTED MATERIALS HANDLING METHODS - (Cont'd.)

Material Category	Deposit Class	
E.1. Coarse Oversize	Gulches Narrow Valleys	Use mobile equipment especially loaders. Use material to build berms for finer tailings.
	Broad Valleys	Use mobile equipment - loaders, scrapers. If pumping feed to plant, use loaders or dozers to stack in mined out areas of cut.
	High Benches	Use loaders and scrapers. If pumping feed to static plant consider using conveyor/stackers to transport material to disposal and use it to build berms for finer tailings and ponds.
E.2. Sluice Tailings	All	Pump tailings to disposal areas and dewater with cyclone. Stack cyclone overflow on valley walls or in old cuts; pipe overflow to ponds.

Types of Equipment

The gravel pumps recommended would be horizontal centrifugal types for black muck, feed gravels and tailings. For settling pond sediments vertical submersible types are recommended.

The horizontal pumps would have Ni-hard linings and dry seal glands. They would be powered by diesel or gas engines via a belt drive system. Submersible pumps would be powered by electric motor. Typical sizes of pump would be:

Imp. gpm slurry	Size
1,500	6 x 8
2,200	8 x 10
3,300	10 x 12

Because of the high water content of pumped material, cyclones would be used to dewater tailings at disposal points. Hydrocyclones of 24 to 36 inches are suggested. The underflow density will be up to 70% solids and contain the plus 200 mesh material.

The type of piping recommended for all applications is 8 or 10 inch HDP piping in 20 foot lengths. The polypropelene pipe is recommended for its lower cost and lighter weight compared to steel pipe.

Any pumping system will require pre-sized feed. For black muck a large protection screen will need to be put in front of the pump box. For screening feed gravel, the type of units used will depend on factors such as; gold particle size, size range of feed, available units on site, if any, and configuration of equipment for height problems and to suit mobile equipment.

The smaller the feed material can be screened to the better the wear rates on the pumps and pipeline. A grizzly followed by a single deck screen or trommel is suggested for the types of site layouts shown in this study.

The conveyors recommended are 24 inch wide and either skid or wheel mounted. They can be either diesel or electrically driven. Several units can be placed in line to transport material the required distance.

Summary of Costs

In a preliminary cost comparison exercise on a series of hypothetical layouts, the current methods of handling tailings were compared to methods using the suggested alternative technology. In some cases the costs of moving both feed gravel and tailings were considered. The results were:

Deposit Class	Material Moved and Alternative Method	Cost to Move Material per cu.yd. of Sluice Feed	
		Current Method	**Alternative Method**
Gulch	Pumping and dewatering tailings	.60	.50
Narrow Valley 'A'	Pumping and dewatering tailings	.44	.45
Narrow Valley 'B'	Pumping and dewatering tailings	.48	.38
Low Bench	Pumping and dewatering tailings	.58	.84
Broad Valley	Pumping pay gravel to sluice. Tailings disposal by gravity	1.71	1.04
High Bench	Conveying paying gravel, conveying oversize, pumping tailings	1.74	1.56

Note: These costs are based on many assumptions and are purely theoretical. They show the relative costs of using only diesel equipment versus using conveying or pumping combined with diesel equipment. They cannot be used to compare operations in different deposit classes, or assumed to represent the total costs of placer mining at any type of deposit.

2.2.4 Site Reclamation Aspects

The two primary requirements of land reclamation at Yukon placer mines should be stabilization of the mined areas and revegetation of the worked placer gravels. Rapid revegetation of the gravels will aid in the stabilization of the ground. The level of work required in stabilizing the ground and revegetation will depend on the expected end use of the land. In this regard broader valley operations may require a higher level of reclamation than Gulch or Narrower valley operations.

As far as it is possible, reclamation work should be carried out concurrently with mining and not left until the valley is mined and the operation closing down. In order to stabilize the gravels and promote revegetation during the mining operation, the methods used to handle materials need to be considered. Pumping and conveying systems allow more flexibility in handling materials and can promote better ground stabilization by allowing gravels to be disposed of against valley sides or in old cuts. The coarse materials generated by screening out the barren gravel can be used for stabilizing stream beds and for building berms, behind which the finer tailings will be disposed of. This finer tailings will form a gentler slope against the valley wall and therefore resist erosion better than at present. In addition the material will contain a better mix of fine and coarse material thus permiting more rapid revegetation.

The other material present at placer operations that might promote better reclamation are black muck and settling pond sediments. Technical difficulties with pumping the black muck may preclude the use of this material as a covering layer for the sloped tailings stacks. However, until field tests have been carried out, the technical and economic aspects of using black muck cannot be accurately assessed. It is known, however, that black muck will provide a medium rich in the materials necessary for revegetation.

The removal of fine settling pond sediments by pumping should be technically achievable provided there is not too much coarse material and wood in the sediments. This material will also be a good medium for revegetation as it contains a high percentage of fine silts. However the costs may not be justified especially if there is not a requirement for cleaning out the settling ponds to provide space for future work.

2.3 CONCLUSIONS

1. Materials handling methods have undergone a series of changes in the past:

   (a) The use of diesel equipment changed the method of moving gravels and increased the level of production.

   (b) The use of punch-plate in the sluice to segregate the finer material improved gold recovery and reduced water consumption.

   (c) The use of static grizzlies to pre-size gravels further improved gold recovery and water conservation.

2. These advances and current ones, including the use of vibrating grizzlies and screens and more mobile equipment for gravel transportation, have created their own materials handling problems, especially in the quantity of tailings that has to be handled.

3. The diesel equipment currently in use is not always the most suitable method for handling material.

4. The next technical advance in materials handling is to try pumping and conveying. These techniques should:

   (a) Improve the efficiency and cost of materials transportation.

   (b) Improve the methods of ongoing reclamation and minimize their costs by:

      - Reducing the work required to reslope waste material and recontour mined areas.

- Improving on the quality of disposed waste materials to promote natural reclamation.

(c) Reduce the cost of operating settling ponds by minimizing the amount of sands and coarse sediments flowing into them.

5. Alternative techniques alone will not solve the problems. They must be incorporated into a well thought out mine plan which accounts for:

   (a) Overall site layout and valley types.

   (b) Size of recovery plant, its portability and proposed locations.

   (c) Areas for waste disposal relative to position of plant and settling ponds.

   (d) Sequence of stripping, mining and dumping of the overburden, gravels and tailings.

6. Advances in implementing alternative technology will be slow as miners have limited capital resources with which to acquire new equipment. Therefore changes in placer mining techniques will only take place as fast and as far as funding permits.

7. At current operations the pumping and conveying systems proposed must fit in with existing equipment. For future operations the materials handling systems can be incorporated into a complete plant and equipment plan. For both current and future operations to adopt these systems they must be:

   (a) Of rugged design, capable of operating in the harsh conditions of placer mining.

(b) Easy to set up, operate, move and maintain, requiring no extra labour or highly specialized skills.

8. The decision on adopting alternative technology will be based on conditions existing at each individual site as the economics of alternative versus traditional methods are totally site specific.

9. The general cost comparisons in this study indicate that using alternative methods may be cost effective under certain conditions. One of the greatest influences on the costs will be the distance material has to be transported. The further the distance, the more cost effective pumping becomes.

2.4 RECOMMENDATIONS

Before placer miners will adopt alternative materials handling systems, they must be rigorously tested and demonstrated to work efficiently and cost effectively. Therefore the following are recommended.

1. Initial field trials concentrate on pumping feed gravels and sluice tailings, as these have the best chance of success, and will be the most beneficial from a cost and reclamation standpoint.

2. One or more placer mining operations should be selected for field trials and pumping systems designed based on the site and operating criteria. Trials should include the following:

   (a) Measuring the total size distribution of the gravels to be handled accurately to estimate the quantities of oversize, tailings, etc., for design work.

   (b) Monitoring the operation closely to record the production statistics and costs associated with the individal tasks and different methods of materials handling.

(c) Recording the effect the pumping system has on recontouring of the old workings and measuring the size distribution of the tailings. Monitoring the progress of natural revegetation. (Several years required).

3. To compare costs of using alternative technology to current methods part of the field trials must concentrate on obtaining accurate operating costs from a number of representative placer operations. This exercise should continue for a number of years to obtain average costs over time. This work should involve close cooperation with the KPMA.

4. Separate field trials should test the pumping of black muck using the same equipment as for gravels. In addition, pumping out settling ponds using submersible pumps should be tested.

SECTION 3

CLASSIFICATION OF DEPOSITS

3.1 BASIS OF CLASSIFICATION

A general system of classifying the placer deposits in Yukon has been established which takes into account the most basic constraints affecting mine planning and operation. This system is based on the type of terrain at the site of the deposit. Four classes of deposits have been recognized. They are:

1. Gulch deposits
2. Narrow valley and low bench deposits
3. Broad valley deposits
4. High bench deposits

Each of the classes of deposits has its own characteristics. These characteristics are described below, and are followed by estimates of the relative abundance of placer deposits in each classification at present and possible future Yukon placer mines and by short descriptions of the types of materials that are present in the deposits.

3.1.1 Gulch Deposits

Gulch deposits occur in narrow, steep valleys at the headwaters of large streams, or along minor tributary streams. The gradients of the surface along six gulches with placer deposits in various parts of Yukon range from 5.8 to 15.0%, and average 9.5%. The gradients of the bedrock-overburden interface at the deposits lie within the same range, but although they slope the same way, the surface of the overburden and the overburden-bedrock interface are not always parallel. This results in some gulch deposits consisting of wedges of unconsolidated material which thicken or thin along the course of the stream. The original valley bottoms in gulches are very narrow. They range from approximately 10 to 65 feet in width. Permanent streams the bench and the valley bottom results in the low bench deposit having an apparent moderate gradient. Low benches are typically situated from 10 to 50 feet above the present creek level. They were formed when stream deposits were abandoned on terraces while the present creek incised its valley. More than one terrace may have been left as steps, along either or both sides of the stream. Like narrow valley deposits, low bench deposits may be covered by thick wedges of barren colluvium or black muck.

Photograph 6 shows a typical low bench deposit. Tailings from dredge mining operations in the adjacent valley bottom are visible in the foreground of the photograph.

3.1.3 Broad Valley Deposits

Broad valley deposits occur in valleys with shallow gradients along the middle and lower reaches of large streams. The gradients of the surface along six broad valley deposits in various parts of Yukon range from 0.1 to 1.0% and average 0.5%. The gradients of the bedrock-overburden interface at the deposits lie within the same range, and the surface of the overburden and the overburden-bedrock interface are usually roughly parallel. The deposits may be shallow, or deep. A deposit is considered to be within a broad valley if the mining operation on it is not restricted by the topography of the site. The originally valley bottom in a broad valley is defined, for the purpose of this report, as being more than 200 feet wide, although it is usually much wider. Permanent streams are present in broad valleys having placer deposits. During times of heavy rainfall, the water level in the stream rises, but freshets or floods do not usually occur.

3.1.4 High Bench Deposits

High bench deposits occur on plateaux 250 feet or more wide, and over 50 feet above the present level of the creek. They are made up of material deposited by large, ancient streams flowing in wide valleys. Present water courses in the area of the high bench deposits may be related to the water courses of the streams which laid may or may not be present in gulches having placer deposits. During times of heavy rainfall, however, freshets may occur.

Photographs 1 and 2 show typical gulch deposits. The location of the deposit along a minor tributary stream is visible in Photograph 1. The steep gradient, and the narrow width of the valley bottom are visible in both Photographs 1 and 2.

3.1.2 Narrow Valley and Low Bench Deposits

Narrow valley deposits occur in valleys with moderate gradients along the middle reaches of large streams, or along major tributary streams. The gradients of the surface along eight narrow valley placer deposits in various parts of Yukon range from 1.3 to 3.0%, and average 2%. The gradients of the bedrock-overburden interface at the deposits lie within the same range, but the surface of the overburden and the overburden-bedrock interface do not always slope in exactly the same directions. This results in some narrow valley deposits trending into present-day hillsides where they are covered by thick wedges of barren colluvium or black muck. In narrow valleys the original undisturbed valley bottoms are 200 feet wide or less. Permanent streams are usually present in narrow valleys having placer deposits. During times of heavy rainfall, the water level rises, but freshets occur only in areas such as the Burwash Creek area where the narrow valleys are surrounded by high, rugged mountains.

Typical narrow valley deposits along major tributary streams are shown in Photographs 3, 4 and 5. The moderate gradient and width of the valley bottom are visible in Photograph 3, while Photographs 4 and 5 show the layouts of mining operations at different narrow valley deposits.

Low benches may occur along the margins of narrow or broad valleys. All low bench deposits are, however, included with narrow valley deposits as mining operations on low benches are restricted by the topography of the site. Low benches are almost always less than 150 feet in width, while the gradients of the overburden-bedrock interface of such deposits are moderate. Even when the low bench lies adjacent to a broad valley with shallow gradient, the difference in elevation between down the deposits, or may have no relation to them at all. The high benches resulted when the present streams incised valleys at elevations lower than those of the large, ancient streams. Because high bench deposits were laid down by large streams, in wide valleys, the gradients of the surface of the deposits and of the bedrock-overburden interface are low, and the deposits may be shallow or deep. Seasonal or permanent streams are usually not found at high bench deposits, but water is present nearby in most cases in streams in the incised valleys.

High bench deposits are shown in Photographs 7 and 8. The elevation of typical benches above the present stream level is shown in Photograph 7, while Photographs 7 and 8 show the broad width and shallow gradient of bench deposits.

3.2 VARIATION OF DEPOSITS ALONG WATERSHEDS

All the deposits along a particular stream need not belong to the same classification. For instance, deposits near the headwaters of the stream may be gulch deposits, while narrow valley deposits are present along the middle reaches of the stream. Broad valley deposits may be present near the mouth of the stream, while low and high bench deposits may be present anywhere along the narrow and broad portions of the stream. Deposits present along a single stream do not, however, necessarily progress from narrow to broad valley classes from the upper reaches of the stream to the lower. Narrow valley and broad valley classes may alternate along the course of a stream, and may be bordered by low or high benches at any point.

3.3 DISTRIBUTION OF YUKON DEPOSITS BY CLASS

Seventeen mining operations in the Klondike district, and four mining operations in the Mayo district, were visited or observed by J.L. Leader and R.L. Debicki during the field trip from September 23 to October 3, 1985. The terrain at each of those mining operations was noted and assigned to one of the four classes of deposits.

Three of these 17 mining operations in the Klondike district were located on various parts of the same deposit at Dago Hill, along Hunker Creek, while two were located on different parts of the same deposit along Dominion Creek. Thus, the 17 mining operations were actually located at 14 different deposits. One of those deposits (K-4) was classed as a gulch deposit. Seven were classed as narrow valley deposits (K-3, K-5, K-16) or low bench deposits (K-1, K-2, K-11, K-12). Four were classed as broad valley deposits (K-6, K-7 and K-8, K-9, K-10). Two were classed as high bench deposits (K-13, K-14a and b and K-15). A list of the placer operations that were visited is given in Table 3-1.

The four mining operations visited in the Mayo district were located at separate deposits. Two of the deposits were classed as gulch deposits (M-1, M-4), and two were classed as narrow valley deposits (M-2, M-3).

TABLE 3-1

LIST OF PLACER OPERATIONS

Ref. No.	Operator and Location	Deposit Class
K-1	Kohlman Explorations Ltd. Bonanza Creek	Low bench
K-2	Northwest Consolidated Industries Ltd. Bonanza Creek	Low bench
K-3	Eldorado Mining Eldorado Creek	Narrow valley
K-4	Beron Placers Co. Ltd. Guy Gulch	Gulch
K-5	Meadow Gold Placers Ltd. Sulphur Creek	Narrow valley
K-6	Granville Joint Venture Sulphur Creek	Broad valley
K-7	Airgold Ltd. Lower Dominion Creek	Broad valley
K-8	J. Erickson and H. Liedtke Lower Dominion Creek	Broad valley
K-9	Consolidated Mines (Yukon) Ltd. Lower Dominion Creek	Broad valley
K-10	Ross Mining Services Ltd. Lower Dominion Creek	Broad valley
K-11	Gatenby's Dominion Creek	Low bench
K-12	Ace Placer Mines Dominion Creek	Low bench
K-13	Queenstake Resources Ltd. Preido Hill	High bench

TABLE 3-1 - (Cont'd.)

LIST OF PLACER OPERATIONS

Ref. No.	Operator and Location	Deposit Class
K-14 (a & b)	Miben Mining Co. Dago Hill	High bench
K-15	Preido Mines Ltd. Dago Hill	High bench
K-16	J & C Holdings Hunker Creek	Narrow valley
M-1	Erl Enterprises Highet Creek	Gulch
M-2	Bleiler Placers Ltd. Highet Creek	Narrow valley
M-3	Duncan Creek Goldusters Ltd. Duncan Creek	Narrow valley
M-4	Bardusan Placers Ltd. Thunder Gulch	Gulch

The distribution of the operations visited among the deposit classes is summarized in Table 3-2.

TABLE 3-2

DISTRIBUTION OF DEPOSITS VISITED

	District		
Class	Klondike	Mayo	Total
	(%)	(%)	(%)
Gulch	7	50	17
Narrow Valley and Low Bench	50	50	50
Broad Valley	29	0	22
High Bench	14	0	11

The distribution amongst the various classes of deposits of all the deposits mined in various districts of Yukon during 1983 and/or 1984 was determined with the aid of the manuscript "Yukon Placer Mining Industry, 1983-1984", not yet in print. The distribution is listed in Table 3-3. The total for all deposits is included in Table 3-4.

TABLE 3-3

DISTRIBUTION OF DEPOSITS BY DISTRICT

Class	Klondike	Stewart River	60 Mile River	Mayo	Burwash	Livingstone Creek	Carmacks	Other Areas
Total Number	120	19	20	19	15	5	22	13
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Gulch	18	21	5	32	33	100	32	23
Narrow Valley & Low Bench	53	68	80	52	60	0	41	62
Broad Valley	8	11	10	16	0	0	27	15
High Bench	21	0	5	0	7	0	0	0

The distribution amongst the various classes of deposit of all the deposits mined during 1983 and/or 1984 was also determined for unglaciated and glaciated regions. Glaciated regions include the Mayo, Burwash and Livingstone Creek districts. Some of the deposits in the group listed as "other areas" also lie within glaciated regions. Areas lying on the margins of glaciated regions, which may or may not show some effects of glaciation, were included in the unglaciated regions. The distribution is summarized in Table 3-4.

TABLE 3-4

DISTRIBUTION OF DEPOSITS IN UNGLACIATED AND GLACIATED REGIONS

	Region		
Class	**Unglaciated**	**Glaciated**	**Total**
Total Number	186	47	233
	(%)	**(%)**	**(%)**
Gulch	19	36	23
Narrow Valley and Low Bench	56	51	55
Broad Valley	11	11	11
High Bench	14	2	11

Gulch, narrow valley, and low bench deposits, or deposits at which mining operations are restricted in some way by the topography of the site, make up more than 70% of the deposits currently being mined at each of the placer mining districts in Yukon. In several of the placer mining districts, they make up more than 85% of the deposits being mined. Such deposits also make up 75% of the deposits being mined in unglaciated regions and more than 85% of the deposits being mined in glaciated regions. Broad valley deposits are more common in some mining districts than others, but are approximately evenly divided between unglaciated and glaciated regions. High level bench deposits are much more common in the Klondike district than in any other district and hence are much more common in unglaciated than in glaciated regions.

3.4 MATERIALS PRESENT AT YUKON PLACER DEPOSITS

There is no consistent relationship between the class of deposit, whether gulch, narrow valley, broad valley, or high bench and the types of materials present at the deposit. This is because the present stream environment at a placer deposit may bear no relationship to the one which existed when the deposit was laid down. Several periods of glaciation, the last of which ended approximately 9,500 years ago, have affected parts of the territory. Glaciers may have been present before, during, or after the placer deposits were laid down. Isostatic adjustments over the last two million years may have changed the slopes or base levels and hence the character of streams, since the placer deposits along them were laid down.

3.4.1 Categories of Materials by Mode of Deposition

The types of material present at Yukon placer deposits may be placed within one of two broad subdivisions: barren unconsolidated material, and gold-bearing material. Within each subdivision several categories of materials, with a wide range of characteristics, may occur. Barren unconsolidated material includes black muck, colluvium, glacial or glaciofluvial material, and alluvial material. Gold-bearing material includes glacial or glaciofluvial material, and alluvial material.

Black muck consists of a mixture of decomposed organic material and wind-blown dust. It is always frozen and contains up to 70% water. Thin lenses of sand or gravel, and small to large pieces of organic debris including tree trunks and the bones of extinct mammals may be present in the black muck. Because black muck was deposited in swampy areas between 20,00 and 40,000 years ago, it occurs more often at narrow valley or broad valley deposits than at gulch or high level bench deposits. It is less likely to be present in glaciated areas than in unglaciated areas. Black muck almost never contains gold.

Colluvium consists of a mixture of earthy material and angular pieces of bedrock derived from the banks of the valley. It is formed through downslope movement of material on the valley walls adjacent to the deposit. Interlaminations of gravel and black muck are present in colluvium in a few cases. Colluvium is more common at gulch and narrow valley deposits than at broad valley or high bench deposits. The steep banks adjacent to gulch and narrow valley deposits result in relatively rapid downslope movement. The narrow width of the valley at gulch and narrow valley deposits results in a greater proportion of the valley bottom being covered than at wide valley deposits. Colluvium does not usually contain gold, although in some of the cases where the colluvium contains interlaminated gravel or at the extreme heads of gulches, gold may be present in colluvium.

Glacial and glaciofluvial material consists of a high percentage of boulders coarser than 8 inches in diameter, and sometimes more than 40 inches across, in a sandy, silty, or earthy matrix. The boulders are usually well rounded. Clay, which may cause fine flakes of gold to adhere to the clasts in the deposits, is also often a constituent. Glacial material formed when overburden of whatever type was present was pushed into disorganized deposits by the action of the glaciers, and was left when the glaciers melted away. Glaciofluvial material formed in streams carrying water and detritus from melting glaciers. Glacial material rarely contains gold in sufficient quantities to be worked economically. Reworking by meltwater into glaciofluvial material sometimes beneficates glacial material sufficiently that it can be worked economically. Glacial and glaciofluvial material may also overlie pre-glacial gold-bearing material, especially where the location of the gold-bearing material in gulches or narrow valleys protected it from being eroded by glaciers. Deposits in areas which have been glaciated comprise approximately 20% of the deposits worked in Yukon in 1983 and 1984. The distribution of gold in glacial and glaciofluvial material is variable, as is the grain size of the gold recovered. Recovery of gold from glaciofluvial material is sometimes more difficult than recovery of gold of the same grain size from the material in unglaciated regions. The grains of gold from glaciated regions are much flatter than the grains of gold from unglaciated regions and tend to "float" on air bubbles or the surface of the water in the gold recovery unit.

Alluvial material consists of sand and gravel deposited by streams. The size, degree of roundness, and percentage of clasts in alluvial gravel are all variable, as are the grain size and grain size distribution of the matrix. Alluvial material may form barren unconsolidated material, or may be gold-bearing. In some cases the barren gravel is quite similar to the underlying gold-bearing gravel, while in other cases it is quite different. Alluvial material may form barren unconsolidated material at placer deposits belonging to all four classifications. It is more common, however, at wide valley and high bench deposits than at gulch and narrow valley deposits. At wide valley deposits, it may be as much as 65 feet thick, and may be even thicker at high bench deposits. Alluvial material forms the gold-bearing material at almost all Yukon placer deposits. The gold may be restricted to a certain horizon within the material, usually at or near bedrock in deposits of all classes, or it may be restricted to a "pay-streak" or swath within the gold-bearing alluvial material in wide valley or high bench deposits. It may also be erratically distributed throughout the alluvial material at deposits of all classes. In addition to the variability of matrix and clast size in gold-bearing alluvial material, and the variability of the distribution of gold within the material, the grain size of the gold is also variable. In general, the grain size of the gold decreases from gulch to narrow valley to wide valley and high bench deposits.

Post-depositional low temperature hydrothermal alteration has affected parts or all of the gold-bearing alluvial deposits of some low and high level bench deposits in the Sixty Mile and Klondike areas, resulting in further variability in the composition of the deposits, and in the distribution of gold within them.

3.4.2 Categories of Materials by Method of Handling

Yukon placer deposits may alternatively be divided into five categories of materials for which different methods of handling are used. The five categories are:

A. Vegetative cover
B. Black muck
C. Waste gravel
D. Pay gravel
E. Tailings

Category A includes the plant cover at deposits of any class, and includes mosses, shrubs and bushes, spruce and poplar trees but rarely birch trees. The moss cover is important because it provides the insulation which keeps the material underlying it permanently frozen. The trees at some deposits may be large enough to be harvested for firewood, but are rarely of sufficient size to warrant harvesting as saw-logs or building logs.

Category B includes the black muck described in Section 3.4.1 of this report.

Category C includes all the barren unconsolidated material at deposits of any class, excluding black muck, which must be stripped before the gold-bearing material can be reached. It therefore includes colluvium and glacial, glaciofluvial and alluvial material, all of which were also described in Section 3.4.1 of this report.

Category D includes the gold-bearing material at deposits of any class. It therefore includes glacial, glaciofluvial, and alluvial material, but is most often alluvial material.

Category E consists of the tailings resulting from the processing of the gold-bearing material. The characteristics of the tailings depend upon the type of processing unit used by the operator at each deposit. If size classification of the gold-bearing material is done prior to sluicing, tailings include separate coarse oversize and sluiced fractions. If classification is not done prior to sluicing, the tailings consist of a single material with a wide range of grain sizes. Sediments collected in settling ponds also formpart of the tailings category.

3.4.3 Size Distribution

Grain size analyses for a variety of Yukon placer materials were available from a number of published and unpublished sources.(1) To complement these data, twenty additonal samples of a variety of materials were colleced and subjected to grain size analysis, as a part of the study. Tables summarizing the grain size distribution of several types of materials are included here. Graphs showing the results of individual analyses of some of the samples are included in Appendix II.

The subdivisions used in the grain size analyses are:

1. Coarser than 3 inches (+3").
2. Finer than 3 inches but coarser than 1 inch (-3", +1").
3. Finer than 1 inch but coarser than 5/8 inch (-1", +5/8").
4. Finer than 5/8 inch but coarser than 10 mesh (-5/8", +10#).
5. Finer than 10 mesh but coarser than 100 mesh (-10#, +100#).
6. Finer than 100 mesh but coarser than 200 mesh (-100#, +200#).
7. Finer than 200 mesh (+200#).

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(1) Sources of data included:

Stanley Associates Eng. Ltd. - Report on placer gold mining.

SIGMA Resource Consultants Ltd. - Report "Water use technology for placer mining effluent control".

Shannon and Wilson Inc. - Report "Placer mining wastewater treatment technology project".

Reid Crowther and Bethell - Size distribution analyses of Yukon Placers.

Beron Placers Ltd. - Various size distribution analyses on properties in the Klondike.

The mesh sizes used are Tyler designations. The sizes of grains passing through the screens and their equivalents in ASTM mesh sizes are listed in Table 3-5.

TABLE 3-5

GRAIN SIZES

Screen Size		Openings	
Tyler	ASTM	inches	mm
3 inches	3 inches	3.0	76.2
1 inch	1 inch	1.0	25.4
5/8 inch	5/8 inch	0.625	15.9
10 mesh	12 mesh	0.0661	1.7
100 mesh	100 mesh	0.0059	0.15
200 mesh	200 mesh	0.0029	0.074

Grain size analyses of five black muck samples are summarized in Table 3-6. All the samples were collected from narrow valley and low bench deposits. Organic debris was not included in the samples.

TABLE 3-6

GRAIN SIZE ANALYSES OF BLACK MUCK

		Grain Size						
Deposit Type	Number of Samples	+3"	-3" +1"	-1" +5/8"	-5/8" +10#	-10# +100#	-100# +200#	-200#
Gulch	0	No Data						
Narrow Valley and Low Bench	5	0%	0-3%	0-6%	0-9%	6-25%	6-40%	32-82%
Broad Valley	0	No Data						
High Bench	0	No Data						

Grain size analyses of 17 samples of gold-bearing material are summarized in Table 3-7. Waste gravels would have simlar grain size distributions. The major variation between samples of feed gravel is the proportion of the sample coarser than 3 inches. Although not indicated in the table, the maximum grain size of samples in feed gravel is also quite variable.

TABLE 3-7

GRAIN SIZE ANALYSES OF FEED GRAVEL

Deposit Type	Number of Samples	Grain Size						
		+3"	-3" +1"	-1" +5/8"	-5/8" +10#	-10# +100#	-100# +200#	-200#
Gulch	5	25-40%	7-19%	4%	11-25%	14-17%	1-6%	5-18%
Narrow Valley and Low Bench	10	0-50%	3-16%	4-11%	25-46%	9-31%	1-3%	2-18%
Broad Valley	1	20%	5%	7%	31%	26%	6%	5%
High Bench	1	30%	12%	6%	13%	17%	4%	18%

The grain size samples of 13 samples of coarse tailings are summarized in Table 3-8. The proportion of the sample coarser than 3 inches in diameter varies due to the use of size classification devices at some operations, as well as to differences between the material being processed. Where size classification devices were used prior to sluicing, the "oversize" fraction was not included with the coarse tailings and a separate "oversize" fraction is also present. A comparison of Tables 3-7 and 3-8 indicates that size classification prior to sluicing is used effectively to remove grains coarser than 3 inches.

TABLE 3-8

GRAIN SIZE ANALYSES OF COARSE TAILINGS

Deposit Type	Number of Samples	Grain Size						
		+3"	-3" +1"	-1" +5/8"	-5/8" +10#	-10# +100#	-100# +200#	-200#
Gulch	3	0-15%	8-22%	10-14%	30-42%	27%	3%	10%
Narrow Valley and Low Bench	7	0-20%	3-20%	4-12%	28-46%	18-43%	2-4%	0-4%
Broad Valley	2	0-10%	0-8%	3-8%	40-54%	25-30%	2-5%	2-9%
High Bench	1	0%	0%	0%	49%	45%	4%	2%

The grain size analyses of 11 samples from settling ponds are summarized in Table 3-9. The coarsest material is present in sediment from a setting pond in a gulch. In all the other ponds sampled, almost all the material present was finer than 10 mesh. In most case, most of the material was finer than 100 mesh.

TABLE 3-9

GRAIN SIZE ANALYSES OF SETTING POND SEDIMENTS

		Grain Size						
Deposit Type	**Number of Samples**	**+3"**	**-3" +1"**	**-1" +5/8"**	**-5/8" +10#**	**-10# +100#**	**-100# +200#**	**-200#**
Gulch	1	0%	10%	9%	Data Incomplete			
Narrow Valley and Low Bench	8	0%	0%	0%	0-5%	7-58%	21-41%	18-72%
Broad Valley	1	0%	0%	0%	0%	7%	28%	65%
High Bench	1	0%	0%	0%	2%	59%	-----39%-----	

The grain size distribution of the various materials present are important when examining alternative materials handling methods for each material category.

SECTION 4

PRESENT MATERIALS HANDLING METHODS IN YUKON

Yukon placer mining operations utilize a wide range of stripping, mining, processing and effluent treatment methods. Methods used at 117 individual operations are summarized below. The 117 operations were selected by using every second property description in the manuscript "Yukon Placer Mining Industry - 1983, 1984".(1) The selections are thus a random and representative sampling of all the operations in the territory. To illustrate changes at Yukon placer mining operations since 1979, figures reported from a survey of 50 individual operations in the report "Water Use Technology for Placer Mining Effluent Control" prepared by Sigma Resources Consultants Ltd. for DIAND are included in the tables.

During 1983 and 1984, 23% of Yukon placer mining operations did no stripping. The methods used by those which did do stripping are listed in Table 4-1.

TABLE 4-1

STRIPPING METHODS AT YUKON PLACER MINING OPERATIONS

	1983-1984			1979
Method	**+10 Feet**	**-10 Feet**	**Total**	**Total**
	(%)	**(%)**	**(%)**	**(%)**
Mechanical	32	47	79	54
Hydraulicking	0	3	3	5
Mechanical plus Hydraulicking	0	19	19	23
Mechanical plus Ground sluicing	1	0	1	18

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(1) "Placer Mining Industry 1983-1984", Unpublished manuscripts compiled by R.L. Debicki for Exploration and Geological Services Northern Affairs Program DIAND, Whitehorse, Yukon.

During 1983-1984, mechanical methods were the most common used to do stripping. A combination of mechanical methods and hydraulicking (the use of water under pressure) was the other main stripping method used. The use of water for stripping, either through hydraulicking, or ground sluicing, decreased from 49% to just 23% between 1979 and 1983-1984, while the use of mechanical methods for stripping increased from 54 to 79%.

The equipment utilized for stripping and mining operations is listed in Table 4-2.

TABLE 4-2

EQUIPMENT UTILIZED AT YUKON PLACER MINING OPERATIONS

Equipment	1983-1984 (%)	1979 (%)
Bulldozers, loaders and hoes	87	90
Draglines alone	1	0
Draglines with other equipment	2	1
Scrapers with other equipment	5	2
Dredges	1	1
Hand	4	4
Hydraulic alone	1	2

Bulldozers, loaders and hoes were by far the most common pieces of equipment used. Most operations utilized at least two of the three. The use of draglines as auxiliary pieces of equipment slightly increased between 1979 and 1983-1984, while the use of scrapers for stripping and for transporting material distances over 500 feet also increased.

A variety of gold recovery systems were used at Yukon placer mining operations. They are summarized in Table 4-3.

TABLE 4-3

GOLD RECOVERY SYSTEMS AT YUKON PLACER MINING OPERATIONS

	1983-1984 Preclassification			1979 Preclassification	
Recovery System	Not Used	Grizzly	Trommel, Screen, etc.	Not Used	Used
	(%)	(%)	(%)	(%)	(%)
Single run sluice	35	14	13		
Multi-run sluice	18	3	16		
Total - Sluices	53	17	29	78	20
Jigs			1		1
Barrels			1		1

Sluice boxes were used almost exclusively as the gold recovery unit. Single run sluice boxes out number multiple run sluice boxes, although the use of multiple run sluice boxes is now increasing.

Also increasing is the use of some preclassification device prior to sluicing. The use of grizzlies, trommels, shaking screening units, and derockers at operations increased from 20% in 1979 to 46% in 1983-1984. A derocker being used to pre-size gravel prior to sluicing is shown in Photograph 9, while a shaking single-deck screen is shown in Photograph 10. Note that both units are being fed by loaders. Photograph 11 shows a gold recovery unit which is moved every few days. It includes a simple grizzly to remove oversize material. A more complex gold recovery unit shown in Photograph 12 is fixed. It includes a trommel to remove oversize material. Grizzlies and the relatively simple derocker are most commonly used with single run sluice boxes, while trommels, and multiple deck screening units are most commonly used with multiple run sluice boxes or jigs. Some gold recovery systems were fixed and not moved during one or more entire mining season. Others were more mobile and moved every few weeks. In a few cases, very mobile gold recovery systems were moved every few days.

Mechanical means of removing tailings were the most predominant. Bulldozers and front-end loaders were the most common machines used. Both screen oversize and coarse sluice tailings were removed by the same methods and typically dumped at the same place. Photograph 13 shows the use of a bulldozer to remove tailings from the sluice box discharge and Photograph 14 shows the use of a front-end loader to carry out the same task.

Effluent from sluicing is treated in one of four ways. The relative frequency of use of each of the methods is summarized in Table 4-4.

TABLE 4-4

TREATMENT OF EFFLUENT AT YUKON PLACER MINING OPERATIONS

Method	1983-1984	1979
	(%)	(%)
No treatment	11	18
Filtration in tailings	11	24
Settling ponds	56	36
Settling ponds with recirculation	22	22

The use of settling ponds increased in 1983-1984 from 1979, while the numbers of operations not treating effluent, or simply allowing it to filter through old tailings decreased. The use of recirculation from settling ponds remained constant between 1979 and 1983-1984, likely reflecting the fact that recirculation was used as a way of overcoming water shortages and not primarily as a method of effluent treatment.

4.1 TYPICAL PLACER MINING OPERATIONS

In addition to the general observations made about Yukon placer mining operations, it is possible to make some general observations about placer mining operations at each of the four classes of deposits. These observations are based on the visits to seventeen mining operations in the Klondike district, and four mining operations in the Mayo district made by R.J. Leader and R.L. Debicki during a field trip from September 23 to October 3, 1985, as well as the manuscript "Yukon Placer Industry, 1983-1984".

The scale of the mining operations generally increases from gulch to narrow valley to wide valley deposits. Mining operations of a range of scales are present at high bench deposits. The characteristics of typical mining operations at each class of deposit are summarized in Table 4-5 and are discussed in more detail below.

TABLE 4-5

CHARACTERISTICS OF TYPICAL MINING OPERATIONS

Deposit Class	No. Employees	Pieces Equip.	Pit Shape	Size Classification	Sluice Boxes	Mining Rate (cu.yd /hour)
Gulch	1-3	1-3	Narrow	Most Operations	Single	30-120
Narrow Valley	3-5	2-4	Rectangular	Some Operations	Single or Multiple	50-150
Broad Valley	5-6	3-5	Square	Some Operations	Single or Multiple	100-200
High Bench - Small	1-2	0-1	Rectangular	None	Single	10- 75
High Bench - Large	4-6	3-4	Square	All Operations	Multiple	75-100

Example Layouts

As a result of the site visit and with reference to the manuscript "Yukon Placer Mining Industry 1983-1984" and photographs, a series of sketch drawings were compiled to illustrate typical placer mining operations for each deposit class.

These drawings, which are located in Appendix I, are referred to in the text and are intended to illustrate the constraints on operations caused by terrain and other factors. A sister set of sketches plus flowsheets were compiled to show how the use of alternative materials handling technology could affect the layout of operations. These sketches are referred to in Section 6.

For each example layout certain site dimensions and operating statistics have been assumed, based on data from a number of placer operations. Although the example sketches were modelled on actual operations, both current and past, they have been simplified for the sake of clarity and altered to illustrate certain aspects of mining practice.

4.1.1 Gulch Deposits

Mining operations at gulch deposits, such as the one in Photographs 1 and 2, typically involve one to three people working on a single shift, and using one to three pieces of mechanized equipment. Where only one piece of equipment is used, a tracked loader is most common. The largest size of equipment used is usually equivalent to a Caterpillar D-8 bulldozer or 980C loader. Stripping is done mechanically, sometimes in conjunction with hydraulicking. The hydraulicking is done to condense the section. Mining is carried out in long, narrow cuts, rarely more than 100 feet wide and 300 feet long. The material mined is processed in a sluicing plant which may include either a grizzly, derocker, or shaking screening unit. Grizzlies are most commonly used. The classification units undersize, which ranges from -5/8 to -8 inches, is most commonly sluiced in a single run sluice box set at a relatively steep gradient. Between 30 and 120 cubic yards of material are processed per hour. Tailings are stacked along the gulch walls, and effluent from sluicing is settled in sediment ponds downstream from the operation. When they are situated in the gulch being mined, the ponds are small. Some gulch operations locate their settling ponds either downstream of the mining operation where the valley gradient of the gulch is less, or in the valleys of the larger streams into which the gulches empty. The sluicing plant is moved several times during the mining season.

Example Layout

Drawing No. 1401-130-1201 shows the layout of a Gulch placer operation. (See also Photographs 1 and 2). The size of cut is assumed to be up to 100 feet wide with a maximum distance from face to recovery plant of 300 feet. The black muck overburden is removed by a combination of ground sluicing and use of bulldozers to push muck into the stream flow.

Pay gravel is stockpiled by dozer and fed to the sluicing plant by a front-end loader. The drawing shows a grizzly with 3 inch spaced bars for pre-sizing of material. The assumed feed rate is 100 cu.yds. per hour. Sluice water is pumped from a downstream pond at 1,800 Imperial gpm. The grizzly oversize and coarse tailings are removed by loader and stacked on the side of the gulch. A series of small settling ponds are located in the gulch, with final settling in the adjoining creek. There is no room in the operation for a permanent creek diversion ditch.

4.1.2 Narrow Valley and Low Bench Deposits

Mining operations at narrow valley and low bench deposits typically involve three to five people working on one, or sometimes two shifts, using two to four pieces of mechanized equipment. The largest size of equipment used is usually equivalent to a Caterpillar D-9 bulldozer, or 988B loader. Stripping is done mechanically, sometimes in conjunction with hydraulicking. Hydraulicking is used to remove the black muck. Work is done in elongated cuts, usually 100 to 300 feet wide and 200 to 500 feet long. The material mined is processed in a sluicing plant which may include either a grizzly, derocker, shaking screening unit, or small trommel. No particular classification unit appears to be preferred over the others for use in narrow valley deposits. Single run sluice boxes, often lined with punch plate over the rifles for the entire length of the box, and set at a moderate gradient, are most commonly used to process the material. Some multiple run sluice boxes are, however, used, and are gaining in popularity. Between 50 and 200 cubic yards of material are processed per hour. Tailings are stacked along the valley walls, or are used to construct berms enclosing settling ponds. Most operators impound effluent from sluicing in settling ponds, although some use filtration through old tailings, where present, to treat the effluent. The sluicing plants at narrow valley deposits are often moved several times during the mining season.

Example Layout 'A'

Drawing No. 1401-130-1202 shows one example of a narrow valley operation. (See also Photographs 3 and 4). This is an example of an operation mining previously dredged ground. Mining is taking place on the right limit bank of the creek. General dimensions of the cut are 300 feet wide by 500 feet long. The overburden muck is stripped using dozers pushing into old cuts. Feed gravel is pushed to the sluice box a maximum distance of 500 feet. There is no pre-sizing of gravel and the feed rate has been assumed at 200 cu.yds. per hour. Water for sluicing is pumped from upstream ponds at 3,500 Imperial gpm. Coarse tailings are dozed into ramps and the fine tailings flow to settling ponds built in old cuts and from dredge tailings. There is a permanent creek diversion system.

Example Layout 'B'

Drawing No. 1401-130-1203 shows an example layout of a narrow valley operation mining new ground. (See Photograph 5). The cuts dimensions are 100 feet by 250 feet. Ground is stripped of black muck using ground slucing by diverting the stream over unstripped areas and assisting by pushing frozen muck with a dozer. Where the valley sides are shallow, muck is stockpiled on the slopes. Feed gravel is pushed by a dozer a maximum of 250 feet to the sluice. No pre-sizing of gravel is done. The assumed feed rate is 150 cu.yds. per hour with 3,200 Imperial gpm of water being used for sluicing. Coarse tailings are pushed into ramps by dozer, while the fine tailings settles out in a series of ponds built between tailings ramps.

Example Layout - Low Bench

Drawing No. 1401-130-1204 shows an example layout of a low bench deposit. (See also Photograph 6). The size of cut is assumed to be 400 feet long by 200 feet wide and the maximum distance to the sluice is 300 feet. Material is pushed from the face by dozer and fed to the sluice plant by loader. The material is pre-sized to -2 inches using a derocker. Gravel is fed to the plant at 100 cu.yds. per hour and sluice water pumped from the creek at 1,800 Imperial gpm. The oversize from the derocker and the coarse tailings are removed to adjacent piles using a loader. The fine tailings flows to a settling pond behind the tailings ramp.

4.1.3 Broad Valley Deposits

Mining operations at wide valley deposits typically involve five to six people working one or two shifts, although from two to twenty-one people were employed at the four wide valley deposits visited in the Klondike district between September 23 and October 3, 1985. Three to five pieces of heavy equipment are usual at such operations, with the largest size of equipment equivalent to a Caterpillar D-9 bulldozer, or 988B loader. Self loading scrapers capable of hauling up to 31 cubic yards of material at a time are more common at broad valley deposits than at narrow valley deposits. Stripping is usually done mechanically although where black muck is present, hydraulic methods are sometimes used in conjunction with the mechanical methods. Work is done in square to rectangular cuts, usually 500 feet or more wide, and up to 1,000 feet long. The material mined is processed in a sluicing plant which may include a grizzly or derocker and a shaking screening unit or trommel. Vibrating screening units are commonly used. Where size preclassification of the material is done, the sluice box may be either a single or multiple run unit, but where size preclassification is not done, the sluice box is almost always a multiple run unit. Between 100 and 200 cubic yards of material are processed per hour. Tailings are stacked in large ramps adjacent to the sluicing plant using loaders or bulldozers, or are transported to tailings disposal areas using scrapers. Effluent from sluicing is settled in large ponds in mined-out cuts. The sluicing plant at wide valley deposits is not usually moved more than once during the mining season.

Example Layout

Drawing No. 1401-130-1205 shows a layout of a broad valley operation mining areas not previously dredged. The valley width is over a half mile and the operation occupies only a small area of the valley. It is assumed that all overburden and waste gravels are removed using mechanical equipment and stacked on barren ground, dredge tailings and in old cuts. The cut dimensions are 1,000 feet long by 500 feet wide and the depth to bedrock is 50 feet. Pay gravel is taken off in horizontal slices using a dozer which pushes the gravel up the ramp to a stockpile a maximum distance of 500 feet. A loader feeds the sluice plant, which includes a 3/4" screen deck for presizing the material. The feed rate is assumed to be 200 cubic yards per hour and sluice water is pumped from a creek diverson reservoir at 3,500 Imperial gpm. Coarse tailings and screen oversize are stacked by loader into ramps that are built in old mining cuts. The fine sediments flow via a channel to large settling ponds built in old mining cuts and dredge tailings.

4.1.4 High Bench Deposits

Mining operations at high bench deposits are of two different scales. Small scale operations involve one or two people working on one shift, and using one piece of mechanized equipment or no mechanized equipment at all. The size of equipment used is usually equivalent to a Caterpillar D-6 bulldozer or 966C loader. Hydraulicking with gravity fed or pumped water is frequently used. Both mechanized equipment and hydraulicking are used for stripping, and to move material to the sluicing plant. In most cases the sluicing plant consists of a single run sluice box set at ground level on the bench. In a few cases, undercurrents have been added to the sluice box. Between 10 and 75 cubic yards of material are processed per hour. Tailings are directed over the rim of the bench and form fans along the margin of the valley below. (See Photograph 7). Effluent from sluicing is confined in settling ponds at the foot of the tailings fan, or is simply allowed to filter over and through old dredge tailings before flowing into the creek.

Large scale mining operations, such as the one illustrated in Photograph 8, involve four to six people working on one or two shifts. Three or four pieces of mechanized equipment are used at such operations, with the largest size of equipment equivalent to a Caterpillar D-9 bulldozer or 988B loader. Stripping is done mechanically, often using tractor-scrapers. Mining is carried out into the hillside in rectangular to square cuts up to 100 feet deep and 500 feet wide. Most of the section is stripped as waste gravel and used to back fill old cuts, before mining and processing of the pay part of the section is begun. The material mined is processed in multiple run sluicing plants or jigging units which usually include vibrating screening units or trommels. Between 75 and 200 cubic yards of material are processed per hour by the units used at large scale oversize is either transported directly to old cuts, or conveyed to stockpiles prior to being transported up the typical tailings ramps. Sluice tailings are either transported by mechanized equipment to be used as backfill and to build ramps, or they are directed over the rim of the bench to form tailings fans. Effluent from sluicing is either impounded in settling ponds in the valley at the foot of the high bench, or in recirculation ponds on the bench. The latter system requires continual removal of sediment from the ponds. This is often done using draglines. The sluicing plant is usually not moved during the mining season and may not be moved for several years.

Example Layout

Drawing No. 1401-130-1206 shows an example layout of a large scale high bench operation. (See Photograph 8). The overburden and waste gravel section is removed using dozer and front-end loaders and the material stacked in old working areas. The total height of the face is assumed to be 75 feet. The pay section is mined by a front-end loader which feeds the material directly to the recovery plant. A tramming distance of +400 feet is assumed. The material is washed and presized to -1/2" using a trommel. The oversize is removed to stockpile by a stacker conveyor. Plant feed rate is assumed to be 150 cubic yards per hour and water consumption 2,700 Imperial gpm. Coarse tailings and oversize are removed by loader and trammed +500 feet up tailings ramp for disposal. The fine sediments are allowed to settle in a series of four ponds. The last pond is used as a recirculation pond for wash water. Make up water has to be pumped from the creek 200 feet below.

4.2 FACTORS AFFECTING MATERIALS HANDLING

The methods and equipment that can be used to handle materials at deposits within different classes are affected by several factors. The valley width, slope of the valley walls, and gradient of the valley are the most important factors. Other factors include the normal flow of water at the sites, the flow of water at the sites during times of flood or low water, the presence or absence of black muck, large boulders and/or deep overburden in the deposits, and the width of the gold-bearing zone of the deposits. The presence of permafrost or groundwater at the deposits also inhibits mining operations. Where permafrost is present, the operator must design his mining plan so that material to be processed is allowed to thaw completely before being mined. Where groundwater is present, the operator must design his pit in such a way that it drains naturally, or else provide some other method of removing unwanted water. In a few cases, mining operations are affected by the type of bedrock present.

Factors not directly related to the terrain at the site of a deposit but still affecting operations include the size of the property held under claims or leases, and the position of the mining operation with regard to the boundaries of the property.

4.2.1 Gulch Deposits

Gulch deposit operations are the most severely affected by terrain. The narrow width of the valley causes the scale of the operation, and the size of the cuts mined to be small. It forces the operator to limit the number and size of pieces of mechanized equipment used, and to move his processing unit to new cuts several times during the mining season.

One restriction is that insufficient space is available to dispose of all the stripped material and tailings. This problem is particularly severe where large amounts of black muck are present. Because the slopes of gulch walls are steep, it is both difficult and costly to move stripped material and tailings from the gulch bottom to disposal areas along the walls using mechanized equipment.

Another factor is the difficulty of building settling ponds in gulches because the valley bottoms are very narrow and the gradient is steep. Dams across the downstream ends of settling ponds must be high if the ponds are to have a reasonable capacity. In addition, settling ponds in gulches are often in danger of being washed out because gulches are subject to freshets at times of heavy rainfall. They also fill up quickly with sand and sediment from the sluice discharge.

Some gulches do not provide a constant flow of water throughout the mining season and the construction of holding ponds and recirculation ponds in the gulch may be necessary.

Nearly two-thirds of gulch deposits occur in glaciated terrain. Because of the presence of this glacial material the gravel being mined contains a high proportion of boulders larger than 6 inches in diameter. In some cases, boulders more than 40 inches in diameter are present. The need to handle such boulders may affect the production rate, require special handling methods and increase the required amount of water for sluicing.

Gulch deposits have sufficient gradient that mine operators do not need to elevate the head of their sluice box to gain the correct slope for sluicing. Operators are generally not required to transport feed material uphill, or to dig drains for effluent, which flows away easily from the sluice box.

4.2.2 Narrow Valley Deposits

Terrain is still a factor affecting operations at narrow valley and low bench deposits but less so than gulch operations. Due to the narrow width of the valley bottom or low bench, the operator mines small narrow cuts, and is restricted in the number and size of pieces of mechanized equipment used. He must usually move his processing unit at least once during the mining season.

Insufficient space is available to dispose of all the stripped material. Space must be provided in most cases for a stable diversion channel for the stream in the valley, away from the area being worked. As in the case of gulch deposits, the slopes of narrow valley walls are steep and it is both difficult and costly using the methods employed at present to move stripped material and tailings from the valley bottom to stable disposal areas along the valley walls.

Settling ponds can be constructed with less difficulty than in gulches, but their size is still affected by the restricted width of the valley bottom. Many of the ponds quickly fill with sand and sediment and become ineffective. Settling ponds in narrow valleys are less subject to being washed out by freshets than are those in gulches, but large fluctuations in flow rates do occur in the streams in narrow valleys, and the settling ponds may at times be in danger of being washed out.

Narrow valley deposits commonly have thick to very thick wedges of black muck, and colluvium containing slabs of locally-derived bedrock overlying the gold-bearing gravel. In areas of permafrost, the wedge of colluvium is in most cases wider and deeper at the foot of a south or west facing valley wall than at the foot of a north or east facing valley wall. The black muck and colluvium can be up to 100 feet thick at some deposits, necessitating much stripping prior to mining. The material mined from narrow valley and low bench deposits does not usually have a high proportion of material larger than 6 inches in diameter.

The moderate gradients at narrow valley and low bench deposits do not affect operations in the way that steep gradients do at gulch deposits. However operators may need to elevate the head of their sluice boxes somewhat to gain the correct slope for sluicing. They are not, however, generally required to extensively elevate feed material or to dig ditches for effluent, which drains away easily from the sluice box.

4.2.3 Broad Valley Deposits

Operations at broad valley deposits are affected by the gradient of the valley, and by the characteristics of the deposits.

At broad valley deposits the gold present is usually not evenly distributed across the valley bottom, but is concentrated in a "pay streak", which may be narrow and covered by a thick layer of barren material. In these cases some of the restrictions of narrow width, as present in narrow valley deposits, may affect the operation if mining has to be done in narrow cuts.

Colluvium is not usually present at broad valley deposits, but thick layers of black muck or barren gravel may overlie the gold-bearing deposits. If present, these deposits make location of the pay streak difficult.

Mining operations at broad valley deposits usually have sufficient space to dispose of stripped material and tailings and to construct settling ponds. Hydraulic methods of stripping are not always possible because the shallow gradient in the valley is insufficient to allow muck to flow away from the operation. If cuts are large, this may affect the operation as material must be transported long distances by machine.

The gold-bearing material found at broad valley deposits usually does not have a high percentage of boulders larger than 6 inches in diameter, but cobbles between 2 and 6 inches are common.

The low gradients at broad valley deposits affect the drainage of effluent. Operators have to elevate the head of their sluicing units to obtain the correct grade and to situate the sluice above the bottom of the cut. Therefore material must sometimes be elevated as much as 50 feet when sluicing pay gravel.

Sufficient space is available to dispose of tailings. However the tailings must be elevated some distance if they are to be stacked on undisturbed barren deposits in the valley bottom, or in ramps near the foot of the sluice box. If they are to be used to backfill old cuts, less elevation is usually required.

Most of the valleys contain streams with more than enough water for sluicing. The valley bottom is wide enough to establish a stable stream diversion around the workings if necessary.

Sufficient space is available at broad valley deposits for the construction of settling ponds. They are not in much danger of being washed out as the creek is usually in a channel away from the settling pond, and because the creeks in broad valleys are not as subject to freshets as are creeks in gulches and narrow valleys.

4.2.4 High Bench Deposits

High bench deposit operations are affected both by the types of deposit and by the terrain at the site. High bench deposits were originally laid down in broad valleys, before uplift resulted in the creeks establishing new base levels as much as 200 feet below the levels of the original creeks. Most high bench deposits consist of a layer of gold-bearing gravel overlain by barren gravel.

In some types of high bench deposit sections of barren gravel up to 150 feet thick require stripping prior to mining. If the stripped material is stacked over barren deposits, it must be elevated up to 65 feet. However, it may also be used to backfill old cuts, in which case it must sometimes be transported long distances.

The gold-bearing material at high bench deposits usually consists of well rounded gravel. In the Klondike district, some of the deposits contain numerous boulders 10 inches in diameter and larger. Post-depositional alteration of the material at some high bench sites in the Klondike district has resulted in the replacement of some clasts, and some matrix material, by clay minerals. The presence of clay and boulders affects the operation and may necessitate washing and size classification of the material prior to sluicing.

An important factor affecting operations is the quantity of water for ground stripping and sluicing available at the high bench deposits. Water may be collected from the headwaters of gulches adjacent to the bench, however only small amounts of water are usually available using this method. In these cases water has to be obtained from the valley below, which involves installing a costly pumping operation. At large scale mining operations, these pumps must be capable of pumping at least 1,000 Imperial gpm to heights as much as 35 feet and through pipelines as much as 5,000 feet long. By recirculating sluicing water using settling ponds on the bench, the need for large ponds in the valley below and continual pumping of large volumes of water from the valley is reduced. However, a small settling pond in the valley and some pumping of make-up water are still required. The ponds on the bench needed frequent cleaning to prevent them from being filled with sediment and reducing their capacity for storing sluicing water.

4.3 MATERIALS HANDLING METHODS AND PROBLEMS

From the descriptions given in Section 4.1, it can be seen that there are only a few methods and pieces of equipment currently used to move material at Yukon placer mining operations. The type and size of the equipment used and the techniques applied vary in each class of deposit owing to the restrictions described in Section 4.2. In fact the methods used vary from operation to operation depending on site specific restrictions and a great deal on the personal ideas of the placer miner. This is what makes each placer operation unique and difficult to classify except in a very broad sense.

The current methods of handling materials have been summarized for six of the materials that may be present at an operation. Although all six will not always be present at any specific operation. These materials fall into the five categories defined in Section 3.4.2 as shown.

Included in the following discussion are the problems that placer miners incur using present techniques and brief recommendations on where alternative systems may help to improve the materials handling operation. These recommendations formed the basis for the design work carried out on alternative systems and reported on in Section 6.

The materials and their categories are:

1. Black muck (organic overburden). **(B)**
2. Waste gravel (overburden). **(C)**
3. Pay gravel (feed to plant). **(D)**
4. Coarse oversize (if pre-sizing is used). **(E)**
5. Coarse tailings (gravel and coarse sand). **(E)**
6. Fine tailings (fine sand and sediment usually found in settling ponds). **(E)**

4.3.1 Black Muck

Black muck, when present, is currently removed by two methods. One technique is to strip the muck in the early part of the season while it is still frozen by using dozers to rip and push it and sometimes loaders to transport it. The muck is either pushed into an old cut to be buried later by gravel, or pushed up the valley sides onto non-minable ground. Once the muck thaws it turns into a viscous and saturated bog owing to the high water content. At this stage it is impossible to use machinery on top of the muck. Some operators strip muck one year head of mining or start stripping in the late fall of the previous year when the temperature is below freezing level.

The other method of removal is to ground sluice or hydraulic the muck using water. Ground sluicing is an all encompassing term for the use of water to move material. In the context of black muck sluicing, it refers to both the use of hydraulic monitors to wash the muck and diversion of the creek through the muck, often assisted by bulldozers pushing into the stream. This was frequently stated as the way operators would prefer to strip muck. It is considerably cheaper than using diesel equipment and the water has the dual action of thawing and removing the material. Once the muck has thawed naturally, it is the only practical method of stripping black muck. The problems here are of valley gradient, environmental constraints and water storage. The use of water to ground sluice black muck is dependant on having sufficient grade to remove the material from the working area and may not be possible in broad valley deposits (see 4.2.3). If the muck cannot be discharged to the streams directly, the operation requires huge areas of settling ponds. As the muck does not settle quickly, this practice is only possible in the limited number of operations which have sufficient areas for pond construction and therefore can handle the large volumes of water and muck. Even then ponds fill up quickly with the muck. Shortages of stream water and an inability to recirculate water will also restrict the amount of hydraulicking possible.

If the problem of trash material in the muck was overcome, and the material successfully dewatered, then ground sluicing might be possible without requiring huge settling areas. Pumping of the slurried black muck and dewatering by cyclone at the disposal site is one possible alternative outlined further in this report.

4.3.2 Waste Gravel

Waste gravels vary greatly in consistency from site to site. Some deposits have only small sized cobbles (i.e.-6 inch) and a relatively consistent size range of gravel and sand, others contain huge boulders (i.e. +3 feet) and have a size distribution ranging down to fine silts. Diesel equipment is currently being used to remove the waste gravel in almost every case. This may be preceded by hydraulicking to pre concentrate the gravel section by washing out the fines. The type and size of equipment used depends on the size range of the gravels, the site terrain, and the size of operation. Generally, Cat D8 or D9 dozers, Cat front-end loaders and in a few cases self-loading scrapers are used.

The main problems encountered are the distance that the gravel has to be transported and the lack of available space to stack the material. Ideally, old cuts should act as disposal areas but, depending on the layout of the operation, this may involve excessively long hauls or pushes. Therefore it is common to see gravel stacked anywhere that is convenient and close to the area of stripping. If old cuts are used, then the waste gravel often covers up previously dumped black muck. Ideally, for reclamation purposes, the black muck would be better spread on top of the gravel.

The use of diesel equipment is probably the most practical and cost effective method for moving this highly variable material. If preconcentration of the gravels is carried out by condensing the section hydraulically, it may be possible for the fines to be slurried and pumped to disposal areas. If the barren horizons consist of sands and silts, then the pumping system suggested for black muck overburden may be applicable. If the quantity of gravel warrants it, a conveying system is one potential alternative. This would require some pre-sizing of material.

4.3.3 Pay Gravel

Some operations are using the same machinery for moving pay and waste gravel. Other operations use different equipment for digging the pay gravel and for feeding the recovery plant (i.e. backhoes). The most basic piece of equipment that is used to feed the sluice plant is a dozer, usually a Cat D7 or D8, pushing from the face of the cut to the box. This method is used mainly in gulch deposits but also in other classes of deposit. Distances to push are often up to 300 feet. Beyond this distance productivity falls of.

If pre-sizing equipment such as grizzlies and screens is incorporated in the recovery plant front-end loaders (Cat 950C and 988C) are commonly used either on their own or in tandem with a dozer building a stockpile. Front-end loaders have the advantage of being able to elevate the gravel material when feeding into a screening or grizzly plant obviating the need for large ramps required for dozers. Photograph 9 shows a loader feeding a plant using a derocker for pre-sizing. Photograh 10 shows a similar method of loader operation but with a shaking screen for pre-sizing.

Other combinations include self-loading scrapers stockpiling for a loader or backhoe and a backhoe digging the face and loading directly to the sluice as shown in Photograph 11.

The choice of equipment also depends on whether the recovery plant is fixed at one spot for the season or moved frequently and whether the muck has to be elevated to feed the plant. Photographs 11 and 12 show examples of highly movable and highly fixed sluice plants. The latter is fed by a dozer but could also be fed by a scraper/dozer or scaper/loader combination if hauls were long. Finally, the personal preferences of the owner and his financial ability to purchase additional equipment is a major factor in what type of equipment is used. In all operations there is a potential to use several different alternatives, all to good effect.

One of the problems with handling the pay gravel is the distance from cut face to recovery plant. If the plant is highly movable the distance can be minimized without loss of production by frequent moves. When the plant is fixed any move would cause serious interruptions to production. Alternative means of feeding a fixed plant may be beneficial to productivity and costs. One alternative method is to pre-size and slurry the material close to the cut face and pump the gravel to the recovery plant. A second alternative is to convey the material dry from the cut to the recovery plant.

4.3.4 Coarse Oversize

In some operations pre-sizing of the feed material is being carried out. Photographs 9-12 show four different methods. The simplest method being used is an inclined static grizzly to remove the larger boulders. Typically the oversize setting is +8 -12 inch. Other methods include the shaking or movable systems including; the "derocker" with a 2 inch setting, vibrating grizzlies with 3 to 5 inch settings, single deck shaking screens or trommels with 3/4 to 1/2 inch holes and double-deck screens with 1/2 and 1/4 inch settings.

The coarse oversize material varies enormously in its size range and at the upper end it may be up to several feet in diameter. The current methods of handling the material usually involve either a tracked dozer pushing the material to form a ramp, or a wheeled loader hauling the material up a ramp. Scrapers are aalso used at a few operations. At some operations the oversize material from the screen or trommel is fed onto a short elevated conveyor that discharges to a stockpile. The stockpile was removed to the permanent waste pile using diesel equipment.

Because the coarse oversize has a large size range, especialy on the upper end, the use of mobile diesel equipment is the most practical means of handling this material. Pumping systems are not a viable alternative. However for static recovery plants and in cases where the size range of the material is suitable for placing on a conveyor, the oversize may be conveyed and spread at the disposal point instead of using diesel equipment.

4.3.5 Coarse Tailings

In almost every operation the discharge from the gold recovery plant is allowed to flow off the end of the sluice or jigs without being retained for further processing. The tailings from the recovery plant usually divide themselves into two fractions. The coarse materials which form heaps of gravel and coarse sand directly below the plant and are referred to as coarse tailings and the finer sand and silty materials which are carried away by the water flows and are referred to as the fine tailings.

The size range of the coarse tailings depends on the size range of the feed and what type of sizing, if any, is used. The coarse tailings are handled at most operations by dozers and loaders and either pushed or hauled up ramps adjacent to the recovery plant. Unless the recovery plant is moved frequently during the operating season, these tailings ramps often become quite large and steep and the material is piled much higher than the original level of the deposits. The problems here are of excessively long and arduous pushes or hauls, and a difficulty in easily and inexpensively rehabilitating these steep ramps.

Where dozers are used to remove tailings, they are frequently working in the slurry of water and sand below the sluice as shown in Photograph 13. This causes a problem of high wear on the tracked parts and high maintenance costs. In addition, the amount of slurry moved per cycle is quite small as much runs under or around the blade, especially if ramps are steep and long. .

Loaders are becoming more popular for tailings disposal as wear on undercarriage parts is less. Photograph 14 shows a typical application. However their productivity can also be quite low and wear excessive if high and long ramps have to be climbed. In addition the loader is transporting a high proportion of water in the bucket as shown in Photograph 15. This water content lowers the actual gravel transporting capability of the loader. Loaders are more effective in disposing of dry material such as wash plant oversize mentioned in Section 4.3.4 and shown in Photograph 16.

Self-loading scrapers are used at a few operations for hauling tailings a long distance in wide valley operations and are efficient. In some high bench deposits the natural elevation of the bench is used to dispose of tailings on the hillside.

The removal of tailings is one area where alternative systems, in particular pumping, ay resolve some of the problems outlined and improve the costs and efficienty of the operation. The use of pumping systems to move taiings is predicted on the pre-sizing of the gravels.

If no pre-sizing is carried out on either the feed gravel or the tailings, then the use of pumping systems for tailings disposal is not possible and present methods are probably the most effective. The conceptual design of pumping systems to move failings formed a major part of this study.

Fixed Recovery Plants

If the type of recovery plant used is fixed, then part of an alternative system is to pre-size and pump the gravel to the recovery plant as suggested earlier. The plant could be located in an elevated position on top of an old cut or tailings pile and the tailings allowed to discharge by gravity to the disposal areas. Another alternative is to have the plant permanently located in an old cut and to pump the tailings from the plant to the disposal area. The disposal site might be an old cut, or area of previous tailings disposal, either from the current operation or older workings. At the discahrge the tailings would be dewatered and stacked. Only the very fine sediments and water would be allowed to run-off to the setting ponds. Another alternative system is to dewater the tailings at the plant and convey the material to the disposal area along with the coarse oversize.

Moveable Recovery Plants

If the type of plant used is to be easily movable, it should be based on skids. The alternative system is to keep the plant close to the face and the screenign unit and recovery plant connected so as to use gravity feed. The tailings would be collected at the discharge and pumped to disposl areas as previously outlined.

There are a number of advantages to these conceptual alternatives over some of the present systems. They will reduce the wear on mobile equipment working in water, enable tailings to be moved longer distances than is economic with diesel equipment, and simplify rehabilitation of waste piles. In addition, they should help solve the problem of settling poinds filling up with sand.

4.3.6 Fine Tailings

As the fine tailings flow away from the discharge points of the recovery plants, some of the coarser material settles out within a short distance. The amount and size distribution of material that settles out at the discharge point depends on the quantity of sluicing water used and the gradient of the valley. In gulch and narrow valley deposits the velocity of the discharge stram is high enough for large quantities of sand and coarse sediments, which normally settle out rapidly, to be carried into the settling ponds.

Settling ponds have now become manditory at all operations, but the number, size, shape, depth, location and effectiveness of these ponds varies enormously from site to site. The design of settling pond is outside the scope of this study and forms the basis for another study.(1) One of the major problems facing operators is that their ponds are filling up. This problem is especially critical where terrain limits the size of the pond that can be constructed (i.e. in Gulches and Narrow Valleys). Man operators no longer have space on their property for additional ponds are now faced with having to clean out their existing ponds.

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(1) Settling Pond Design Study for Sigma Resources Ltd., Vancouver, Contract YEDA 06 - DIAND, Yukon.

There are two problems with this. Firstly the consistency of a pond's material prohibits the use of tracked or tired heavy equipment on its surface except when it is frozen. The layer of frozen material is often limited in depth and may easily be penetrated by heavy equipment with possible disastrous results. Few operators have machinery with long reaches, such as backhoes or draglines, with which to safely muck the ponds. The second problem is where to dispose of the material from the ponds. Settling ponds are frequently located adjacent to the stream and if the material is dumped outside the ponds, it could flow into the creek during spring runoff and heavy rains.

The suggested alternative methods of handling recovery plant tailings described above will reduce the quantity of coarse material entering the ponds and hence extend their life. The problem still exists as to how to remove material from active ponds which are needed by miners for future use. Any method using diesel equipment will be limited in success.

One solution to mucking out full ponds involves slurrying the sediments and pumping them to old working areas or tailings piles for dewatering and disposal. This possible solution was investigated as part of the study.

4.4 COSTS OF MATERIALS HANDLING

The study scope of work called for determining the costs associated with different materials handling activities for each classification of deposit. It became apparent early on in the study that there was insufficient information available to accurately record costs to this detail. In addition the costs of moving materials are extremely site specific and depend entirely on the type of equipment used and the method of operation.

With the aid of members of the KPMA, some historical costs of operation were collected and analyzed. The results of this work presented in 4.4.2 clearly show the problems of trying to obtain accurate cost data for individual materials handling tasks. No comprehensive records of production or costs are kept by the majority of placer miners on an individual machine or activity basis. This fact, coupled with the tremendous variability between individual operations, and the types and condition of machines used made it impossible to obtain reliable and consistent cost information.

There is very little cost data available in literature on placer mining and much of the information given is out of date. The few recent articles examined tended to give only general costs of operating and these are presented in 4.4.2 as an indication of total operational costs. They are of little use when comparing materials handling methods on a task by task basis.

In order to assess the viability of using alternative materials handling methods, their costs must be compared with those of traditional methods. Therefore as part of this study, it was necessary to obtain as accurately as possible the capital and operating costs for various types of diesel equipment.

Current purchase prices for diesel equipment both new and used were obtained and are listed in Section 4.4.1. Average ownership and operating costs for the range of equipment selected were obtained from catalogues or calculated using standard methods. These costs are included in Section 4.4.2. The cost data presented will be useful when comparing the relative costs of using different machines and have been used in Section 6 to compare the economics of operating only tracked loaders and dozers for tailings disposal and when incorporating pumping systems in the disposal system.

4.4.1 Equipment Purchase Prices

There are a tremendous number of makes and types of machines used in Yukon placer mining. The most common piece of machinery that will be found on all medium and large operations is a tracked-dozer. Wheel-loaders are becoming more popular at operations, especially for tailings removal. They are a more productive machine for transporting material longer distances and do not suffer from undercarriage wear in the tailings slurry. At broad valley operations and higher productivity mines, tractor-scrapers for hauling feed gravel and tailings, and hydraulic excavators for feeding sluicing plants are becoming more numerous. At small one or two man operations, especially in gulches where one piece of equipment has to perform all tasks, the tracked-loaders are still popular.

Table 4-6 lists the different makes and types of equipment, included in the cost study and their weight, power and bucket capacity. These are given to enable quick comparisons of similar machines of different manufacturer. Equipment made by Caterpillar is by far the most numerous and popular at the placer operations. However, other makes of machines are also used and these are included.

TABLE 4-6

DIESEL EQUIPMENT SPECIFICATIONS

Make and Type		Machine Weight	Power Output	Bucket Capacity
		(lb.)	(hp)	(cu.yds)
Tracked-Dozers				
Cat	D7G	45,340	200	-
Cat	D8K	70,500	300	-
Cat	D9L	114,653	460	-
Komatsu	D85 P-6	58,060	220	-
Komatsu	D155 A-1	74,290	320	-
Komatsu	D355 A-3	100,150	410	-
Tracked-Loaders				
Cat	953	30,270	110	2.0
Cat	963	39,760	150	2.5
Wheel-Loaders				
Cat	950B	32,400	155	3.0
Cat	966D	43,000	200	4.0
Cat	980C	58,000	270	5.25
Cat	988B	89,780	375	7.0
International	540	35,750	190	3.75
Clarke	125C	38,750	210	4.0
Terex	72-71	89,800	388	8.0
Tractor-Scrapers				
Cat	627B	88,900	225+225*	20.0
Cat	637D	114,325	450+250*	31.0
Hydraulic Excavators				
Cat	225	52,650	135	.75 - 1.75
Cat	235	86,700	195	1.0 - 2.25
Cat	245	138,470	325	2.0 - 3.75
Hitachi	UH181	90,400	250	1.75 - 2.75
Hitachi	UH20	112,000	300	2.0 - 3.75
Hitachi	UH261	132,000	350	2.0 - 3.75
Hitachi	UH30	156,000	400	3.25 - 4.5
Hitachi	UH501	198,000	500	3.75 - 5.5

* Horsepowers are for Tractor and Scraper.

Notes (1) Bucket capacities are PCSA heaped.
Maximum capacity is for rehandle loose material.

In Table 4-7 the purchase costs of machines are listed. The new and used equipment prices were either provided by equipment suppliers or taken from catalogues of average equipment list prices for 1985. New prices are for 1985 machines with no tax or transport costs to site included. Caterpillar prices are F.O.B. Whitehorse, all others are F.O.B. Vancouver. Certain machine types listed are no longer manufactured and therefore prices were not available (N/A) or rough estimates had to be made of current worth. Used prices are based on equipment of 1981 vintage or more recent. Machines were assumed to be in good condition with a 60-90 day suppliers warranty on power trains. Used prices are quoted on the same basis as new ones. The monthly rental rates for caterpillar equipment was provided for comparison to ownership costs provided later.

Auction prices are based on machines 5-6 years old with no warranty on condition, but assumed to be in reasonable order. Prices are F.O.B. auction site. The prices were taken from a catalogue of equipment auction selling prices for all U.S.A. and Canadian auctions during 1985. These are average prices for all sales of a particular machine type auctioned during the year. It must be noted that the last bid prices for machines of similar quality and age may vary by a factor of two or more from sale to sale. Therefore the price quoted is only a very general guideline.

TABLE 4-7

PURCHASE COSTS OF DIESEL EQUIPMENT

Make and Type		New List Price (1)	Used List Price (2)	Auction/Fire Sale Price (3)		Monthly Rental Price (1)
		($Cdn.)	($Cdn.)	($Cdn.)		($Cdn.)
Tracked-Dozers						
Cat	D7G	295,900	143,000	75,500		14,500
Cat	D8K	340,000	183,000	89,800		24,500
Cat	D9L	590,000	324,000	97,700	(D9H)	27,500
Komatsu	D85 P-6	N/A	147,000	47,700		N/A
Komatsu	D155 A-1	N/A	217,500	53,400		N/A
Komatsu	D355 A-3	N/A	298,000	32,500		N/A
Tracked-Loaders						
Cat	953	142,700	90,000	26,200	(951C)	7,500
Cat	963	185,000	110,000	46,200	(955L)	8,500

TABLE 4-7

PURCHASE COSTS OF DIESEL EQUIPMENT - (Cont'd.)

Make and Type		New List Price (1)	Used List Price (2)	Auction/Fire Sale Price (3)	Monthly Rental Price (1)
		($Cdn.)	($Cdn.)	($Cdn.)	($Cdn.)
Wheel-Loaders					
Cat	950B	179,800	130,000	51,600 (950)	8,500
Cat	966D	254,000	169,000	69,800	10,500
Cat	980C	325,000	275,000	120,200	16,500
Cat	988B	477,000	230,000	154,400	19,500
International	540	212,900	151,400	N/A	N/A
Clarke	125C	226,700	164,600	33,600 (125B)	N/A
Terex	72-71B	N/A	N/A	103,600	N/A
Tractor-Scrapers					
Cat	627B	475,600	250,000	155,000	25,500
Cat	637D	803,100	350,000	105,700	32,500
Hydraulic Excavators					
Cat	225	192,400	108,000	74,000	12,500
Cat	235	331,700	265,000	112,200	16,000
Cat	245	637,220	395,000	162,800	20,500
Hitachi	UH181	265,000	159,000	63,000 (UH171)	N/A
Hitachi	UH20	400,000	200,000	49,000	N/A
Hitachi	UH261	500,000	N/A	N/A	N/A
Hitachi	UH30	N/A	250,000	136,000	N/A
Hitachi	UH501	750,000	N/A	N/A	N/A

Notes: (1) Cat prices supplied by Finning Tractor, Whitehorse.
Komatsu prices supplied by RivQuip, Vancouver.
Hitachi prices supplied by Chapman Industries, Vancouver.
All others extracted from "Mining Cost Service" catalogue published by Western Mine Engineering.

(2) Cat prices supplied by Finning Tractor.
All others estimated using Dataquest Inc.'s "Guide for Construction Equipment".

(3) Prices averaged from "The Last Bid" by International Equipment Exchange Publications.

All prices in dollars Canadian.
U.S. prices were converted using a 1.4 multiplier.

Table 4-8 shows a selection of actual purchase costs incurred by placer miners. All the equipment was purchased used. The origins and conditions are unknown.

TABLE 4-8

SELECTION OF ACTUAL USED EQUIPMENT PRICES

Make and Type		Year of Purchase	Year of Manufacture	Years Old	Purchase Price
Cat	D6	1980	1974	6	106,500
Cat	D7F	1981	1974	7	79,300
Cat	D8H	1982	1970	12	98,000
Cat	D8H	1982	1967	15	70,000
Cat	D8H	1981	1972	9	100,000
Cat	D8K	1984	1980	4	155,000
Cat	D8K	1982	1981	1	325,000
Cat	D8K	1985	1981	5	202,300
Cat	D9H	1985	1979	6	200,000
Cat	950	1979	1973	6	80,600
Cat	966	1982	1972	10	66,700
Cat	966	1982	1978	4	122,500
Cat	988	1984	1977	7	195,000
Cat	988	1982	1978	4	317,000

Note: Purchase price includes the cost of interest on borrowed money to acquire the equipment.

The table demonstrates how variable the cost of equipment is especially in the used equipment market. This makes the assessment of ownership costs very difficult. An old machine purchased recently may incur lower costs than one purchased a while back but of recent manufacture. This difference may show up in an increased operating cost for the older machine caused by major repair requirements. However that cost may be masked by differences in machine utilization. Table 4-9 amply demonstrates this.

TABLE 4-9

EXAMPLES OF ACTUAL MATERIALS HANDLING COSTS BY VARIOUS MACHINES

Type of machine		D6	D7F	D8H	D8H	D8K	D8K	D8K	D9H	950C	966C	988C	988C	627B(1)
Hours used/season		350	169	45	412	2,000	795	650	1,900	700	439	2,300	730	722
Machine only cost/hour		49	73	382	74	40	90	111	79	24	45	61	104	91
Machine + labour cost/hour		74	98	407	99	65	115	136	104	49	70	86	129	112
Seasons owned		6	5	4	5	2	4	1	1	7	4	2	4	
Cost/cu.yd.														
Stripping	vegetation				.33		1.36						?	
	muck	1.85				.52		1.13	.52			.58		
	gravel				.50	.75			.56			.90		
Feeding pay gravel		1.23	.41		.99	.41	1.05	1.00	.52	.41	1.56			
Tailings disposal		1.64			1.98	.73		1.11	.74	1.63	1.56	.65	1.30	.74
Pond construction			.41	2.71		.73	.68		.83	1.63		.69		
Pond cleaning			.41			1.45	.77		1.39			1.15		
Rehabilitation					.50		.68	.97	.42					
Feed rate to sluice cu.yd./hour		[illegible]	240		100	160	110	136	200	120	45	-	-	-

Notes:

(1) All information shown is from KPMA cost exercise except (1).

(2) Hourly machine cost does not include contract maintenance labour or cost of major overhauls and cost of tire replacement.

4.4.2 Operating Costs

The major work on collecting historical operating costs was carried out by Mr. L. Bleiler and Mr. R. Johnson of the KPMA. They canvassed cost information from a number of placer miners and compiled the results. Table 4-9 shows the results of this exercise broken down by machine and showing the cost per cubic yard for moving various types of material. The method used to calculate the costs and the assumptions used are detailed in Appendix III.

The costs presented consist of ownership cost, operating expenses (fuel, lube, P&M) and operating labour only. They do not include any allowances for administration, camp, vehicles, power, exploration, start-up and wind-down. Nor do they show costs of sluicing gravel or gold concentrating and refining. They are the basic costs for carrying out certain tasks.

The variation in costs are extremely large when comparing both different materials handling tasks and different machines doing the same task. These variations can be summarized from Table 4-9 as follows:

		Cost in $1 cu.yd.	
	Range	**Mean**	**Std. Dev.**
Stripping vegetation	0.33-2.16	1.28	.917
Stripping muck	0.52-1.85	0.92	.579
Stripping gravel	0.50-0.90	0.68	.182
Feeding sluice box	0.41-1.56	1.91	.402
Disposing of tailings	0.65-1.98	1.21	.480
Construction of ponds	0.41-1.63	0.90	.421
Cleaning ponds	0.41-1.45	1.03	.440
Reclamation	0.42-0.97	0.64	.244

There were a number of sources of error and inaccuracy that resulted in the wide fluctuations and lack of expected trends. The prime reason was that no well established, consistent method of cost accounting existed at the placer mines. All operators categorized their costs differently, thus not all the machine cost figures may contain the identical sets of costs. Most of the operations had insufficient or no data for certain areas and many figures had to be guessed at. Although most operators calculate the total cost of their operation on an annual basis, only larger public companies are presently recording detailed costs and other statistics for each individual machine and for each task.

Other sources of error that affected the costs in Table 4-9 were:

(1) The sample period for many machines was too short, thus not allowing ownership and major repair costs to be averaged out. One or two years does not give a good average cost. For this reason backhoes, which have only recently been introduced in the placer industry were not analyzed for costs.

(2) The machines were all of different age and year of purchase, as shown in Table 4-8, and all had varying purchase and resale values. This dramatically affected the ownership costs.

(3) The length of push or haul and therefore productivity varied greatly from site to site.

(4) The hours each machine was utilized varied greatly affecting hourly operating costs.

(5) The measurement of machine output was often a poor guess. Most operators use different means of account for cycle time, loads per hour etc. Also, blade and bucket capacities are only rough estimates. Operators

interpretation of a cubic yard varies. Some use a bank yard, others work in loose yards. The whole area of production statistics is often fraught with inaccuracies, as many quantities are hard and time consuming to measure.

Most placer miners lack sufficient funding to acquire all their equipment simultaneously. Instead the building block approach is used and equipment is added in stages, and is used for different tasks. This results in an ever-changing organization with a varying cost structure.

Other sources of data were used for comparison of machine costs to those presented above.

For example another placer operation in the Yukon mining approximately 130 cubic yards per hour of pay gravels quoted the following costs:

Cat 627B	Scraper	$91.0/hour
Cat D8K	Dozer	$60.0/hour
Cat 966	Loader	$40.0/hour
Cat 235	Backhoe	$40.0/hour

No labour component was included in these costs and it is assumed that ownership costs were also not included.

As the costs shown in Table 4-9 are not complete or reliable enough for a cost comparison, average costs for the ranges of machines listed in Table 4-6 were extracted and modified from a cost reference guide. Table 4-10 lists these under ownership, overhaul, operating and total hourly costs. Ownership includes depreciation and overhead charges such as interest and taxes. Major overhaul costs are based on the assumption that machines will be rebuilt at intervals and these costs have to be accrued. Operating costs include field repair parts and labour and the usual operating supplies. Total hourly costs include operating labour at $25.00, which is an average all found price including benefits.

The operating life of each machine is extremely difficult to assess and will depend on operating conditions and maintenance practices. The figures given in Table 4-10 were based on equipment manufacturers suggestions. Significant changes in operating life will significantly affect the ownership cost component. The assumed 1,400 operating hours per season was based on a six month season and a single 10 hour shift per day. An 80% utilization factor was included. Changes in yearly operating hours will affect the overhead costs and number of operating seasons based on a fixed operating life.

TABLE 4-10

AVERAGE OWNING AND OPERATING COSTS FOR DIESEL EQUIPMENT

Make and Type		Operating Life Hours	Ownership Cost $/Hour	Major Overhaul $/Hour	Operating Cost $/Hour	Total Hourly Cost $/Hour
Tracked-Dozers						
Cat	D6D	10,000	31.79	10.89	25.36	93.04
Cat	D7G	10,000	48.64	16.21	38.76	128.61
Cat	D8K	13,000	53.94	16.45	54.54	149.93
Cat	D8L	15,000	61.98	18.17	61.13	166.28
Cat	D9L	15,000	84.35	26.68	83.75	219.78
Komatsu	D85 P-18	10,000	56.58	19.42	43.81	144.81
Komatsu	D155 A-1	13,000	61.74	19.59	57.78	164.11
Komatsu	D355 A-3	15,000	73.99	23.38	74.13	197.00
Tracked-Loaders						
Cat	953	10,000	28.00	8.85	19.38	81.22
Cat	963	10,000	36.60	11.83	25.00	98.43

TABLE 4-10

AVERAGE OWNING AND OPERATING COSTS FOR DIESEL EQUIPMENT - (Cont'd.)

Make and Type	Operating Life Hours	Ownership Cost $/Hour	Major Overhaul $/Hour	Operating Cost $/Hour	Total Hourly Cost $/Hour
Wheel-Loaders					
Cat 950B	10,000	34.29	10.06	27.78	97.13
Cat 966D	10,000	45.82	11.93	36.48	119.23
Cat 980C	13,000	55.08	19.12	49.42	148.62
Cat 988B	15,000	76.75	19.25	73.67	194.68
Intl. 540	11,000	40.89	10.07	31.75	107.71
Clarke 125C	11,000	39.77	9.79	36.53	111.09
Terex 72-71B	14,000	69.63	18.22	62.50	175.35
Tractor-Scrapers					
Cat 627B	14,000	69.04	20.98	81.05	196.07
Cat 637B	16,000	108.51	36.81	127.92	273.24
Backhoes					
Cat 225	10,000	43.59	21.65	28.90	119.14
Cat 235	11,000	72.81	39.14	48.35	185.30
Cat 245	12,000	112.57	58.68	74.75	246.00
Hitachi UH172	10,000	67.54	33.52	48.63	174.69
Hitachi UH20	12,000	85.44	44.02	63.27	217.73
Hitachi UH261	14,000	93.30	44.70	72.47	235.47
Hitachi UH30	14,000	115.08	55.16	86.33	281.57
Koehring 666	12,000	80.85	41.66	62.12	209.63

Notes: (1) Costs extracted from "Cost Reference Guide" for construction equipment by Equipment Guide Book Co.

(2) Costs based on an assumed operating period of 1,400 hours per season.

(3) Total hourly cost includes operating labour at $25.0 per hour.

(4) CRG quoted U.S. prices converted to Canadian dollars using 1.4 factor.

(5) Operating life hours as based on Caterpillar handbook recommendations.

There are four particular machines most commonly used for tailings and coarse oversize removal in the placer industry. These are:

Cat	D8K	Tracked Dozer
Cat	950B	Wheel Loader
Cat	966D	Wheel Loader
Cat	980C	Wheel Loader

These machines were selected for the cost comparions made in Section 6. Consequently a more detailed cost estimate was made of ownership and operating costs using the Caterpillar handbook method. Calculation sheets are included in Appendix III.

The summary of costs is as follows:

		Ownership $/Hour	Operating $/Hour	Total $/Hour*
Cat	D8K	52.98	55.53	133.51
Cat	950B	30.99	24.12	80.11
Cat	966D	43.39	32.49	100.88
Cat	980C	55.51	40.81	121.32

* Includes $25.00 per hour operating labour.

No major overhaul cost is included. It was assumed that the machine would be sold for its residual value without major re-building. These costs compare closely to the ones in Table 4-10. However they are still average costs and do not take into account the increase or decrease in costs associated with carrying out tasks of different degrees of difficulty.

4.4.3 Conclusions

Obtaining accurate historical cost data for handling different materials was not possible for the reasons given earlier. The costs shown in Table 4-9 can only be used as a very rough indicator of actual machine costs. They are not to be interpreted as reliable data representing all the operators costs.

The theoretical hourly machine costs calculated, using assumed data on new equipment, are only an indication of likely average costs. However, they are the best cost data to use for comparison with alternative systems and form the basis of the cost calculations for the example layouts in Section 6.

Operating costs for any method of materials handling are site specific. To obtain an accurate comparison, the current costs at selected sites must be obtained by carefully monitoring the operation. It is recommended that the obtaining of reliable statistics and cost information become an essential part of any further field work on materials handling technology.

SECTION 5

MATERIALS HANDLING SYSTEMS USED ELSEWHERE

An investigation was made into the materials handling methods used in other placer mining areas and other industries. The purpose of this study was to find examples of alternative materials handling systems that might be applied in the Yukon industry. The study centred on locating industries and operations that were employing conveying and gravel pumping techniques.

A number of methods were used to collect information. The CANMET computer database of mining technology abstracts was searched for relevant articles. The Vancouver Public Library and U.B.C. Library catalogues were examined for pertinent technical books and conference proceedings. Equipment suppliers, operators and government agencies were contacted regarding information on operations using gravel pumping systems.

The work on researching alternative handling methods was limited in success. Most articles reviewed were either very general in their treatment of materials handling or out of date. Equipment suppliers provided a few references to operators using pumping systems but were not able to give specific details on these operations. Attempts to contact operators using these methods were not successful.

The following sections give a general overview of methods used elsewhere and where appropriate reference to specific sites using conveying and gravel pumping techniques.

5.1 OTHER PLACER MINING AREAS

Five areas were selected for examination. In each area both pumping and conveying techniques are used to varying degreees. No mention has been made of Australia and South America because of a lack of information. They are known to use similar techniques to the areas mentioned.

5.1.1 Alaska

Mining methods in Alaska are very similar to Yukon. Some dredging is still carried out around Nyac and other coastal areas. The majority of mines use mechanized methods for moving materials and sluice plants for recovering gold. D.J. Cook (1) gives an excellent review of the different mining techniques. Screening plants to pre-size material are becoming popular in order to reduce water consumption and improve fine gold recovery. One operator is using a wobbler feeder for classification with apparent success (2). The cost of this unit was quoted as U.S.$36,000, F.O.B. factory in 1979.

G. Haskins (3) reported on the use of a trommel washing plant followed by a conveyor-stacker for disposal of oversize material. The use of the stacker for tailings versus using a tracked-dozer was estimated to save 50-70¢ per yard over a total cost of U.S.$2.60 per yard. Other methods of cost improvement by applying efficient methods of material handling are mentioned by S. Haskings (4). The methods described included the use of a scraper for ground stripping. Proposed improvements included using a scalping device to remove boulders and installing a trommel. This change of method was to recover the fine gold and increase recovery from 22% to 70%.

A paper by D. Colp (5) describes a static high production plant in the South Alaska Range. This 200 cubic yard per hour plant uses conveyors to transport material from the feed hopper and grizzly to the three decks of screens. All the oversize (60% all +¼ inch) is conveyed to a waste stack. A tracked dozer removes the sluice tailings and waste stack. An article by O.L. Schumacher (6) describes and costs a mechanized operation of similar location but smaller production.

Personal communication by the author with Alaska government departments and equipment suppliers indicated that no one appeared to be pumping black muck, sluice tailings, or settling pond sediment. Pumping of gravels, except in the case of dredges, is not currently practised in the Alaska Placer Industry. One supplier (7) referred to a miner using their alluvial treatment plant in the Circle Mining District. This is a unitized jigging plant with a trommel washer. This plant incorporates stacker conveyors for oversize and a series of small gravel/slurry pumps for moving material to the jigging units. The tailings are dewatered before discharge using a cyclone. The plant, capable of processing 200 cubic yards per hour of bank run material, is manufactured by IHC of Holland and costs $570,000 U.S., F.O.B. Rotterdam.

5.1.2 British Columbia

The methods of materials handling are similar to those used in Alaska and Yukon. Most operations rely on diesel equipment to move material.

A paper by L. Olynyk (8) describes the methods of handling materials. Backhoes and loaders are more popular than dozers for feeding pay gravel to the plant. Wash and pre-sizing plants appear to be used at most operations. Conveyors are not used to transport feed material to the plant. However short conveyor lengths are often used to take material from hopper to screen and to stack screen oversize. Operators are attempting to clean out their settling ponds with loaders or backhoes. A cost of over $1.00 per cubic yard was quoted.

One mine, Auramet, was reported by B. Gordon (9) to be pumping feed material. The mine, situated in the Cariboo district of B.C., has material up to 36 inches in size. Gravel is fed by backhoe to the three-deck screening unit at 300 cubic yards per hour. The oversize is stacked by conveyor. The -¼ inch undersize is pumped at a 2.3 pulp density by an Allis-Chalmers SRL-C 6 x 8 pump to barrel concentrators. The plant uses 1,500 gpm of wash water. The pumps have operated for two seasons without a major fault.

Another miner, Mr. F. Nestel, situated near Wells, was reported to be pumping tailings away from his sluice. The feed gravel is pre-screened to -½ inch and an old 10 inch dredge pump used to transport the tailings for disposal over old working areas. No dewatering device is used at discharge. The tailings are flattened by dozer once naturally dewatered.

5.1.3 South Western U.S.A.

California, Nevada, and Arizona all have placer mining operations. The level of placer mining activity is less than Yukon or Alaska and the different climate and terrain results in different problems. Very little literature was available on the materials handling techniques being used. Communication with local placer miners (10) indicates that at sites with fixed recovery plants, conveyors are used extensively to move feed material to the plant and remove oversize. The dryness of the material makes it easy to convey. Recirculation of water is an imporant aspect of operating in the arid climates.

Only one site was known to be using gravel pumps. This site, visited by the author, was located in the Olinghouse placer area 30 miles northeast of Reno. Feed gravel is mined at a rate of 200 cubic yards per hour and transported to the wash plant trommel by a series of conveyors. (See Photograph 17). The trommel undersize is screened further on a single vibrating deck to -3/8 inch. This material is then pumped using a 10 x 10 Gallagher gravel pump to the enclosed recovery plant where a bank of cyclones dewaters and deslimes the gravel ready for jigging. (See Photographs 18 and 19). The pump, which is electrically driven through a gearing system, has operated for a year without significant wear. The jig tailings is pumped to a spiral classifier where the sand fraction is dewatered for conveying to the dump. (See Photograph 20). The overflow from the classifier is settled using a thickener tank as part of the water recirculation system. Although the plant has been successfully pumping -3/8 inch material for a year, the time period of operation is too short to assess the long term costs of operation. The capital cost of the washing and recovery plant is far higher than any operation in the Yukon and the fixed layout of the plant is inappropriate for the operating conditions in Yukon.

5.1.4 The Far East

Both gold and tin mining are carried on extensively in Malaysia, Thailand, Indonesia and the Philippines. There are differences between the methods of recovery used for the two metals, but the materials handling techniques are similar. In a comprehensive book by Harrison (11) on mining alluvial metals, two main methods are defined. Mining by dredge and gravel pump mining. Dredging is carried out using large floating pontoon dredges with either a complete on board concentrating plant, or a gravel pumping system to transport material to an onshore plant.

Gravel pump mining for tin is referred to in three of the references cited (12, 13, 14). In brief, the method uses high-pressure monitors to break up the alluvium and sluice it to a central sump. Vertical-lift gravel pumps are used to pump the slurry to the sluicing plant outside of the mining cuts.

The tailings from the sluices are settled in large ponds before the water is allowed to discharge to the river system. Reclamation of old workings is becoming mandatory in many countries, especially Malaysia and pumped tailings are being increasingly employed. The gravel-pumping system has been used successfully for over 50 years. The types of pumps used today are of the vertical type in which the motor and the pump are rigidly joined and direct coupled. The pump unit is raised and lowered by chain block to accommodate varying levels of slurry. Typical sizes of pumps used are those with 7 inch or 8 inch diameter inlets driven by 100-150 hp electric motors. Costs of gravel pump mining vary widely. One example cost quoted was $0.57 U.S. per cubic yard in 1977.

5.1.5 U.S.S.R.

Very little information is available concerning the costs of gold placer industry in Russia. Only one book was located that gives technical details of their materials handling methods (15). This book illustrates a number of standard washing and recovery plants. Each plant model is designed for different capacities of feed gravel and wash-water. Many of these units use short conveyor lengths to transport feed or screen oversize, reducing the need for mechanical equipment.

A common feature of one series of units is the use of jet pump washers. These were used as early as 1960. The gravel/sand is delivered by a bulldozer to a hopper and then transported using a jet pump to the head of the sluice 30-40 feet higher up. These pumps are quoted as handling 2,000 cubic yards per day. Jet pumps are also used in the recovery plant to move material and are more common than sand/gravel centrifugal pumps for this work. Cyclones are occasionally used for dewatering but do not seem to be common features of the Russian placer mining units.

5.2 OTHER INDUSTRIES

Three industries were selected for study that make extensive use of pumps and conveyors for transporting coarse gravel. Other industries that use slurry pumps to handle finer materials were not examined. Examples of these would be the coal mining industry, pumping coal slurries and the hard rock mining industry where many SAG milling operations use 10-14 inch pumps to transport material from mills to screens and cyclones.

5.2.1 Sand and Gravel Quarries

Pumping and conveying methods are used at sand and gravel quarries. Most operators use conveyors to transport feed material to the screening plants and then to stockpile the coarse well drained products. Gravel pumps are being used by a few operations to transport pre-sized material from the quarry floor to the plant. Smaller slurry pumps to handle sand are used at many operations to move the finer-sized products. Hydrocyclones are also used at many operations to dewater the fine sand products before stockpiling.

The hydraulic transport of gravel is common in the U.S. mid-west. Also, one quarry near Winnipeg and another near Toronto transport gravel by pumping. However, no quarries contacted in the British Columbia lower mainland reported using gravel pumps to feed their screening plants.

5.2.2 China Clay Industry

The china clay mines of Cornwall, England have used gravel pumps for many years to transport the slurry of sand, stone and clay from the pit bottom to the process plant. The stone and sand fractions are made up of an unweathered feldspar and very angular quartz fragments. A very hard and brittle mixture. The system is not unlike the gravel pump mining of tin in Malaysia except that horizontal electrically powered pumps are used instead of vetical pumps.

The clay plus sand and gravel (stent) is washed from the pit face using hydraulic monitors operating at up to 250 psi. The slurry travels to the pit bottom where gravel pumps elevate the material out of the pit. Because of the depth of some pits, pumps are often connected in series at stages up the incline. One pit manager contacted (16) has five pumps in line and is handling densities of up to 1.3 with stones up to 4 inches across. His system can handle up to 98 tons per hour of sand and stones plus 18 tons of clay in suspension. The size of pumps used range from 8 inch to 10 by 12 inches. Pump impellars are made of Ni-hard and adjustable to allow for wear. Linings and impellers can last up to six weeks when handling this brittle mixture. Pumps are either manufactured in-house by the company's engineering works or purchased from Warman Pumps Ltd.

The two methods of dewatering used in the processing of clay are spiral classifiers and vibrating dewatering screens. Cyclones do not seem to be used much for dewatering.

The pipeline used to transport the slurry is 8 or 10 inch flanged steel pipe. This pipe is lined with polyurethane and has excellent wear characteristics with a life of 8-10 years of continuous duty (17). This pipe is manufactured by the company in-house and sold world wide to other users such as the NCB for coal slurry and Rio Tinto Mines, Spain for handling ore slurry.

5.2.3 Dredging Operations

The typical dredge used for harbour work or land fill handles extremely large volumes of very coarse gravel. One recent operation in B.C., run by Centennial Dredging was pumping 1,000 cubic yards per hour of gravel containing rocks up to 6-8 inches. A 20-inch pump was used and the material transported two miles in a 20-inch steel line. The gravel slurry had a 14% solids ratio. Another example of high production dredge mining of gravels is the movement in South Africa (18) of up to 2.0 million tons of beach sand containing heavy minerals. Here 24/20 Warman pumps are used on the dredges. Each can handle up to 2,200 tons per hour of slurry at 40% solids ratio. The material is coarse, abrasive beach sand and rocks up to 13 inches across have passed through the pumps.

Both the examples quoted are for pumping operations much larger than are anticipated for Yukon Placer mines. However, they serve to demonstrate that pumping and transportation of gravels with large size ranges is frequently accomplished in other industries.

5.3 SUMMARY

In his textbook on alluvial mining (19), MacDonald states that:

> "From the first recorded use of pumping devices for conveying solids ... placer technology has come to rely more on pumps for solid transportation than upon any other form of materials handling and slurry pumps are now the central features in most placer operations."

Mr. MacDonald was mainly referring, in this statement, to the placer industries of Asia and Australia where gravel pumping at dredging and hydraulic mines is common. His observation reinforces the conclusions of this survey that pumping and conveying of gravels, under the right conditions, are suitable materials handling systems for moving placer gravels.

The sizes of pumps used in the industries that were reviewed vary from large 20 inch dredge pumps down to 8 inch pumps for handling finer gravels. Currently pumping of gravels is not practiced at all in the Yukon and rarely in Alaska and B.C. However, it is a proven method and has potential for increasing operating efficiency and facilitating reclamation in these placer mines. Therefore the conceptual design of gravel pumping systems to feed pay gravel to the plant and dispose of tailings has formed a major part of this study.

Conveyors, such as those used at sand and gravel quarries, have also been incorporated into the proposed materials handling systems, where practical, as transportation devices for feed gravel to the wash plant and coarse well drained material to disposal areas.

SECTION 6

CONCEPTUAL DESIGNS OF ALTERNATIVE SYSTEMS

6.1 INTRODUCTION

This section provides a survey of available equipment, conceptual designs and cost details for the alternative materials handling systems recommended in Section 4.3. These are systems to handle black muck, feed gravels and tailings and settling pond sediments. The designs for pumping systems for feed gravels and sluice tailings were given more consideration as these are the systems most likely to have an immediate benefit to the placer industry and also the highest chance of success. This is born out by the literature review covered in Section 5 which showed that, although not used widely in the American placer mining industry, gravel pumping is used successfully in many other areas.

Following the sections on equipment and materials handling concepts, a series of example layouts are given to demonstrate how gravel pumps and conveyors might be used. These examples are based on the typical placer operations described earlier in Section 4 but modified to show how the alternative handling systems might be applied. Comparative costs are presented to show the difference when adding pumping and conveying systems for gravel transportation versus using only diesel equipment.

The use of pumping and conveying equipment to replace or supplement mobile equipment in handling gravels is predicated on one important fact. All the systems proposed require some level of pre-sizing of the material. If alluvial gravels are to be handled unclassified, then these alternative systems will not work or be economic and the existing methods using mobile diesel equipment are the best practical technology.

6.2 TYPES OF EQUIPMENT AND COSTS

6.2.1 Pumps

The single most important factor affecting centrifugal slurry or gravel pump selection is the slurry classification. There is no specific demarkation point where one pump type ceases to be effective and another takes over, thus no universally accepted standard exists to classify abrasive solids-handling pumps. For the purposes of this report, the following categorization illustrated on Table 6-1 is used.

TABLE 6-1

CLASSIFICATION OF PUMPS ACCORDING TO SOLID PARTICLE SIZE

Tyler (in.)	Standard Opening (mm)	Sieve Mesh	Material Grade	Rubber Lined Pumps	Hard Iron Pumps	General Pump Classification
+.625	15.85	-				Dredge Pumps
+.525	13.33	-	Shingle and Gravel			
+.441	11.20	-				
+.371	9.42	-				
+.321	7.93	2.5				
+.263	6.68	3				
+.221	5.61	3.5				Gravel and Sand Pumps
+.185	4.70	4				
+.156	3.96	5				
+.131	3.33	6				
+.110	2.79	7				
+.093	2.36	8				
+.078	1.98	9				
+.065	1.65	10				
+.055	1.40	12	Coarse and Medium Sand			
+.046	1.17	14				
+.039	.99	16				
+.033	.83	20				
+.028	.70	24				
+.023	.59	28				
+.020	.49	32				Slurry Pumps
+.016	.42	35				
+.014	.35	42				
+.012	.30	48				
-.010	.25	60	Fine sand and Silt			

Centrifugal solids handling pumps differ in design and construction largely according to the maximum size of the particles to be pumped. Gravel or dredge pumps feature large clearances for the passage of gravel and cobble-sized fragments. Sand pumps are restricted to handling finer grained sediments containing only occasional small pebbles. Although not strictly classified as centrifugal pumps, jet lift pumps are included because they incorporate multi-stage centrifugal water pumps and find use in some placer applications.

Pumps are designed for either horizontal or vertical mounting. Horizontally mounted pumps offer the widest range of applications; they cost less and are easier to maintain in general service. The vertical types are preferred wherever difficult suction conditions can be avoided by using a submersible pump or where the headroom is limited in confined spaces.

Dredge and Gravel Pumps

Dredge and gravel pumps are designed for handling solids with large particle size ranges and are the most versatile of all solids handling pumps. They have the ability to pump mixtures of sand, mud and gravel-containing particles that are too large for most other pumps.

Sand Slurry Pumps

Sand slurry pumps are used for pumping relatively clean, free-flowing sands in concentrating plant service and in some beach-mining operations. They differ in construction from gravel pumps in that, normally, the pump casings are split and impellers and liners are supplied in moulded rubber except where sharp objects such as shells, wood fragments and similar trash may be present, when special steel alloys are used to resist the wear. Sand pumps are usually lighter in construction than gravel pumps and have narrower passages.

Jet Lift Pumps

Jet lift pumps are the least efficient of all centrifugal type pumps and, generally, the total jet system efficiency from prime mover, through the water pump and jet lift is around 20% or less, whereas a comparable submerged pump system has an overall efficiency several times gr[illegible]. However, jet lift pumps can usually pump at higher solids concentrations than other dredge pumps.

Pump Selection

As abrasive solids bearing mixtures pass through a pump, the wet surfaces will be subjected to varying degrees of wear. Wear in this service cannot be precisely predicted. The most affected parts in order of severity are: impeller, casing volute, suction inlet and shaft seal. Recognizing that elimination of wear is impossible, parts life can be prolonged and maintenance reduced by a sound approach to pump selection.

For typical placer mining applications, pump selection should be based on:

- Low pump RPM, as a guideline wear varies approximately as the cube of the RPM.
- Good abrasion resistant materials. As a general rule, use hard metal-lined pumps for solids greater than 1/4" and rubber lined pumps for solids less than 1/4".
- Generous wear allowances on parts subject to wear.
- Hydraulic design minimizing effects of wear.
- Simple mechanical design providing quick and easy access to all wearing components for maintenance and replacement.
- A high degree of interchangeability.
- Dry gland seals, since a clean gland seal water supply is most likely unavailable.

Since hard metal or rubber impellers cannot be reduced in diameter to meet different conditions, the pump should be [illegible]t driven. Pump performance can then be achieved by selecting the desired shea[illegible]tio to give the pump speed required.

Belt drives are tolerant of some misalignment, thus unskilled mechanics can readily work on them.

Horizontal slurry, sand or gravel pumps can be conveniently powered by diesel or gasoline engines, while submersible dredge type pumps would require electric or hydraulic motors which would be powered from diesel driven generator or hydraulic pump sets.

The following Table 6-2 lists a sample of the more prominant manufacturers of solids handling pumps and the types of pumps they have to offer. Many other pump manufacturers exist but they are too numerous to list here.

Drawing Nos. 1401-210-1201 to 1402-210-1208 illustrate how pumping techniques can be incorporated into typical placer mining operations. For simplicity, the various pumping arrangements have been grouped into three tailings pumping performance ranges: 1,458, 2,166, and 3,332 Imp.GPM (1,750, 2,600 and 4,000 US GPM). Several pump manufacturers were contacted for pump recommendations, for pumping typical sluice -5/8" tailings as shown on the flowsheets. Their recommendations for this application, and budget pricing are listed on Tables 6-3 to 6-5.

It is recognized that sluice tailings particle size analyses will vary widely, however for the purposes of pump recommendations, a single mesh analysis was assumed, as follows:

5/8"	to	# 10 mesh	39% by weight
# 10 mesh	to	#100 mesh	32% by weight
#100 mesh	to	#200 mesh	8% by weight
Less than		#200 mesh	21% by weight
			100%

Specific gravity of slurry 1.1

20% solids content of slurry

TABLE 6-2

PUMP MANUFACTURERS AND PRODUCT RANGE

Manufacturer	Horizontal Slurry Pump	Vertical Slurry Pump	Horizontal Sand and Gravel Pump	Vertical Sand and Gravel Pump	Dredge Pump	Jet Pump
Denver-Orion	x		x			
Sala	x	x	x			
Hazelton	x	x				
Warman	x	x	x		x	
Worthington	x	x	x	x		
Galigher-Ash	x	x	x			
Goulds (Morris)	x	x	x		x	
Georgia Iron Works (GIW)	x		x			
Toyo	x	x	X	x	x	x
Flygt		x			x	
Allis-Chalmers	x					

Note: Numerous other pump manufacturers exist. The above list is only a sampling of the more prominent manufacturers.

TABLE 6-3

BARE PUMPS - 1,458 IMP.GPM FOR -5/8" TAILINGS

Application	Manufacturer	Model (Size)	Type	Max. Solid	Lining	Price
-5/8 Tailings	Denver-Orion	200/150F (8"x6"x24)	Horizontal Sand/Gravel	2¼"	Ni-Hard	$18,500
-5/8 Tailings	Goulds (Morris)	CKX (8"x6"x19½")	Horizontal Dredge/Gravel	4-1/8"	High-Chrome Hard Iron	$16,000
-5/8 Tailings	G.I.W.	8x8 LSA 25 (8"x8"x24½")	Horizontal Sand/Gravel	3"	Gasite 4 Hard Metal	$20,700
-5/8 Tailings	Toyo	SPL 150C (8"x6"x17.3")	Horizontal	2.6"	High-Chrome	$ 8,000
-5/8 Tailings	Worthington	6M163 (8"x6"x16.6")	Horizontal Sand/Gravel	2.1"	Hard Metal	$11,000

TABLE 6-4

BARE PUMPS - 2,166 IMP.GPM FOR -5/8" TAILINGS

Application	Manufacturer	Model (Size)	Type	Max. Solid	Lining	Price
-5/8 Tailings	Denver-Orion	250/200F (10"x8"x24")	Horizontal Sand/Gravel	2¼	Ni-Hard	$19,000
-5/8 Tailings	Goulds (Morris)	CKX (8"x6"x19½")	Horizontal Dredge/Gravel	4-1/8"	High-Chrome Hard Metal	$16,000
-5/8 Tailings	G.I.W.	8x10 LSA 32/25 (8"x10"x31-3/4")	Horizontal Sand/Gravel	3"	Gasite 4 Hard Metal	$22,650
-5/8 Tailings	Toyo	SPL 200 (10"x8"x21.3")	Horizontal Sand/Gravel	3.3"	High Chrome	$12,300
-5/8 Tailings	Worthington	8M193 (10"x8"x19.25")	Horizontal Sand/Gravel	2.8"	Hard Metal	$12,650

TABLE 6-5

BARE PUMPS - 3,332 IMP.GPM FOR -5/8" TAILINGS

Application	Manufacturer	Model (Size)	Type	Max. Solid	Lining	Price
-5/8 Tailings	Denver-Orion	300/250F (12"x10"x24")	Horizontal Sand/Gravel	2¼"	Ni-Hard	$19,250
-5/8 Tailings	Goulds (Morris)	CKX (10"x8"x24½")	Horizontal Dredge/Gravel	5-7/8"	High-Chrome Hard Iron	$23,950
-5/8 Tailings	G.I.W.	10x12 LSA 32/25 (10"x12"x31-3/4")	Horizontal Sand/Gravel	4½"	Gasite 4 Hard Metal	$23,850
-5/8 Tailings	Toyo	N/A	N/A	N/A	N/A	N/A
-5/8 Tailings	Worthington	10M234 (12"x10"x23.35")	Horizontal Sand/Gravel	3.6"	Hard Metal	$17,600

6.2.2 Conveyors

For most placer mining operations, 24 inch wide belt, three roll trough conveyors will be more than adequate. Eighteen inch wide conveyors might be adequate in some applications but the cost savings are minimal and [illegible]d not justify their selection. The resale value of a 24 inch conveyor would be appreciably more than a light 18 inch unit.

Inexpensive skid-mounted stationary conveyors are available and provide good mobility when provided with lifting straps for easy handling. These probably satisfy the bulk of placer requirements but the portable wheel-mounted units provide maximum flexibility.

The wheel-mounted units can be provided with tow hitches, kingpin attachments and swivel wheel assembles in order to reposition on site, move via highways to original or different sites with a standard truck tractor, or to use as a radial stacker to distribute material.

Powered radial travel and adjustable height features are available but probably not warranted at most placer operations. Conveyor relocation by mobile equipment is preferred, and adjustable height is available using inexpensive winch and cable mechanisms which would be adequate for most.

Electric, diesel or gasoline drives are available with complete control systems, these would normally drive the conveyor through a V-belt drive system.

Many manufacturers of stationary and portable equipment of this type exist, most having similar product lines differing only in quality and price. Price differential for similar sized equipment is illustrated in Table 6-6.

Several units have been selected for comparison purposes. This information is shown on the following Table 6-6. Fifty and one hundred foot diesel driven portable wheel-mounted stacker units were used for comparison. For capital and operational cost analyses later, quoted prices will be reduced by 10% to reflect fixed conveyors.

TABLE 6-6

CONVEYORS - DIESEL DRIVEN WITH ADJUSTABLE HEIGHT

Application	Manufacturer	Type	Length	Tonnage	hp	Driver	Price
-3" Sands and Gravels	Transcontinental	24" Belt	50'	140-280	5	Diesel	$ 17,800 *
-3" Sands and Gravels	Transcontinental	24" Belt	100'	140-280	15	Diesel	$ 48,400 *
-3" Sands and Gravels	Industrial Equipment	18" Belt	50'	140-280	5	Diesel	$ 76,000
-3" Sands and Gravels	Industrial Equipment	24" Belt	50'	140-280	5	Diesel	$ 84,000
-3" Sands and Gravels	Industrial Equipment	18" Belt	100'	140-280	10	Diesel	$120,000
-3" Sands and Gravels	Industrial Equipment	24" Belt	100'	140-280	15	Diesel	$129,000

Notes:

- Prices include diesel drives, under-carriage and wheel assemblies.

* Reduce these by 10% for fixed stationary conveyors.

6.2.3 Dewatering Devices

Having created a gravel/sand/water slurry in the screening/sluicing process, it is desirable to separate coarse materials and deposit them with as little water content as possible.

Hydrocyclones are an excellent inexpensive piece of equipment for dewatering tailings gravels and sands. Good separation efficiencies are available to minus 200 mesh with underflows of up to 70% solids. Overflow streams can then be piped to settling ponds for fine solids settling.

A dewatering cyclone relies for its action on centrifugal forces generated by the high tangential velocities of the flow. The incoming slurry forms a primary vortex around the inner cone wall and, in this zone, the tangential component increases away from the cone wall towards the centre of the cyclone, reaches a maximum and then decreases rapidly to zero. Thickened solids are discharged at the spigot and the effluent forms a smaller vortex around the axis of the cyclone. Several units have been selected for comparison. This information is shown on Table 6-7.

Vertical components of the velocity act downwards near the cone walls and upwards near the axis. An intermediate zone or envelope, having zero and vertical velocity, separates the coarser solids moving downwards to the discharge spigot from the effluent containing finer solids moving upwards. Because of the reduced size of the inner vortex and its requirement to pass the bulk of the flow, there is an increase in circumferential speed and higher centrifugal forces are generated resulting in a more efficient separation in the finer sizings. As a result, the rejected fine particles larger than the size of separation are returned to the primary vortex and once more have an opportunity to be discharged with the spigot product.

The capacity and performance characteristics of hydrocyclones are controlled by several interrelated factors such as specific gravity of solids, specific gravity of liquid, size distribution of solids and percent solids by volume.

TABLE 6-7

HYDROCYCLONES

Application	Manufacturer	Model	Capacity	Size	Lining	Weight	P	Price
-5/8" Tailings	Lawjack	HSE-824	1,750 US GPM	24" dia.	Linatex	1,690 lb.	8-10 psi	$10,605
-5/8" Tailings	Lawjack	HSE-1030	2,600 US GPM	30" dia.	Linatex	2,292 Lb.	8-10 psi	$13,830
-5/8" Tailings	Lawjack	HSE-1236	4,000 US GPM	36" dia.	Linatex	3,200 lb.	8-10 psi	$17,980
-5/8" Tailings	P.J. Hanna			26" dia.				$12,000
-5/8" Tailings	P.J. Hanna			26" dia.				$12,000
-5/8" Tailings	P.J. Hanna			26" dia.			20 psi	$12,000

Physical properties of the cyclone itself have significant effects on performance. Cyclone diameter, feed inlet area, vortex finder, cylinder and cone length, cone angle and feed inlet pressure are some of these properties.

While hydrocyclones have flexible operating ranges, final selection should be determined by the manufacturer when provided with the desired performance requirements.

Desirable features are:

- Easily replaceable wear liners.
- Sectioned cylinder and cone to facilitate liner replacement.
- Adjustable underflow regulator.
- Victaulic couplings instead of flanges for pipe connections.

Other Dewatering Devices

Two other methods of dewatering a sand/gravel/water slurry are spiral classifiers (sand screw) and dewatering screens. Both are more static pieces of equipment and would need to be supported on a skid mounted rig.

Most processing equipment companies manufacture classifiers. Examples are: Denver Equipment Co., Wemco, and Eagle Iron Works. Classifiers are made in many configurations of tank and spiral. They can create a sand separation of 65-200 mesh minimum size. Most classifiers are driven by electric motors. One example of their use is for dewatering different product sizes in the sand and aggregate industry. Classifiers are manufactured with spiral diameters ranging from 12 inch to 90 inch and with tan [illegible]ngths from 6 feet to 50 feet. The size of classifier will depend on the flow rate, requ [illegible] d conveying capacity, material distribution etc. Examples of costs for classifie [illegible] en below. These do not include motors and are average prices mid-western U. [illegible] tax or transportation.

Screw Dia.(in.)	Tank Length (ft)	Capacity tph Solids	List Price Canadian $	Auction Average Canadian $
20	19S	21 - 35	22,400	-
36	25S	66 - 110	42,000	16,000
48	32S	123 - 205	74,200	20,300
48	32D	246 - 410	126,000	-

S = Single screw
D = Twin Screw
Auction prices vary enourmously. Averages are only a guide.

Spiral classifiers are much bulkier than hydrocyclones and considerably heavier. They can be problematic when handling a high proportion of clay materials. For these reasons they are not as versatile as hydrocyclones for dewatering sluice tailings, and considering the price not recommended for the applications covered in this report.

Dewatering screens are manufactured by Derrick Manufacturing Corporation and others. They consist of a steep variably increasing inclined deck (22°-35°), covered in a Linatex slotted rubber surface. The deck vibrates at a high frequency (3,600 RPM). They are used for dewatering coal, iron ore, fine sands, phosphate ore, heavy mineral sands and mill tailings. Dewatering ability can be improved by applying a vaccum to the final dewatering section. These screens are normally used in conjunction with a hydrocyclone separator, although use on their own is possible.

Screen deck sizes vary according to the required capacity. Lengths of deck are usually 100-124 inch and widths vary from 12 inch to 38 inch. Dewatering screens require more attention and maintenance than hydrocyclones and also an electrical power source for operation. They are not suitable equipment for use in dewatering sluice tailings.

6.2.4 Screens, Trommels and Grizzlies

In order to reduce overall feed gravel size to a level which will be acceptable for pumping and sluicing, it will be necessary to pre-screen feed gravels. Different sites and deposits will require different techniques but primarily inclined vibratory screens or trommels are recommended.

To protect screens from mechanical damage, they should follow a grizzly or similar device which will eliminate oversize material, large rocks, etc. The undersize from these then feeds the screen. Some screens can be supplied with integral grizzly decks but it is expected that most placer operations will utilize modular techniques incorporating available materials.

Generally, inclined vibrating screens are more applicable to the placer mining situation but horizontal and low profile units are available for specific applications where lack of elevation presents a problem. Horizontal screens are more efficient at size separation but are considerably more expensive than inclined screens. Single, double and triple deck screens are available but it is expected that most placer operations will not require anything more than a single deck screen.

Desirable features in a screen are: adjustability of the vibrating mechanism for tuning of the machine operation; easily removable and serviceable screens; quick access for repair; easily serviced sub-assemblies; interchangeable parts.

Screens come in many lengths and widths depending on the capacity and size split required. The decision on which screen size and make to use will be totally site specific and only a sample of screen sizes and prices are shown in Table 6-8. These costs are for the basic screen only, F.O.B. factory. Mounting of the screen for use as a transportable module and freight charges could double these prices. Alternatively miners may manufacture their own decks as is done in some cases now (see Photograph 10) and save on the screen purchase price. The price of screening decks at auctions varies considerably depending on demand, condition and number of screen decks.

TABLE 6-8

WET VIBRATORY SINGLE DECK SCREENS

Application	Manufacturer	Capacity (tph)	Size (ft)	Model	BHP	Driver	Price
-3" o/s 5/8" u/s 5/8"	C.E. Tyler	140	4' x 8'	Ty-Rocket S	10	Electric	$ 14,000
Sands and Gravels	C.E. Tyler	210	5' x 12'	Ty-Rocket S	10	Electric	$ 15,000
Sands and Gravels	C.E. Tyler	280	6' x 12'	Ty-Rocket S	10	Electric	$ 20,000
Sands and Gravels	Simplicity	140	3' x 6'	MC-65	3	Electric	$ 10,250 *
Sands and Gravels	Simplicity	210	3' x 8'	MC-65	3	Electric	$ 10,600 *
Sands and	Simplicity	280	4' x 8'	MC-65	5	Electric	$ 12,000 *

* Motor Extra

Gravels

Trommels are currently being used at some high bench deposits (see Photograph 12). They are more effective than flat screens in breaking up clays. The size of openings in trommels can vary between 1 inch to 1/2 inch diameter. Because of their size, weight and requirement for careful alignment, the use of trommels will be confined to static plants with the feed material transported from the cut by conveyor mechanical equipment. Trommels vary in size accor[illegible] desired capacity and are usually custom made for a specific site. The following [illegible] an indication of average prices for new equipment. No resale or auction prices are available. In the Yukon there are a number of old dredge trommels left that might be refurbished at a reasonable price:

Diameter (in)	**Length (ft)**	**Capacity (cu.yd./hr)**	**Cost ($)**
36	16	40	50,000
48	23	85	73,800
60	25	250	105,000
72	25	350	200,000
84	43	500	296,000

No motor included in price

Source: "Mining Cost Service Catalogue" - Western Mine Eng.

Most grizzly arrangements will be particular to the site and prefabricated to individual needs. A number of vibrating grizzly units are manufactured to specific sizes and a selection of average prices are listed below. Included in the list is the price of a "Derocker" which has been classed as a grizzly rather than a screen.

Width (ft)	**Length (ft)**	**Cost ($)**
3	5	25,000
3.75	7	30,000
4.5	8	38,000
5	10	70,000
Derocker		70,000

6.2.5 Piping

Numerous piping systems are available for use in this type of service. Of interest to the placer miner are cost, life and weight (for handling). Table 6-9 lists price and weight per foot for polyurethane lined, high density polyethylene (HDP) and standard carbon steel pipe.

As can be seen from the table, the HDP pipe is approximately half the price and one fifth to one sixth the weight of comparative carbon steel pipe.

HDP pipe is finding increasingly greater use in slurry service where it has demonstrated exceptionally high abrasion resistance. Other advantages are low friction resistance and high flexibility. Some disadvantages are its lower pressure rating than steel and the fact that more care is required in handling and placement to avoid external damage. Where possible, placement on sharp rough gravels should be avoided.

While the minimum bends associated with flexible straight pipe runs would not be expected to show significant wear, sharp elbows in HDP pipe systems should be steel or rubber lined steel since HDP can wear rapidly in turbulent locations.

HDP piping systems can be assembled by thermal butt fusion, flanged fittings, mechanical fittings, victaulic style 44 fittings and Sclairloc couplings.

Abrasion resistant material conducting hoses can be utilized to connect piping systems to fixed equipment such as pumps and cyclones. Rotation of the pipe to avoid differential wear on one sector is recommended.

TABLE 6-9

COMPARATIVE PIPING COSTS AND WEIGHTS

Size (dia.)	Polyurethane Lined		Polyethylene (Sclairpipe)		Carbon Steel Schedule 80		Carbon Steel Schedule 40	
	Price/ft. ($)	Wt./ft. (lbs)	Price/ft. ($)	Wt./ft. (lbs)	Price/ft. ($)	Wt./ft. (lbs)	Price/ft. ($)	Wt./ft (lbs)
6"	69.90	22.5	4.95	3	17.20	28.6	8.55	19
8"	124.30	28.6	7.40	5	26.60	43.4	13.00	28.6
10"	148.10	27.5	9.80	6.6	32.15	64.4	19.35	40.5
12"	183.20	34.2	15.80	10.4	39.5	88.6	25.90	53.6

6.3 BLACK MUCK PUMPING SYSTEMS

6.3.1 Fixed Pumping Location

Where topography permits, it would be desirable to have a fixed pumping station location. This would permit the use of a pump box arrangement that could be used with a diesel driven horizontal slurry or gravel pump, thus maximizing pumping efficiency and minimizing equipment requirements and capital cost.

Monitoring of black muck would be required to liquefy and move the muck which then could be directed by channels to the pumpbox location for pumping elsewhere. This method would rely a great deal on elevation drop from the area being stripped to the pumpbox location.

Since branches, roots and other similar debris can be expected, a large surface area coarse screening device would be required ahead of the pumpbox. This would need to be cleaned periodically.

This type of system would utilize a semi-fixed discharge piping system which would be less labour and cost intensive in terms of relocation and handling during the operating time, than would piping systems associated with mobile pumping stations.

In particularly bad overburden situations involving large amounts of debris, it may prove advantageous to use a vertical submersible dredge type pump in a fixed location.

This unit consists of a vertical submersible dredging pump and a cutter assembly. The pump has a built-in agitator which is linked directly to the motor shaft. The agitator slurries the material and directs it towards the impeller. The cutter assembly is strapped to the pump casing and protrudes slightly beyond the pump suction. Designed to be suspended, this unit could be hung inside the pumpbox with wire lines.

The submersible dredging pump unit is an adaptable machine which is dependable under rigorous conditions. There is practically no restriction on the depth of water cover required to permit succcessful operation. The mechanical configuration of the pump makes replacement of worn parts fast and simple. With the cutter attachment fitted, the unit is highly efficient providing that the cutter is able to break down consolidated material. The disadvantages are the high equipment costs and the requirement for either an electric or hydraulic power generator to drive the integral electric or hydraulic motor. The power source would have to be located close by, particularly if a hydraulic unit was involved.

Where site conditions permit or where overburden depths are significant, the submersible pumps could be suspended in an excavated hole thus eliminating the pumpbox. Stripped material could be channeled to this point. This type of arrangement would require a framework and suspension system from which to hang the pump unit. Monitoring of the material would have to be done in such a way as to avoid clogging the intake with wood.

It is fully anticipated that with all the above possibilities, rock, cobble stones, etc., would be left behind. Monitoring is expected to wash only the fine organic materials and light debris down the drainage channels to the pump.

This method of moving black muck is as yet untried. Even if it is technically feasible, the extra capital costs of purchasing the pumping system may negate the savings made by sluicing the muck versus using mechanical equipment.

6.3.2 Mobile Pumping Location

The submersible dredge pump discussed in 6.3.1 could also be utilized in mobile fashion by using it in conjunction with mobile equipment such as a front-end loader. Suspension of this pump from a loader bucket would enable the operator to drag the pump around through the material to be stripped. This technique may be of use at some placer operations, particularly those involving flat topography and thick layers of overburden as might be found in broad valley deposits.

The technique has several disadvantages:

- It may be necessary to dedicate a piece of mobile equipment, i.e. front-end loader and an operator to this service.
- Continuous movement of the pump would necessitate corresponding relocations of discharge piping.
- Either monitoring or high pressure water jets integral with the pump assembly would be required. Monitoring suggests additional manpower while integral water jets involve additional piping which would have to be moved.
- The pump would require a mobile power source.
- The problem of wood debris would be more accurate than for a fixed pumping system.

6.3.3 Piping and Distribution

Pumping of black muck is an efficient mode of material handling considering that in its natural unfrozen state, the water content is normally high.

By using pumping systems to transport it, simple easily moved piping systems can be utilized to direct part of the muck to areas such as old tailings ramps and oversize piles where the highly organic material could be spread in order to re-vegetate otherwise barren areas.

P.V.C. piping is light, strong, flexible, easily handled, easily assembled and has low friction factor and would be well suited to this application. This pipe could be easily laid over most terrain in order to move muck to the desired area. The muck would have to be dewatered by filling voids in the coarse tailings and oversize material onto which it was pumped. The success of this technique will be very dependant on the ability of the pumped material to dewater when deposited on old tailings and the available storage area.

The larger the valley the more likely it will be that sufficient storage areas can be found. If a way to rapidly settle the muck was found, then it would be advantageous to settle the slurry in settling ponds. The clarified water would be recirculated to the monitors. This might overcome the problem of high water consumption when sluicing black muck. Again this method is more applicable to broad valleys where large settling ponds can be built.

6.4 HANDLING OF FEED GRAVELS AND TAILINGS

6.4.1 General

Each placer operation is faced with different problems which obviously affect materials handling methods. Topography, deposit type, overburden quantities, site layout, physical distances involved, capital and operating budgets, and the financial status of each operation, as well as numerous other considerations, must be evaluated when deciding which materials handling techniques will be used for feed gravels and tailings.

The techniques evaluated in this report are: mobile equipment such as front-end loaders, bulldozers and backhoes; trough type belt conveyors, sand and gravel pumps and hydraulic transport systems.

Generally speaking any unnecessary handling of "no value" oversize material should be avoided. Reducing feed gravel in size should be accomplished as close to the working face as is possible. The location for this must also consider oversize removal since time and energy expended on oversize material placement is non-productive.

Where site conditions permit, screening feed gravels, removing coarse oversize, sluicing pay gravel and pumping tailings can be accomplished in one location. This type of plant eliminates the requirement for materials handling between grizzly and screen or screen and sluice thus minimizing capital, operating and maintenance costs.

However site conditions do not always permit this and other alternatives such as mobile equipment, conveying and pumping are available.

6.4.2 Conveying Feed Gravels

Some operations will be more suitable for conveying than others. Gravel transportation by conveying ideally suits locations where it is necessary to locate screening equipment remote from the working face.

Since conveying of feed gravels to the processing plant must be done in dry form, deposit type and moisture content will be important considerations. Deposits which permit dry removal of large oversize material (+3 inches) at the working face, will be compatible with conveying systems.

Conveyors provide one of the most inexpensive means to transport and gain elevation with a dry material stream. Conveying systems can be modular and can link two or more conveyors together in series to negotiate even the worst terrain provided that the conveyor design limitations are not exceeded.

Modular conveying systems using pre-selected standard lengths, i.e. 50 to 100 feet can be relocated to suit new plant arrangements. Standard lengths and components can significantly reduce the requirement for spare parts.

Modular conveyor sections can be provided with integral diesel engine and v-belt drives to reduce dependency on site generator sets. If adequate power is available, electric motors can be used.

Conveyors once installed are capable of operating over a wide range of tonnage conditions without required drive changes.

6.4.3 Pumping Feed Gravels

In operations where wet or sticky deposits are encountered, wet oversize removal will be necessary using sprays at grizzly or de-rocking elements. It may then be convenient to locate the screening equipment close to the working face remote from the sluice, and pump the feed gravels.

Most gold values found in the Yukon is less than 1/2 inch, thus it is recommended to reduce wear and maintenance on pumps and piping systems, by prescreening feed gravels prior to pumping to at least this size.

Where knowledge of the deposit to be worked permits screening to smaller sizes than 1/2 inch without loss of values, this should be strongly considered since particle size being pumped significantly affects pumping system life.

6.4.4 Pumping Sluice Tailings

Sluice tailings presently are primarily removed by mobile equipment. Presizing of feed gravel as previously discussed will allow the pumping of tailings to the disposal location.

This would be accomplished by incorporating a pump box, pump, v-belt drive, diesel engine and fuel day tank on skid-mounted bases. See Drawing No. B-1401-210-1226. The sluice would discharge into the pump box where tailings would be pumped away.

To prevent the tailings pump box from running dry, a weir could be incorporated in the pump box to spill a small water volume to ground on a continuous basis.

Careful matching of flow rates and heads for water supply pumps, feed gravel pumps and tailings pumps at each operation could ensure that all three pumps are mechanically identical, an important consideration for maintaining spares, flexibility and interchangeability.

6.5 REMOVING SETTLING POND SEDIMENTS

6.5.1 Reduce Clean Out Requirement

There are numerous reasons why it is advantageous to not have to clean out settling ponds.

Obviously any labour, energy or equipment consumed in an effort to clean out a settling pond has a cost, in terms of both dollars and time taken away from gold recovery. This cost, if it can be reduced or eliminated, will improve profitability.

Presently settling ponds may become filled by solids from numerous sources including stream water sediments from upstream, the settling of suspended solids generated by stripping black muck, sediments generated by removal of overburden sands and gravels and sediments generated by normal sluicing of pay gravels.

Of the above, black muck and overburden gravel stripping along with typical sluicing procedures will generate the bulk of the settleable solids encountered, therefore if these activities could be performed in a fashion which will minimize the discharge of solids to the settling ponds, pond life should be significantly greater.

By collecting and pumping black muck to old tailings and oversize disposal locations, some quantities of muck will be allowed to collect and dewater within the available void space of this previously discharged coarse material. If done in a logical and thoughtfully planned approach, some of the suspended solids may be filtered out and retained by this coarse material thus reducing solids deposition in the settling ponds.

Similarily, by utilizing pumping techniques and hydrocyclone dewatering for tailings disposal, the quantities of sand and coarse sediments flowing to the ponds should be significantly reduced. The plus 200 mesh solids will be deposited with the tailings stream discharging from the hydroclone overflow. This slurry material should dewater quickly leaving even fine solids behind in the tailings deposit. This will aid in soil stabilization and revegtation of worked cut areas.

6.5.2 Pond Clean Out

Periodically even with the best of precautions taken, a pond may require clean out. Present methods primarily involve use of mobile equipment or draglines.

As an alternative, slurrying and pumping could effectively be employed to remove settled material. This could be done in a similar fashion to the removal of black muck previously mentioned. The slurried material could be piped to areas with tailings and oversize deposits and allowed to dewater. Pumping will only be possible in ponds where there is little trash wood material.

A submersible vertical dredge pump with excavator type cutter assemblies and/or water jets would be well suited to this application. Toyo manufacture such a unit which has been successfully used on numerous tailings pond reclamation and underwater trenching applications moving up to 70% solids material.

Drawbacks to this approach are:

- The high equipment cost versus the limited requirement at an individual placer operation.
- The necessity to move the pump around in the pond. This could necessitate mobile equipment and some form of mobile frame or cable suspension mechanisms.
- The need for large areas of coarse material for dewatering.
- The use of cyclones will not have much effect on material -200 mesh.
- The requirement for a mobile power source.

6.6 EXAMPLES OF ALTERNATIVE SYSTEMS

A series of example layouts are illustrated in the B1401-210 series of drawings attached in Appendix I. The drawings show example layouts utilizing conveying and/or pumping systems based on the 1401-130 series of drawings outlined in Section 4. They are intended to show general concepts only and not to represent the best solution to site specific materials handling problems.

In the narrower valleys it was advantageous to move the sluicing plant as close to the working face as practical to avoid unnecessary handling of materials. Where it was not possible to locate the sluice itself close to the working face, feed gravels were conveyed or pumped to the sluicing location. The example of assumed feed gravels were not wet or sticky. In another example pumping techniques were shown. Estimated pump performance requirements are shown in Table 6-10.

Pumping of gravels will necessitate pre-screening in order to reduce both gravel volume and particle size to reduce wear on the pump and piping elements. To protect the pre-sizing screen from damage by large oversize material (+3") a grizzly or similar device was shown prior to the screen.

Arrangements incorporating a grizzly, screen, sluice, pumpbox and pump in a single stacked arrangement utilizing gravity flow between components will require sufficient elevation. See Drawing Nos. B1401-210-1221 to B1401-210-1223.

The required elevation can be obtained either by constructing a new ramp, utilizing an existing ramp or utilizing the adjacent valley side. For each placer operation, height requirements will depend on:

- Feeding mechanism to plant, a dozer obviously requires more elevation than a front-end loader.
- Grizzly size and slope and whether it is wet or dry.

TABLE 6-10

ESTIMATED PUMP DATA FOR PUMPING ALTERNATIVES

Deposit Type	Capacity Imp.GPM	Required Head (ft.)	Estimated BHP
Gulch	1,610	110	78
Narrow Valley "A"	3,110	100	137
Narrow Valley "B"	3,120	80	111
Low Bench	1,000	100	45
Broad Valley	2,730	125	155
High Brench	2,880	90	114
New Valley	1,562	90	63

- Vibratory screen size and angle of inclination.
- Sluice length and angle of inclination.
- Pumpbox size.

After sluicing and gold recovery, it will be necessary to continuously dispose of the tailings. With all of these arrangements, pre-sizing of gravels has been done, thus pumping presents a simple alternative to mobile equipment.

Piping can be laid as required to pump tailings to hydrocyclones positioned in several alternate locations. Valley sides and existing ramps can be utilized to elevate the cyclone in order to maximize the amount of tailings material that can be deposited in a single location. Relocation can conveniently be done by adding or removing standard pipe sections and dragging the skid-mounted cyclone to its new location.

Once existing excavations in the valley bottom have been filled, the cyclone can be located on a roadway constructed on the valley side being worked, then, as the workings proceed up the valley, the cyclone can follow depositing tailings in a uniform embankment sloped at the angle of repose of the material deposited.

Planned deposition of material, integrated with the overall mining plan would ensure sufficient space is left available for settling ponds and other site specific requirements.

Oversize material would still need to be moved by mobile machinery or alternately conveyed. This material can be used for berm and road construction where required and any extra can be pushed to the valley side for later cover up by sluice tailings.

Cost Comparison

For each example layout the costs of using only diesel equipment as per B1401-130 series drawings were compared to costs when adding [illegible] and conveying systems to the materials handling methods as per B1410-210 series. These costs do not represent the total operating cost but only the costs for carrying out specific tasks. In the examples for Gulch and Narrow Valley deposits, only tailings removal costs are compared. For Broad Valley and High Bench deposits, both pay gravel transport to plant and tailings are compared. For each example the comparative costs are tabled to show both the hourly production cost and cost per cubic yard of feed material to the plant. These costs are based on many assumptions regarding operating conditions, equipment performance and maintenance costs. They are order of magnitude costs and only valid for comparison between methods.

The operating data and material size distributions were based on information from typical operations working in similar types of deposits. Diesel equipment productivities were based on assumed average machine performances taken from the Caterpillar Handbook and applied to the operating conditions of each example layout. For each task being compared, the calculated theoretical costs were compared to the required production. For equipment not dedicated to the task full time, the total hourly operating costs were pro-rated to obtain an hourly cost per task. (See Appendix III for explanation of method and example work sheets). No account was taken of the difficulty or increased wear and energy consumption associated with different jobs.

6.6.1 Gulch Deposit

This example is illustrated on Drawing No. B1401-210-1201 and Flowsheet No. B1401-210-1211. The arrangement incorporates a stacked grizzly, screen, sluice and pumpbox thus requiring ramp or sidehill elevation. Tailings are disposed of by pumping and hydrocyclone separation. Hydrocyclone overflow discharges via a pipeline to a settling pond for removal of fine suspended solids. For fixed equipment capital and operating costs, see Table Nos. 6-11 and 6-12.

TABLE 6-11

GULCH DEPOSIT - EQUIPMENT LIST

Equipment	Type	Size	Weight(lbs)	Diesel Fuel	Capital Cost
Grizzly Assembly	Static	7'-6"x8'-0"	4,000	N/A	$ 6,600
Screen and Skid	Single Deck	28 ft.^{2} min. (4'x8') 3 hp	2,800	0.13 GPH	$17,000
Sluice*	N/A	N/A	N/A	N/A	N/A
Pumpbox and Skid	N/A	(5'-3")^3	600	N/A	$ 1,650
Pump and Skid	Horizontal	1,600 GPM 8"x6" or 8"x8"	5,300	N/A	$23,650
Diesel Pump Drive	John Deere 4239D	Nominal 70 hp	1,250	3.4 GPH	$14,850
Cyclone Feed Piping	Sclairpipe	8" dia., 350'	1,750	N/A	$ 3,300
Cyclone and Skid	Linatex	24" dia.	2,450	N/A	$13,300
Cyclone Discharge Piping	Sclairpipe	8" dia., 250'	1,250	N/A	$ 2,300

* Not considered here, is assumed common to all operations.

TABLE 6-12

COST COMPARISON OF TAILINGS REMOVAL

Example 1 - Gulch Deposit

Drawing Nos. 1401-130-1201
1401-210-1201

Flowsheet No. 1401-210-1211

TECHNICAL DATA

		No Pumping	With Pumping
Plant feed	cu.yds./hr	100	100
Grizzly oversize	cu.yds./hr	25	25
Screen oversize	cu.yds./hr	-	13
Coarse tailings	cu.yds./hr	38	62
Fine tailings	cu.yds./hr	37	

		No Pumping		With Pumping	
		Fixed[1] Equipment	Mobile[2] Equipment	Fixed[3] Equipment	Mobile Equipment
Number and type of equipment			1-950B	1 pump	1-950B
Capital cost	$	6,600	179,800	82,650	179,800
Ownership costs	$/hr	1.03	30.99	12.98	30.99
Operating costs	$/hr	.47	24.12	17.97	24.12
Total hourly cost	$/hr (incl.labour)	1.50	80.11	35.95	80.11
Theoretical production	cu.yds./hr	-	88	-	214
Required production	cu.yds./hr	100	63	62	38
Percent of time on task(s)		100	72	100	18
Hourly cost for task(s)	$/hr	1.50	58	35.95	14
Cost of feed	$/cu.yd.	.02	.58	.36	.14

Notes:

(1) Capital cost for basic screen.
Hourly cost worked out as per Appendix III example sheet.
(2) See Appendix III hourly ownership/operating cost calculations.
(3) Capital cost based on Table 6-11. Hourly costs as per Appendix III.

6.6.2 Narrow Valley and Low Bench Deposits

Narrow Valley "A" Deposit

This example is illustrated on Drawing No. B1401-210-1202 and Flowsheet No. B1401-210-1212. This arrangement also incorporates a stacked grizzly, screen, sluice and pumpbox. Required elevation is gained using a ramp and existing contours on the valley bottom. An alternate sidehill arrangement could have been selected but it would have been further from the working face. Tailings can be disposed into existing holes or sidehill deposits by pumping and hydrocycloning. Hydrocyclone overflow goes to a settling pond area to settle out fine suspended solids. For fixed equipment capital and operating costs, see Table Nos. 6-13 and 6-14.

TABLE 6-13

NARROW VALLEY "A" DEPOSIT - EQUIPMENT LIST

Equipment	Type	Size	Weight(lbs)	Diesel Fuel	Capital Cost
Grizzly Assembly	Static	7'-6"x8'-0"	4,000	N/A	$ 6,600
Screen and Skid	Single Deck	60 ft.^{2} (5' x 12'), 5 hp	5,250	0.22 GPH	$20,350
Sluice*	N/A	N/A	N/A	N/A	N/A
Pumpbox and Skid	N/A	(6'-6")^3	700	N/A	$ 1,950
Pump and Skid	Horizontal	3,110 GPM 10"x8" or 12" x 10"	5,900	N/A	$26,400
Diesel Pump Drive	John Deere 6359T	Nominal 125 hp	2,000	5.9 IGPH	$18,150
Cyclone Feed Piping	Sclairpipe	10" dia., 500'	3,300	N/A	$ 6,150
Cyclone and Skid	Linatex	36" dia.	4,450	N/A	$22,550
Cyclone Discharge Piping	Sclairpipe	10" dia., 200'	1,320	N/A	$ 2,450

* Not considered here, is assumed common to all operations.

TABLE 6-14

COST COMPARISON OF TAILINGS REMOVAL

Example 2 - Narrow Valley Deposit 'A'

Drawing Nos. 1401-130-1202
1401-210-1202

Flowsheet No. 1401-210-1212

TECHNICAL DATA

		No Pumping	With Pumping
Plant feed	cu.yds./hr	200	200
Grizzly oversize	cu.yds./hr	-	70
Screen oversize	cu.yds./hr	-	20
Coarse tailings	cu.yds./hr	132	110
Fine tailings	cu.yds./hr	26	

		No Pumping	With Pumping	
		Mobile Equipment	Fixed Equipment	Mobile Equipment
Number and type of equipment		1-D8K	1 pump	1-D8K
Capital cost	$	340,000	104,600	340,000
Ownership costs	$/hr	52.98	16.13	52.98
Operating costs	$/hr	55.53	26.99	55.53
Total hourly cost	$/hr (incl.labour)	133.51	48.12	133.51
Theoretical production	cu.yds./hr	204	-	297
Required production	cu.yds./hr	132	110	90
Percent of time on task(s)		65	100	30
Hourly cost for task(s)	$/hr	87	48.12	40
Cost of feed	$/cu.yd.	.44	.24	.20

Narrow Valley "B" Deposit

This example is illustrated on Drawing No. B1401-210-1203 and Flowsheet No. B1401-210-1213. This arrangement incorporates a stacked grizzly, screen, sluice and pumpbox. Required elevation is gained using a ramp on the valley bottom. An alternate sidehill arrangement could have been selected. Tailings are shown discharging by hydrocyclone located on existing ramps. A sidehill cyclone discharge arrangement could also be incorporated. Hydrocyclone overflow is directed to a settling pond to settle fine suspended solids. For fixed equipment capital and operating costs, see Table Nos. 6-15 and 6-16.

TABLE 6-15

NARROW VALLEY "B" DEPOSIT - EQUIPMENT LIST

Equipment	Type	Size	Weight(lbs)	Diesel Fuel	Capital Cost
Grizzly Assembly	Static	7'-6"x8'-0"	4,000	N/A	$ 6,600
Screen and Skid	Single Deck	60 ft.^{2} (5'x12'), 5 hp	5,250	0.22 GPH	$20,350
Sluice*	N/A	N/A	N/A	N/A	N/A
Pumpbox and Skid	N/A	(6'-6")^3	700	N/A	$ 1,950
Pump and Skid	Horizontal	3,120 GPM 10"x8" or 12"x10"	5,900	N/A	$26,400
Diesel Pump Drive	John Deere 6359T	Nominal 125 hp	2,000	4.8 GPH	$18,150
Cyclone Feed Piping	Sclairpipe	10" dia., 300'	1,980	N/A	$ 3,700
Cyclone and Skid	Linatex	36" dia.	4,450	N/A	$22,550
Cyclone Discharge Piping	Sclairpipe	10" dia., 100'	660	N/A	$ 1,200

* Not considered here, is assumed common to all operations.

TABLE 6-16

COST COMPARISON OF TAILINGS REMOVAL

Example 3 - Narrow Valley Deposit 'B'

Drawing Nos. 1401-130-1203
1401-210-1203

Flowsheet No. 1401-210-1213

TECHNICAL DATA

		No Pumping	With Pumping
Plant feed	cu.yds./hr	150	150
Grizzly oversize	cu.yds./hr	-	15
Screen oversize	cu.yds./hr	-	20
Coarse tailings	cu.yds./hr	98	115
Fine tailings	cu.yds./hr	52	

		No Pumping	With Pumping	
		Mobile Equipment	Fixed Equipment	Mobile Equipment
Number and type of equipment		1-D8K	1 pump	1-D8K
Capital cost	$	340,000	100,900	340,000
Ownership costs	$/hr	52.98	15.85	52.98
Operating costs	$/hr	55.53	24.17	55.53
Total hourly cost	$/hr (incl.labour)	133.51	45.02	133.51
Theoretical production	cu.yds./hr	180	-	388
Required production	cu.yds./hr	98	115	35
Percent of time on task(s)		54	100	9
Hourly cost for task(s)	$/hr	72	45.02	12
Cost of feed	$/cu.yd.	.48	.30	.08

Low Bench Deposit

This example is illustrated on Drawing No. B1401-210-1204 and Flowsheet No. B1401-210-1214. As with previous examples, this arrangement also incorporates a stacked equipment layout including derocker, vibrating screen, sluice and pumpbox. Elevation gain is from a constructed ramp on the flat bench area but a sidehill arrangement could also be utilized. Tailings are shown pumped to either sidehill or ramp discharge location. Hydrocyclone overflow is piped to setting ponds to settle fine suspended solids. For fixed equipment capital and operating costs, see Table Nos. 6-17 and 6-18.

TABLE 6-17

LOW BENCH DEPOSIT - EQUIPMENT LIST

Equipment	Type	Size	Weight(lbs)	Diesel Fuel	Capital Cost
Derocker					$70,000
Screen and Skid	Single Deck	25ft.^{2}min. (4'x8'), 3 hp		0.13 GPH	$16,000
Sluice*	N/A	N/A	N/A	N/A	N/A
Pumpbox and Skid	N/A	(4'-6")^3	500	N/A	$ 1,400
Pump and Skid	Horizontal	1,000 GPM "x"	5,300	N/A	$26,400
Diesel Pump Drive	John Deere 3179D	Nominal 50 hp	1,050	2.0 GPH	$12,650
Cyclone Feed Piping	Sclairpipe	6" dia., 300'	900	N/A	$ 1,900
Cyclone and Skid	Linatex	24" dia.	2,450	N/A	$13,300
Cyclone Discharge Piping	Sclairpipe	6" dia., 100'	300	N/A	$ 660

* Not considered here, is assumed common to all operations.

TABLE 6-18

COST COMPARISON OF TAILINGS REMOVAL

Example 4 - Low Bench Deposit

Drawing Nos. 1401-130-1204
1401-210-1204

Flowsheet No. 1401-210-1214

TECHNICAL DATA

		No Pumping	With Pumping
Plant feed	cu.yds./hr	100	100
Grizzly oversize	cu.yds./hr	35	35
Screen oversize	cu.yds./hr	-	17
Coarse tailings	cu.yds./hr	42	48
Fine tailings	cu.yds./hr	23	

		No Pumping		With Pumping	
		Fixed Equipment	Mobile Equipment	Fixed Equipment	Mobile Equipment
Number and type of equipment			1-980C	1 pump	1-980C
Capital cost	$	70,000	325,000	142,310	325,000
Ownership costs	$/hr	11.00	51.51	22.34	55.51
Operating costs	$/hr	5.08	40.81	35.12	40.81
Total hourly cost	$/hr (incl.labour)	17.33	121.32	62.46	121.32
Theoretical production	cu.yds./hr	-	226	-	309
Required production	cu.yds./hr	100	77	48	52
Percent of time on task(s)		100	34	100	17
Hourly cost for task(s)	$/hr	17.33	41	46	21
Cost of feed	$/cu.yd.	.17	.41	.63	.21

6.6.3 Broad Valley Deposit

This example is illustrated on Drawing No. B1401-210-1205 and Flowsheet No. B1401-210-1215. This arrangement differs from the previous ones in that sluicing is remote from the working face. It is convenient here to sluice directly at the tailings disposal point. Filling of the previous cut can be done directly by positioning the sluice on an existing ramp and discharging into the cut. This arrangement utilizes a pumping system for feed gravels as opposed to present techniques using mobile equipment. A hydrocyclone is not required here but relocation of the sluice will be required occasionally to distribute the tailings throughout the cut. Tailings water will be routed through surface channels to settling ponds for settling of fine suspended solids. For fixed equipment capital and operating costs, see Table Nos. 6-19 and 6-20.

TABLE 6-19

BROAD VALLEY DEPOSIT - EQUIPMENT LIST

Equipment	Type	Size	Weight(lbs)	Diesel Fuel	Capital Cost
Grizzly Assembly	Static	7'-6"x8'-0"	4,000	N/A	$ 6,600
Screen and Skid	Single Deck	60 ft.^{2} (5'x12'), 5 hp	5,250	0.22 GPH	$20,350
Sluice*	N/A	N/A	N/A	N/A	N/A
Pumpbox and Skid	N/A	(6'-6")^3	700	N/A	$ 1,950
Pump and Skid	Horizontal	2,730 GPM 8"x 10"	5,900	N/A	$26,400
Diesel Pump Drive	John Deere 6359T	Nominal 125 hp	2,000	6.7 GPH	$18,150
Sluice Feed Piping	Sclairpipe	10" dia.1,200'	7,920	N/A	$14,750

* Not considered here, is assumed common to all operations.

TABLE 6-20

COST COMPARISON OF ALL MATERIALS HANDLING

Example 5 - Broad Valley Deposit

Drawing Nos. 1401-130-1205
1401-210-1205

Flowsheet No. 1401-210-1215

TECHNICAL DATA

		No Pumping	With Pumping
Plant feed	cu.yds./hr	200	200
Grizzly oversize	cu.yds./hr	-	28
Screen oversize	cu.yds./hr	70	42
Coarse tailings	cu.yds./hr	76	130
Fine tailings	cu.yds./hr	54	

		No Pumping		With Pumping	
		Fixed Equipment	Mobile Equipment	Fixed Equipment	Mobile Equipment
Number and type of equipment			1-D8K; 2-966D	1 pump	1-D8K; 1-996D
Capital cost	$	20,350	848,000	88,200	594,000
Ownership costs	$/hr	3.20	139.76	13.86	96.37
Operating costs	$/hr	2.52	120.51	25.80	88.02
Total hourly cost	$/hr (incl.labour)	6.97	335.27	14.66	234.39
Theoretical production	cu.yds./hr	-	212/36[illegible]	-	220/244
Required production	cu.yds./hr	172	200/346	130	200/70
Percent of time on task(s)		100	100/100	00	100/29
Hourly cost for task(s)	$/hr	6.97	335	—	163
Cost of feed	$/cu.yd.	.03	1.68	.22	.82

6.6.4 High Bench Deposit

This example is illustrated on Drawing No. B1401-210-1206 and Flowsheet No. B1401-210-1216. This arrangement utilizes a more stationary type of plant incorporating a trommel and jigs. Since the plant is distant from the work face and the feed gravel is dry (not considered wet or sticky), a grizzly and dry conveying system is utilized to transport feed material to the plant. The grizzly location is as close to the face as practical. Its location utilizes existing elevation drops and oversize material is eliminated as quickly as possible prior to conveying. A segmented conveying system moves material to the trommel. A second conveying system removes trommel oversize. Tailings are pumped to hydrocyclones on top of the old tailings ramps. For fixed equipment capital and operating costs, see Table Nos. 6-21 and 6-22.

TABLE 6-21

HIGH BENCH DEPOSIT - EQUIPMENT LIST

Equipment	Type	Size	Weight(lbs)	Diesel Fuel	Capital Cost
Grizzly Assembly	Static	7'-6"x8'-0"	4,000	N/A	$ 6,600
Trommel	N/A	4'-6"dia.x 25'-5" Lg		0.9 GPH	$120,750
Sluice*	N/A	N/A	N/A	N/A	N/A
Pumpbox and Skid	N/A	(6'-6")3	700	N/A	$ 1,950
Pump and Skid	Horizontal	2,880 GPM 8"x10" or 10"x12"	5,900	N/A	$ 26,400
Diesel Pump Drive and Fuel	John Deere 6359T	Nominal 125 hp	2,000	5.0 GPH	$ 18,150
Trommel Feed Conveyor	Trough Belt	24", 3x100' 24", 1x50' 50 hp Total	(14,000) (14,000) (14,000) (7,000)	2.2 GPH Total	$238,500
Cyclone Feed Piping	Sclairpipe	10"dia., 360'	2,380	N/A	$ 4,400
Cyclone and Skid	Linatex	30" dia.	3,300	N/A	$ 17,500
Cyclone Discharge Piping	Sclairpipe	10" dia., 100'	660	N/A	$ 1,200
Trommel Oversize Conveyor	Trough Belt	24", 2x100' 30 hp, Total	(14,000) (14,000)	1.3 GPH Total	$125,000

* Not considered here, is assumed common to all operations.

TABLE 6-22

COST COMPARISON OF ALL MATERIALS HANDLING

Example 6 - High Bench Deposit

Drawing Nos. 1401-130-1206
1401-210-1206

Flowsheet No. 1401-210-1216

TECHNICAL DATA

		No Pumping	With Pumping
Plant feed	cu.yds./hr	150	150
Grizzly oversize	cu.yds./hr	-	3
Screen oversize	cu.yds./hr	30	27
Coarse tailings	cu.yds./hr	56	120
Fine tailings	cu.yds./hr	64	

		No Pumping		With Pumping	
		Fixed Equipment	Mobile Equipment	Fixed Equipment	Mobile Equipment
Number and type of equipment			1-980C; 1-996C		1-980C
Capital cost	$	188,250	579,000	560,450	325,000
Ownership costs	$/hr	29.58	98.90	88.08	55.51
Operating costs	$/hr	7.62	73.30	61.18	40.81
Total hourly cost	$/hr (incl.labour)	39.70	222.00	154.26	121.32
Theoretical production	cu.yds./hr	-	155/96	-	195
Required production	cu.yds./hr	147	150/86	120	180
Percent of time on task(s)		100	100/100	100	100
Hourly cost for task(s)	$/hr	39.70	222.00	154.26	121.32
Cost of feed	$/cu.yd.	.27	1.48	1.03	.81

6.6.5 New Valley Operations

Two alternative methods of materials handling are shown on Drawing Nos. B1401-210-1207/1208 and Flowsheet Nos. B1401-210-1217/1218. These examples are intended to show two alternative methods of mining the same deposit. Both utilize pumping, one tailings only and one both feed and tailings.

The first arrangement shows a pre-sizing and sluicing plant together using gravity feed. The material is fed to the plant using a front-end loader. Tailings is pumped from the sluice box to the disposl area where it is discharged down the side of the old cut behind a berm of coarse oversize material. The coarse oversize is removed from the plant using a smaller diesel loader. Fixed equipment capital costs and operating costs for tailings removal are shown in Table Nos. 6-23 and 6-24.

The second arrangement differs in having the screening plant close to the face and pumping the feed travel to the sluice plant. Tailings is disposed of in the same manner as the first example. No. costs.

TABLE 6-23

NEW VALLEY OPERATION OPTION "A" - EQUIPMENT LIST

Equipment	Type	Size	Weight(lbs)	Diesel Fuel	Capital Cost
Grizzly Assembly	Static	7'-6'x8'-0"	4,000	N/A	\$ 6,600
Screen and Skid	Single Deck	60 ft.^{2} 5'x12' 5 hp	5,250	0.22 GPH	\$ 20,350
Sluice*	N/A	N/A	N/A	N/A	N/A
Pumpbox and Skid	N/A	(5-3")^3	600	N/A	\$ 1,650
Pump and Skid	Horizontal	1,562 GPM 8"x6" or 8"x8"	5,300	N/A	\$ 23,650
Diesel Pump Drive	John Deere 4239D	Nominal 70 hp	1,250	3.4 GPH	\$ 14,850
Feed Cyclone Piping	Sclairpipe	8" dia., 400'	2,000	N/A	\$ 6,000
Cyclone and Skid	Linatex	24" dia.	2,450	N/A	\$ 13,300
Cyclone Discharge Piping	Sclairpipe	8" dia., 200'	1,000	N/A	\$ 3,000

* Not considered here, is assumed common to all operations.

TABLE 6-24

COST ANALYSIS - NEW VALLEY OPERATION

Example 7 - Deposit 'A'

Drawing Nos. 1401-130-1207
1401-210-1207

Flowsheet No. 1401-210-1217

TECHNICAL DATA

		No Pumping	With Pumping
Plant feed	cu.yds./hr	-	150
Grizzly oversize	cu.yds./hr	-	48
Screen oversize	cu.yds./hr	-	20
Coarse tailings	cu.yds./hr	-	82
Fine tailings	cu.yds./hour	-	

		Feeding Sluice	Disposal Oversize Tails	Disposal Sluice Tails
Number and type of equipment		980C	950B	1 pump
Capital cost	$	325,000	179,800	89,400
Ownership costs	$/hr	55.51	30.99	14.04
Operating costs	$/hr	40.81	24.12	19.09
Total hourly cost	$/hr (incl.Labour)	121.32	80.11	38.13
Theoretical production	cu.yds./hr	156	142	-
Required production	cu.yds./hr	150	68	82
Percent of time on task(s)		100	48	100
Hourly cost for task(s)	$/hour	121	38	38.13
Cost of feed	$/cu.yd.	.81	.25	.25

SECTION 7

SUMMARY OF RECOMMENDED TECHNOLOGY

The following summary is based upon the observations of the study team during the field trip, which are presented in Section 4.3, and the conceptual designs developed in Section 6. In some cases the existing methods of handling materials have been recommended as they appear to be the most practical technology and alternative systems do not appear to be feasible or economic. Where alternative systems (i.e. pumping and conveying) have been recommended, the technology suggested is proven and in common use elsewhere. However it has yet to be demonstrated to work under the conditions in the Yukon and this must be done before the alternative systems can be considered feasible. It is also important to establish the actual cost benefits of using alternative methods as those shown in Section 6.6, being based on theoretical layouts and costs, can only be used as an indication.

As materials handling methods have to be considered on a site by site basis, the following are only general indications as to where the current methods, using mobile equipment, are clearly the best and where the systems developed in this study show a potential for improving the operation's efficiency and level of reclamation.

7.1 REMOVING VEGETATIVE COVER

The vegetative cover consists of the tree, moss and underbrush covering the overburden and gravel layers. The depth of cover varies from area to area and may have been removed during previous mining activity.

Recommendations

1. Deposits covered with salvagable trees should be logged only for firewood, not for commercial timber.

2. The vegetation should be stripped using diesel equipment, the most suitable being tracked-dozers.

3. In narrow valleys the vegetation should be disposed of in old workings as the valley sides are too steep to contain stockpiles.

4. If the material has to be moved long distances at broad valleys or high benches, then loaders and trucks should be used instead of tracked-dozers.

7.2 STRIPPING BLACK MUCK OVERBURDEN

Black muck may consist of only fine silt and organic material. In many deposits the muck includes varying amounts of detrified wood, bedrock slabs and root material. The use of tracked equipment to strip this material, especially in narrow valleys, is very expensive and problematic when the muck is thawed but saturated.

Recommendations

In Narrow Valleys

1. Muck should be stripped when frozen by pushing it downhill into old workings, as valley sides are too steep to hold unfrozen stockpiles.

2. Field trials should be conducted on hydraulicking the muck into a slurry and pumping it to disposal areas. The success of pumping will depend on:
   - Having sufficient water for hydraulicking.
   - Successfully screening out any rocks and wood debris.
   - Providing sufficient storage area for natural settling.

These factors are site specific and may have to be dealt with differently at each operation. It will not be possible to use cyclones to dewater muck.

3. The pumping unit should be usable on other tasks such as gravel pumping and therefore a horizontal pump is recommended.

4. If possible the muck should be used in part to cover old tailings dumps and settling pond surfaces as experience in the Yukon has shown that it is a good revegetation medium.

In Broader Valleys

1. Muck should be stripped using diesel equipment where the gradient is too shallow to allow muck to flow. Pumping should not be tried in shallow gradients as the system is too expensive and labour intensive to be economical.

2. In deposits with sufficient gradient and storage black muck should be stripped hydraulically and the muck drained by gravity into storage areas.

3. Old dredge tailings should not be relied upon for storage for black muck. Often the actual void space available is small and the filtering capabilities limited.

4. The stripping operation should be planned so that black muck is disposed of over waste gravel and tailings in previous cuts rather than vice-a-versa.

7.3 STRIPPING WASTE GRAVEL

Waste gravels are the portions of the alluvial gravel section that contain only trace amounts or no gold at all. Waste gravels are more common at Broad Valley and High Bench Deposits.

Recommendations

1. The most cost effective and productive methods should be used to strip off the waste gravel section. This precludes the use of screening equipment to classify the gravel.

2. In narrow valleys waste gravel should be stripped using diesel equipment. Tracked-dozers in combination with loaders should be used for short hauls. If space permits and there are few boulders, scrapers should be considered for long hauls.

3. In broader valleys and on high benches, the same methods should be used. For moving large volumes of gravels, scrapers, on-highway and small off-highway trucks will be most productive.

4. The choice of which types of equipment to use is site specific and should depend on gravel size range, moisture content, volume, haul distances and the financal resources of the operator.

5. In broad valleys and high benches the use of conveyors should be considered as alternatives to scrapers and trucks. They will only be economical to use if loading and discharge points are fixed.

6. At operations pre-concentrating gravel hydraulically, pumping the fines should be considered. Pumping under any other conditions will not be possible as material will not be sized. Pumping will require sufficient valley grade for slurry to flow.

7. Pumping of fines should use the same techniques suggested for black muck. Fines will be easier to pump, as they contain less detrital material than muck. Gravel fines can be dewatered using cyclones.

8. The gravel stripping operation should be planned so that waste gravels are placed in old cuts and working areas first and then covered by fine tailings or black muck.

7.4 FEEDING PAY GAVELS TO PLANT

Pay gravels, like waste, vary in size distribution from site to site. Large boulders and angular gravel are more common in narrow valleys. The depth of the pay section can vary from a few feet to over 50 feet in height.

Recommendations

1. All feed material should be pre-sized to remove the coarse material prior to sluicing. This will:
    - Reduce the required amount of sluice water.
    - Increase the recovery of fine gold.
    - Obviate the need for box tenders.
    - Allow alternative materials handling systems to be used.

2. This study has assumed a size split of 5/8 to 1/2 inch for screening. However, it is recommended that material be screened down to as fine a size as practical for pumping. This will considerably reduce the wear on pump parts and pipelines.

4. Pre-sizing and washing plants should consist of a grizzly followed by one or two stages of screening. Nugget traps can be placed between stages.

5. In Gulch and Narrow Valley operations recovery plants should be kept close to the face with wheel-loaders, on their own or in conjunction with dozers being used to feed the plant. Backhoes are also recommended and are particularly useful when moving plants quickly.

6. In Broad Valleys and High Bench Deposits, where more permanent plants are used, loaders and scrapers are recommended for moving feed gravel. For very long hauls, the use of trucks should be considered.

7. As an alternative to using mobile equipment dry screening of gravel in the cut and conveying it to the sluice plant should be considered. This will depend on:
   - Material being dry.
   - No loss of gold in oversize caused by sticking, i.e. clay material.
   - The plant location remaining fixed.

8. Where material requires wet screening, consideration should be given to pumping the feed to the plant. Pumping systems are more movable and flexible than conveyors.

7.5 REMOVING TAILINGS FROM PLANT

The tailings consists of coarse oversize from grizzlies and screens and the sluice discharge. If no pre-sizing is carried out, the sluice discharge contains all the tailings material.

Recommendations

Coarse Oversize

1. At movable plants, mobile equipment, especially loaders and scrapers, are recommended for removing oversize material.

2. At more permanent plants, short stacker conveyors are recommended. They should discharge to a stockpile which is removed by loader.

3. Where haul distance to disposal points are long and discharge points fixed, conveyor systems to the disposal area should be considered as an alternative to mobile equipment.

Sluice Tailings

1. For unscreened gravels mobile equipment should be used to remove tailings. Pumping systems are not feasible.

   Wheel-loaders or scrapers are recommended as the water/gravel slurry causes high undercarriage and bearing wear on tracked machines.

2. For screened gravels, pumping systems should be tested as alternatives to using mobile equipment. The tailings should be dewatered at discharge using cyclones and stacked in old cuts or against valley walls behind berms built out of oversize material. This dewatered material will form slopes of approximately 30 degrees inclination. The composition of the material will include fine material down to 200 mesh. Therefore the resultant tailings piles will have a good potential for natural revegetation and will not require extensive reclamation work. Any black muck cover on the tailings piles will aid natural revegetation.

Settling Ponds

1. The use of a tailings pumping system should significantly reduce the amount of coarse material entering the ponds. This will extend pond life and alleviate the problem of limited storage capacity.

2. Whenever possible, existing settling ponds should be left to revegetate and not cleaned out. The silts should be allowed to revegetate naturally, or aided with a cover of black muck.

3. Where ponds require cleaning, the use of a submersible gravel pumping system should be considered. Disposal of the re-slurried sediments will be a major problem.

SECTION 8

RECLAMATION OF PLACER OPERATIONS

8.1 SUMMARY AND CONCLUSIONS

Placer mines in the Yukon vary considerably in their biophysical characteristics and in the mining techniques used. However, some generalizations about site characteristics and materials can be made. Landscape classification of deposits in Gulch, Narrow Valley, Broad Valley and Bench deposits is useful from both materials handling and reclamation points of view.

From the viewpoint of plant establishment and growth, black muck, fine tailings and settling pond sediments are generally suitable materials. Present disposal methods for waste gravels and tailings create poor materials for revegetation because of their low water and nutrient holding capacities. However the suggested alternative materials handling technologies offer an opportunity to dispose of materials in a more suitable fashion that will leave mine sites in a physical condition that will promote natural or artificial revegetation.

A fundamental requirement of reclamation is to leave the mined areas in a stable condition with respect to erosion and in a condition suitable for maximizing natural revegetation. Waste gravels and coarse tailings should be placed in a stable configuration. Areas capable of holding a capping of fine material (or black muck) should be capped to provide a suitable substrate for vegetation establishment and growth. If the proposed alternative materials handling technologies provide practical and economic techniques of doing this, they will make a great contribution to the natural reclamation of placer mining areas.

Studies of the rate of revegetation in relation to substrate conditions and proximity to undisturbed, surrounding vegetation would be helpful. Another area that could be examined is the use of fertilizers to enhance natural revegetation. To be most helpful in developing meaningful reclamation guidelines, such studies should be carried out within a framework of regional and terrain ("deposit") classifications.

Until these questions have been addressed and the costs of revegetation assessed, emphasis should be placed on improving materials handling aspects of reclamation and allowing natural revegetation to take place. Observations by Brady (1984) and Stanek (1982) as well as casual field observations indicate that natural revegetation in much of the Yukon will be relatively rapid and reliable as long as there is a suitable substrate for germination, survival and growth of vegetation and a nearby seed source. Artificial methods may be justified in some cases, but even intensive cultural practices (e.g. seeding, planting and fertilizing) will not eliminate the need for a suitable substrate.

8.2 CURRENT LEVELS OF RECLAMATION

8.2.1 Reclamation Guidelines in the Yukon

The Yukon Water Board adopted some general, draft guidelines that outline measures for restoring mine sites to natural conditions; camps are required to be cleaned up, foundations buried, major excavations backfilled and recontoured, overland drainage diverted around disturbed areas and erosion control measures implemented where necessary. Compacted areas are to be ripped, topsoil spread over the site and the entire site revegetated. Guidelines also exist for control of effluent and stream water quality.

The degree of compliance to guidelines has not been evaluated in this study; however, Brady (1984) indicates that little reclamation work has been conducted. Guidelines were reviewed by the Yukon Placer Mining Public Review Committee (YPMPRC 1983) but no new guidelines or legislation have been presented.

8.2.2 Reclamation Problems

Reclamation methods commonly used for open pit mines are not necessarily readily adaptable to placer mines. The small size and often transient nature of Yukon placer mines restricts capital expenditures and makes coordination of reclamation with seasonal mining activities difficult.

Segregation of different sizes of materials is inherent in placer mining. The degree of segregation and other details vary significantly from site to site but, traditionally, fines and other suitable plant growth materials (such as black muck) are removed and waste gravels, pay gravels and coarse tailings are left covering relatively large areas. The coarse substrate is low in nutrients and plant-available water; seed catch, germination, plant survival and growth are poor. Steep slopes on the sides of tailings can further aggravate the situation. Natural revegetation is often slow; more rapid vegetation is generally desired for various reasons including erosion control, maintenance of water quality, re-establishment of wildlife habitat and aesthetics.

Seeding, planting, fertilization and other cultural measures can speed up revegetation. However, such efforts will likely be wasted without a suitable substrate for plant growth.

Development of workable reclamation techniques require some thoughtful compromises. Techniques must be reasonably simple and readily applicable in the field, otherwise, they will not work. On the other hand, the diversity of mine site conditions and mining practices can make general techniques difficult to apply. For example, black muck is generally a good plant growth medium and it would be desirable to use it as a capping over coarse materials. However, if there is much large, woody debris present in the muck (as is normal), it is not feasible to transport it by pumping. Another example is that although adequate quantities of black muck may be present in gulch deposits, there is limited space available at operations which will likely make stockpiling impossible.

8.2.3 Reclamation Costs

Reclamation costs vary for mines according to differences in end land use objectives, climate, substrate and other environmental factors. No specific cost data for placer mines has been available for review in this study. Reclamation costs for 17 open pit mines in British Columbia ranged from about $1,300 to $2,100 per hectare (in

1979 dollars). However, reclamation of gravel pits in the Yukon suggests revegetation costs may be in the order of $400 to $500 per hectare. Such estimates could be used to give a rough indication of the possible range of reclamation costs for placer mines in the Yukon until more appropriate data and cost analyses are made available through field work tests.

8.3 REVIEW OF RECLAMATION ELSEWHERE

Reclamation of placer mines in Alaska and British Columbia has some applicability to the Yukon. The United States Department of the Interior Bureau of Land Management, has recently adopted guidelines for surface mining (Durst 1981) and the U.S. Environmental Protection Agency, in cooperation with the Alaska Department of Environmental Conservation, has specific requirements for placer mining effluent. However, virtually no attempts have been made to shape waste or tailings piles or to cover them with soil, muck or other growth media (Maneval 1982). Revegetation has frequently occurred, but mainly on materials with physical and chemical properties that are favourable for plant establishment and growth. In contrast to placer mines, reclamation is preplanned for most open pit mines in the United States, British Columbia and many other Canadian provinces.

Reclamation guidelines for British Columbia have been developed by the Ministry of Energy, Mines and Petroleum Resources and apply to open pit mines. Buildings, machinery and scrap material must be disposed of, foundations must be buried and revegetated, waste dumps are sloped to an angle where vegetation can be maintained and revegetation of tailings ponds may be required. Guidelines for reclamation of placer mines in British Columbia are also provided by the Ministry (MEMPR 1984). Basic requirements include provisions for clean-up of camps and other facilities, backfilling of pits, ripping of compacted areas and revegetation. Other requirements may be specified as conditions of obtaining a placer mining permit.

A large amount of reclamation information, pertaining mainly to open pit and coal strip mines, is readily available for British Columbia and Alberta (for example see Michaud 1981; Sims et al. 1984). Information on revegetation of northern areas is also given in CAGS (n.d.) Hardy Associates (1980), Maneval 1982, Paterson and

Peterson (1977), Stanek (1982), USDA (1972) and University of Alaska (1973). Some of this literature may be applicable in varying degrees to placer mining in the Yukon. However, without more knowledge of specific site conditions and reclamation requirements, it is premature to draw hard and fast conclusions on their applicability.

8.4 EFFECT OF ALTERNATIVE TECHNOLOGY

Past mining practices have focused on exploiting mineral reserves and reclamation has been regarded as a separate activity following the mining operations. Implementation of alternative technologies presents a new opportunity to integrate reclamation practices with mining practices and thereby improve the effectiveness and lower the cost of reclamation. Systems of pumping and conveying materials will facilitate the placement of materials in a more stable manner and more suitable for plant growth. Materials may be economically transported over greater distances than at present. There is also a potential for more flexibility in designing waste pile configuration and slopes to favour ground stability and revegetation. In many cases the coarse, waste material will be used to form berms that contain finer grained materials or black muck in areas where they can be used as substrates for vegetation.

There are numerous possibilities for improved biological and cost effectiveness of reclamation arising from adoption of new materials handling technology. However, these need to be tested in field trials covering a variety of biophysical and operational conditions before anything more definitive can be said. Some further suggestions specific to different classes of deposits are given in Section 8.5 of this report.

8.4.1 Stability of Mined Areas

The steep slopes of current tailings ramps makes them susceptible to erosion especially during the spring run-off period. Also because of their slope and lack of fine material, revegetation is slow to become established. This also increases the instability of the piles. A major objective of land reclamation is to ensure the materials remain stable and resist erosion by the creeks as this leads to siltation of the creeks and a general degradation of the land.

Alternative materials handling methods, especially pumping of tailings, offer new approaches to stablizing the gravels without incurring unreasonable costs. The act of stabilizing the materials is not an additional cost requiring reworking of the piles. Instead the method of placing the gravels at the disposal site includes ground stabilization. Coarse oversize from the pre-classification stage can be used to build berms behind which finer material is spread. Also these boulders can be used as rip-rap in a creek diversion bed to restablize the stream bed. As the oversize material will consist of gravels from 5/8" up to boulder size, it will act as a barrier to stop stream erosion of the finer sands. Other uses for this gravel includes road construction and berm construction for settling ponds and creek diversions etc.

The finer tailings material is pumped to a cyclone situated behind the berm of coarse material. The dewatered sands and silts are discharged from the cyclone and allowed to form a natural slope against the valley sides. (See Drawings for reference). The angle of repose of this material is not known exactly at this time but is expected to form a much flatter slope than the traditional tailings ramps. This will assist in ground stabilization by lowering the slope of the material and hence the erosional force of water running down it. Because this material will have a better mix than that in the existing tailings ramps and will have a shallower angle, plant growth will be established sooner (see next section). This will increase the stability of the ground. If it was proven possible to pump black muck, then by spreading this material over the tailings gravel, the plant revegetation rate could be further speeded up.

Development of effective pumping systems to transport settling pond sediments may also benefit the rehabilitation of old mining cuts at certain operations. The sediments are a favourable medium for vegetation and could be pumped out of the settling ponds and into mining cuts previously filled with coarse tailings materials. This would also free existing ponds for future use. However, the cost of moving this material must be investigated as it may not prove to be an economical solution.

The costs of reclamation form part of the overall cost of moving material to disposal points. Therefore they cannot be broken down into a specific cost associated with reclamation. It is recommended that reclamation of the mined areas be carried out at the same time as sluicing. Costs to reclaim and stablize the ground behind the working areas may also include a few hours of dozer time to build berms and flatten the top of the tailings pile. If the use of pumping systems proves successful, this extra work should be minimal. Until trials have been carried out on pumping and dewatering tailings, the costs of reclamation cannot be accurately calculated although preliminary costs are shown in the tables in Section 6.

8.4.2 Revegetation of Mined Areas

Soil particle size and other substrate and site characteristics related to plant available water have been reported by several authors as major factors influencing the rate and extent of revegetation of placer mining spoils (Brady, 1984; Holmes, 1980; Rutherford and Meyer, 1981); our field reconnaissance supports such findings.

In general, pumping of fine tailings can enhance revegation by mixing fines with coarse materials or by capping coarse waste or tailings with fines. In either case, rooting zone water storage capacity may be greatly increased. Water retention is mainly attributable to the fine soil fraction (particles 2 mm). All other things being equal, available soil water is reduced roughly in proportion to the volume fraction of coarse (2 mm) particles. Many waste gravels and coarse tailings have an available water storage capacity of about zero. Such materials will not support vegetation unless there is subsurface water flow near the surface during some part of the growing season.

As another general rule of thumb, the best substrate materials for plant growth, with respect to particle size, are composed of about 20 to 70% particles smaller than a #10 sieve but larger than a #270 sieve and less than about 28% clays (particles 0.002 mm); these correspond to sandy loam, silt loam and loam soil textural classes commonly referred to in agriculture (see Berg, 1979).

Seed germination and young seedling survival may also be poor on coarse materials. Cropping with fine tailings or where possible black muck would be expected to improve seed soil content and moisture regime and therefore enhance revegetation.

Nutrients as a limiting factor in revegetation of Yukon or Alaska placer mines have not received much detailed study. General knowledge of soils along with some literature (for example, Maneval, 1982), suggests that nitrogen and, perhaps, phosphorus could be deficient plant growth on most mineral substrates. Chemical soil analysis conducted by Stanek (1982) along the Dempster Highway further supports such speculation. However, Stanek found generally adequate levels of nitrogen and phosphorus in black muck. If the suggested alternative methods of handling and storing black muck prove successful, at least in some situations, it could be a useful addition for improving substrate moisture regime and fertility.

8.5 RECOMMENDED LEVELS OF RECLAMATION

Discussion of appropriate levels of reclamation requires reference to end land use objectives. In theory, at any site materials can be stabilized and vegetation established within a few years following completion of mining operations. In practice, the application of technology and other knowledge is largely limited by economic considerations. Reclamation costs must be judged against tangible or intangible reclamation benefits. This cannot be done unless an end land use is clearly identified. Examples of end land uses might be: recreational areas, wildlife habitat (including fish habitat), and commercial forest. Goals and objectives are discussed futher in the following report section (Section 8.6). Some suggestions regarding reclamation practices are given below for each class of placer deposit.

8.5.1 Gulch Deposits

The confined work area in Gulch deposits precludes successfully stockpiling soil, black muck or other materials suitable for future use as a plant growth medium. Although it may be possible to push black muck up against the valley walls and contain it from flowing downhill (when it thaws) by building toe dykes or berms of waste gravels. However, this is known to be a costly and time consuming activity. Generally black muck is easier to push downhill towards the creek by use of hydraulic or mechanical means.

If the content of coarse rock and wood is low enough, the systems of pumping black muck suggested in 6.3 might be tried to cover coarse waste materials. The feasibility of these methods will be influenced by the timing of mining and reclamation activities and will need to be tested and examined further before being recommended as suitable practices.

The rate of establishment of vegetation by natural means should be relatively fast in Gulch deposits because of the proximity to natural seed sources. The degree of this effect will vary, however, depending on characteristics of the native vegetation surrounding any particular deposit.

End land uses for Gulch deposits are likely to be for wildlife habitat or wild land (in general). Areas disturbed from mining at any one time may be relatively small and undisturbed vegetation is often in close proximity to disturbed areas. It therefore seems that, as a generality, a relatively low level of reclamation effort should be required.

8.5.2 Narrow Valley Deposits

The materials handling ideas suggested for Gulch deposits could be applied to Narrow Valley Deposits; in fact, they may be more applicable to Narrow Valleys. Sluice tailings can be placed along the valley walls using pumping or mobile equipment and pond sediments and black muck might be spread by pumping to hollows between old tailings mounds and onto the relatively flat slopes of the pumped tailings.

End land uses and appropriate levels of reclamation effort for narrow valley deposits will probably most often by broadly similar to those for Gulch deposits.

8.5.3 Broad Valley Deposits

Broad Valley deposits allow the greatest potential for storage of black muck or fine material that can be a favourable substrate for vegetation. Systems for storing and transporting muck and fine tailings and later pumping or otherwise conveying them over coarse waste materials should be investigated. Waste gravels and tailings may be placed in old workings or built into piles or mounds. In order to encourage revegetation, slopes on any piles should be reduced to about 27 degress or less. Alternatively, slopes could be left at an angle closer to the material angle of repose and revegetation efforts would then be concentrated on flat and gently sloping areas in between. If trees and tall shrubs are established, they would eventually screen the steep, bare areas. Effectiveness of this approach would depend much on the actual scale and geometry of waste piles and mounds. Erosion on the steep faces of coarse gravelly materials should be minimal and should not pose a problem with respect to water quality.

In some cases, end land uses and appropriate levels of reclamation effort for Broad Valley deposits will be similar to those for Gulch and Narrow Valley deposits. However, there may be more situations in broad valleys where human settlement, high wildlife habitat or recreation values, fish habitat or water quality for downstream users could be a concern. Then greater reclamation efforts would be justified.

Another end land use might be future placer mining - either reworking of old tailings or working closer to the valley walls and on low benches. The possibility must be recognized and considered in setting reclamation requirements. (Similar comments might apply, although less commonly, to some Narrow Valley and High Bench Deposits.

8.5.4 High Bench Deposits

In those operations where tailings are directed over the rim of the bench, it would be desirable for reclamation purposes to level the bench and apply a layer of black muck or fine mineral material as a capping. Some roughening or slight terracing of the tailings slope profile may be necessary and the addition of organic material will aid revegetation. Such practices may be very costly so further investigations of appropriate techniques of materials handing and reclamation should be undertaken. The stacking of tailings against the side of the cut face as suggested in Section 6.6 would help to accomplish the task of natural revegetation.

8.6 SUGGESTIONS FOR GUIDELINES

Clear goals and objectives for reclamation of placer mines in the Yukon should be established. For example, Brady 1984) suggested the following goals for rehabilitation of placer mines in the Klondike area.

- To produce soil conditions which provide protection against soil erosion equivalent to, or better than premine conditions.
- To produce soil conditions which support the desired vegetation structure.
- To establish a level of vegetative ground cover which provides protection from soil erosion equivalent to, or better than premine conditions.
- To maintain vegetation which is capable of regeneration under natural conditions prevailing at the site.
- To promote the establishment of a vegetation structure which is compatible with the designated post mine land use.
- To maintain a desired standard of water quality flowing from disturbed areas.
- To maintain a desired quantity of water in disturbed stream channels.
- To maintain the physical stability of disturbed stream channels during expected peak streamflow events.

Ultimately, specific objectives should be developed to ensure that rehabilitation goals are achieved. Different objectives will be needed for different regions and site classes within the Yukon.

The Yukon is a large area with considerable diversity in climate, natural vegetation, soils and geology. Land use will also differ considerably between different regions. Reclamation guidelines should therefore be developed with respect to a regional land classification such as the Ecoregions defined by Oswald and Senyk (1977). Active placer mining in the Yukon is concentrated in two of these Ecoregions: the Klondike River and the Mayo Lake - Ross River.

Within these broad regions, several vegetation types can be identified and these may also be useful for incorporation in guidelines because of correlations between vegetation types and species selection for revegation or land use. For example, Brady (1984) lists eight vegetation types in the Klondike River region: Black Spruce - Feathermoss Woodland, Aspen - Bearberry Forest, White Spruce - Paper Birch - Labrador Tea Forest, White Spruce - Buffaloberry Forest, Black Spruce - Sphagnum Muskeg, White Spruce - Alder Riparian Forest, Riparian Willow Shrub and Riparian Alder Scrub.

Classification of placer mines according to Gulch, Narrow Valley, Wide Valley and High Bench deposits is useful from a materials handling point of view. Once sufficient information is gathered, this terrain classification can be integrated with regional land classification (such as Ecoregions of Oswald and Senyk 1977) and more local vegetation types (such as those listed by Brady 1984) to provide a comprehensive framework for reclamation guidelines.

8.7 REFERENCES

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