Klondike Placer Miners Association

The Use of Radiotracers to Evaluate Gold Losses at Klondike Placer Mines

(1989 Mining Season)

by

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1 SUMMARY

The Yukon's numerous (185) placer gold mines are still a major social and economic force in this developing economy. Gold recovery at each of the various sluiceboxes is not optimized due to extremely difficult sampling logistics and a shortage of technical expertise and industrial research.

Sluiceboxes are very simple, reliable, inexpensive and yield very high concentration ratios, typically in excess of 10,000:1. This combination is very difficult to beat and explains why the sluicebox is still the only device used in the Yukon to recover placer gold.

Testing sluiceboxes with conventional sampling and evaluation techniques is very costly, time consuming, and problematic. Most placer gold ores are of very low value and contain a very limited number of distinct gold particles in a large volume of pay gravels. The effect of a single gold particle can cause large random errors (nugget effect). Standard errors are unpredictable and ranged from 7 to 50% even when large sample volumes (2 to 7 cubic yards) consisting of hundreds of increments are processed, due to the frequent occurrence of coarse gold particles in the tailings from conventional sluiceboxes (Clarkson 1989).

Nuclear tracer tests are more accurate, (standard errors ranged from 2 to 5%), faster, cheaper and safer than conventional sampling. In 1989, the recovery efficiency at several sluicing systems were determined by mixing gold tracers into the feed streams of eleven placer mines (G through Q) in the Yukon Territory. Four distinct sizes of radiotracers were used and their recovery was related to the design and operational characteristics of the individual sluiceboxes and their pay gravels.

Most of the sites which were tested in 1989 used bulldozer-fed triple run sluiceboxes; only three of the eleven sites prescreened their pay gravels. The manually monitored sluiceboxes which were equipped with large distributors and sluice gates (H, I & L) had much higher screening efficiencies than the Ross Boxes (O & P). However none of the distributors in the triple run boxes could match vibrating screening equipment for screening efficiency and consistent feed rates, important factors in efficient gold recovery. In many cases the poor screening efficiency of triple run boxes reduced gold recovery by underutilizing the side runs and overloading the center run with fine pay gravels, boulders and excess water volumes.

This paper presents the existing and potential gold recoveries, and recommends sluicebox designs and operating parameters based on the results of the nuclear tracer testwork in 1989 (sites G through Q) and the conventional sampling program of 1988 (Clarkson 1989, sites A through F).

2 CONCLUSIONS

2.1 OVERALL LOSSES

Overall losses ranged between 71 and 0 percent or from $2.5 million (site H) to less than $1000 (site J) per 1200 hour season and averaged $385,000 (graph 8). These losses could be reduced to a maximum of 11% (site H) and an average of 4% by screening the pay gravels to -1 inch and modifying the sluiceboxes according to section 3's recommendations. This would result in an average increase in revenue of $306,000 per site (graph 9). In many cases screening systems would also lower operating costs by reducing labour, water pumping and/or heavy equipment requirements.

Site H and P had the highest gold losses due to inappropriate riffle and matting design. During the testing program the overall recovery at site H was increased from 29% to 62% (graphs 4 and 6B) by replacing its doubled expanded metal riffles and cocoa matting with single expanded metal riffles and Nomad matting. These minor modifications resulted in additional revenues of $1.2 million per sluicebox/season.

The sluiceboxes with screened feed (G, J & K) had the highest recoveries but even these systems required one inch angle iron riffles to improve coarse (+1 mm) gold recovery. For example, site G's overall recovery efficiency was improved from 96 to 99% when its sluice runs were narrowed to half the original width and one inch angle iron riffles were installed.

Virtually all of the sites without screening (H, I, L, M, O, P & Q) will payback the capital investment in screening equipment in less than one season. Many others should have additional revenue in the first season of operation. Site Q is committed to install a Supersluice diesel/hydraulic operated screening system capable of being fed with a D9 bulldozer. For a capital cost of less than $100,000, season revenues are estimated to increase by $345,000. Other placer operations are planning to implement similar improvements.

The total recovery for four gold size fractions was determined at each site, a better indicator of sluicebox performance than the overall recovery. Estimated recovery improvements were based on comparisons between screened operations from the 1989 nuclear tracer and the 1988 conventional sampling programs. There is a very limited amount of reliable data regarding the recovery of jigs and other gravity concentration devices but they are unlikely to provide cost-effective alternatives to sluiceboxes for primary placer gold recovery.

2.2 SIZES AND SHAPES OF KLONDIKE PLACER GOLD

The most common gold size (mode) in the pay gravels ranged from +0.30 mm (+48 mesh, sites K & P) to +1.2 mm (+14 mesh, sites N & G) but was usually between +0.30 and +0.60 mm (+48 & +28 mesh, graph 1D). The tracer testwork indicated that there is very little gold (1% on average) finer than 0.15 mm (100 mesh) in active Klondike placer deposits. These data do not provide information about gold particles beyond the +1.2 mm (+14 mesh) size fraction to protect the participant's privacy.

On average most of the lost gold was coarser than 0.3 mm (48 mesh) in size. However, each operation had its greatest gold losses in a different size fraction depending on its gold size distribution, pay gravel clay content, and the design and operation of its sluicebox.

The Corey Shape Factors for gold from these Yukon placer mines are similar, except for site N which was unusually massive. Analysis of the gold from different cleanups at three sites, including those from the 1988 program, indicated that the gold size distribution and Corey Shape Factors in any given placer deposit are highly variable even within successive pits of the same deposit (graph 2). There was no significant difference in the shape factors of the recovered and lost gold at 5 of the 6 sites sampled in 1988.

2.3 EFFECT OF SCREENING ON GOLD RECOVERY

Most of the sites which were sampled in 1989 used bulldozer fed triple run sluiceboxes. Only three of the sites (G, J & K) used a vibrating screen, however the overall recovery at these operations was significantly higher (96-100% vs 29-89%). Site K screened the feed to its triple run Ross Box with a vibrating screen deck. Site M used a stationary grizzly and Site N used a Derocker moving bed grizzly which screened to 2.5 inches. Overall gold recovery with site N's clay-rich gravels and abundant galena was slightly lower at 85%. Graphs 3D and 6D clearly demonstrate the effect of screening on gold recovery with conventional sluiceboxes.

These results agree with published data from the 1988 program (graph 7A) and from the Soviet Union (Zamyatin). Graph 7B illustrates the effect of reducing the top size of pay gravels from 5/8 inches to 5/32 inches on the recovery of a shallow fill (expanded metal riffle) sluicebox. Dramatic recovery improvements can result when the pay gravels are screened.

2.4 EFFECT OF RIFFLE TYPE AND MATTING

Expanded metal riffles are effective at recovering gold particles finer than 1 mm, however tracer tests confirmed that angle iron riffles are required to efficiently recover gold coarser than 1 mm. The 1988 program demonstrated that coarse gold (+1 mm) losses with expanded metal are very dramatic as the particle size increases. Angle iron riffles require higher water flows and/or steeper gradients for proper action. At site G the recovery of coarse gold was improved by narrowing the ends of the sluice runs and adding 1.25 inch angle iron riffles, even though a nugget trap dilated with low pressure water was already employed.

Doubled expanded metal riffles are much more susceptible to riffle packing than single expanded metal riffles. Doubles are full and/or packed where they contact the matting or scoured clean where they are separated from the matting due to warpage or wear. At sites with clay-rich pay gravels (site H) doubles were responsible for extreme gold losses. Where the pay gravels were free of clay and readily washable (site L) the doubles worked almost as well as single expanded metal riffles except that they more than doubled the volume of sluicebox concentrate which had to be upgraded.

The flat bar riffles used at sites O and P avoided packing and remained loose but they created extreme turbulence and deflected most of the pay gravels up to the top of the slurry flow. Very few tracers were retained in the flat bar sections of sluice runs. One inch angle iron riffles do not tend to pack as readily as larger angle iron riffles. They create much less turbulence and appear to promote higher gold recovery than flat bar riffles.

Both cocoa and the very coarse Monsanto matting appeared to be unable to retain fine -0.3 mm (-48 mesh) gold as effectively as Nomad matting. Cocoa matting lacks sufficient void spaces unless two or three layers of fine expanded metal are placed above it (site N). The bottom two thirds of the Monsanto matting tends to pack hard leaving only the top one third of the coarse matting available for gold retention.

2.5 EFFECT OF FEED RATE ON GOLD RECOVERY

Poling demonstrated in the laboratory that as the solids feed rate is increased beyond 8 loose cubic yards/hr per foot of sluice width, the recovery of gold was reduced, especially at finer sizes (0.18 mm, -65+100 mesh). The 1989 tracer tests and the 1988 sampling program also found that sluice runs operating near or below these feed rates had higher gold recoveries than overloaded runs.

2.6 OSCILLATING SLUICEBOXES

An oscillating sluicebox may be an advisable alternative for pay gravels with a high proportion of clays or heavy minerals which would otherwise pack the riffles of a conventional sluicebox. When riffles are packed, gold particles are unable to pass through to the matting resulting in extreme gold losses. An oscillating sluicebox has its sluice runs suspended from cables and is oscillated in a horizontal circular "panning" motion by the rotation of a motor driven eccentric.

Despite the clay-rich pay gravels at high bench sites G and B (from 1988) and near optimum feed rates, the oscillating sluice runs kept the expanded metal riffles from packing and provided reasonable gold recoveries (graphs 6A & 7A). Gold from the clay-rich White Channel gravels at site J was recovered efficiently from a well designed conventional sluicebox, but the feed rates per foot of sluice width were very low (7% of optimum) and large volumes of water were used.

2.7 LIMITATIONS OF TRIPLE RUN SLUICEBOXES

Triple run sluiceboxes rely on the ability of their distributor's stationary punch plate to screen the pay gravels and distribute them to side runs. At many operations, most of the water entering the distributor had to stay above the punch plate to push large rocks along. Fine pay gravels and gold are inevitably trapped in these excessive volumes of turbulent waters and swept off with the boulders at high speed (10-17 ft/s) down the center run.

These distributors were often so inefficient that they reduced gold recovery by underutilizing the side runs (7-70% of optimum) and overloading the center run with boulders and fine pay gravels (300-700% of optimum). The short sections of punch plate which were installed in some center runs to direct fine gravels to an undercurrent run were even less effective. Additional gold losses occurred in the center runs when rocks were wedged between the riffles, disrupting proper riffle action.

Before the sluiceboxes were cleaned up, the radiotracers were located in each sluice run with a scintillometer. Sluice runs with significant gold values along the full length of the run usually had poorer overall recoveries (all unscreened systems). The tracers which were recovered in the center and underflow runs traveled further than those in the side runs (graphs 5A & 5C).

Some sites (M, O, P & Q) improved their chances by recovering gold in a dump box area in advance of their inefficient distributors. At sites O, P & Q, the dump box's undersize gravels were not distributed to the side runs but were discharged back on top of the distributor to be screened once again.

Sites H, I and L used "LD" triple run boxes with manually operated monitors, very large distributors (100 ft2) and sluice gates to control the discharge from the distributor to the side runs. The LD boxes had much higher screening efficiencies (64-79%) than the Ross Boxes (14-39%) and none of the feed surges common to boxes with unmanned monitors. Graph 3D illustrates that the LD sluiceboxes generally had higher gold recoveries per foot of sluice run that the Ross or other homemade triple run boxes. However, even these LD distributors could not match screened sluicing systems for screening efficiency, consistent feed rates, and gold recovery.

3 RECOMMENDATIONS

The highest gold recoveries occurred at sites which screened their feed to -1 inch, used both expanded metal and angle iron riffles on top of Nomad matting for every sluice run and fed their runs near optimum feed and water rates. Expanded metal riffles are efficient at recovering placer gold particles finer than 1 mm while angle iron riffles are more efficient at recovering those greater than 1 mm. Slick plates allow gold particles to segregate to the bottom of the pay gravel slurry where they are more readily available for recovery by the riffles.

Field and laboratory testwork has indicated that sluicebox runs should be designed and operated at the following specifications for optimum recovery levels:

a) Pay gravels should be prescreened to at least -1 inch, washed thoroughly prior to sluicing and feed rates should be controlled with mechanical feeders and/or manually operated wash monitors;

b) Every sluice run should have a sixteen foot long section of coarse expanded metal riffles (4-6 lbs/ft2) which is wide enough to process 8 loose cubic yards/hr/ft with at least 160 Igpm of process water per foot of sluice width. The riffles must be tight against the Nomad matting to prevent scouring between the riffles and the matting;

c) Optimum slopes for the expanded metal riffles section will range from 1.5 to 2.5 inches/foot and should be set at a slope at which they do NOT pack and DO tend to deposit a crescent of heavy minerals and gold directly downstream of each individual riffle (loose gravels may partially fill the rest of the riffle);

d) The expanded metal section of the sluicebox should be followed or preceded by a narrower eight foot length of sluice run fitted with one inch angle iron riffles. At least 360 Igpm of slurry per foot of sluice width is required to operate the angle iron riffles. Try to reduce or avoid rooster tails by gradually narrowing runs or by using baffles;

e) The one inch angle iron riffles should be aligned at 15 degrees from the vertical towards to top of the box, located with a clear distance of 2 to 2.5 inches between each riffle and mounted above Nomad matting;

f) The angle iron riffle section may have to be set at a steeper gradient of up to 3 inches/foot to avoid packing;

g) Riffles and matting must be easily removed so that more frequent cleanups (every 24 hours) will be performed (tracers which are not retained in matting will move down the sluice run, especially during start up periods); and

h) A section of slick plate should be placed in front of riffle sections to allow gold segregation in the slurry.

Sites G, J and A (1988) demonstrated that a sluicebox can recover almost all of the placer gold in a Klondike deposit when feed control, adequate washing and fine screening are provided to a sluicebox. Sites G and B (1988) also illustrated that an oscillating sluicebox was a reasonably efficient gold recovery device for fine pay gravels which tend to pack the riffles of conventional sluiceboxes.

The washability of pay gravels and the size distributions of placer gold particles should be determined before deciding on the type of gold recovery equipment to be used. Once the equipment is in operation, periodic tests should be conducted to detect the extent and causes of gold losses.

Additional field testing of existing placer operations should be conducted to:

a) confirm the additional gold recoveries resulting from the recommended modifications; and

b) expand the knowledge of gold recovery at a greater variety of deposit types and recovery equipment.

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5 OBJECTIVES

The primary objectives of the Gold Recovery Project are to evaluate gold losses with statistically based sampling programs, determine how to improve gold recovery, assist miners with the recommended technology, and make this information available to the entire placer industry.

An additional objective of the 1989 research program is the development of nuclear tracing technology as a cost-effective method of determining gold losses.

6 THE SLUICEBOX

6.1 Introduction

The sluicebox has been used in the Yukon since the Klondike Gold Rush, and with very few exceptions, is still the only device used for primary placer gold concentration. A sluicebox is a rectangular flume containing riffles on matting, through which a dilute slurry of water and alluvial gravel flows (figure 1).

As the slurry passes over riffles it forms a vortex which scours the placer gravels and drives the washed gold particles into the matting. The most popular sluice riffles include expanded metal, angle iron (Hungarian) and flat bar. Cocoa matting or the more effective synthetic "Nomad" matting is placed under the riffles to retain the gold particles. To remove the gold concentrates, the sluiceboxes are shut down and the riffles and matting are taken apart and cleaned.

Sluice boxes are very simple, reliable, inexpensive and yield very high concentration ratios, typically in excess of 10,000:1. This combination is very difficult to beat and explains why the sluice is still very popular.

6.2 Triple Run Sluiceboxes

Several larger Yukon placer operations use triple run sluiceboxes consisting of a slick plate, dump box recovery area, distributor, center run, undercurrent run and side runs (figure 2). The slick plates are mixing areas where the pay gravels are washed with either stationary or manually operated water monitors. Manually operated monitors provide better washing and help control surges of pay gravels.

Dump boxes are sections of punch plate suspended above a set of riffles and/or matting. Some of the fine pay gravels will pass through these punch plate holes and have their free gold collected by these riffles. The heavy sections of punch plate above the riffles in a dump box must be raised before its riffles and matting can be cleaned.

The distributor is a crude screening device which uses stationary punch plate to screen out fine pay gravels and direct them on to an undercurrent or set of side runs. Most of the water entering the distributor must stay on top of the distributor so that large rocks and boulders will be pushed along. Fine pay gravels and gold are inevitably trapped in these turbulent excessive water flows (300% to 600% of the water required for optimum sluicing) and continue with the boulders at high speed down the center run.

Distributors are often too small (less than 100 ft2) and are fitted with punch plates which contain too few holes or have small holes (less than 3/4"). The high water velocity of the pay gravel slurry above a distributor reduces its efficiency and limits the top size of gravels which can get through its holes. Many distributors are counter productive to gold recovery because they overload the center run with fine pay gravels and underutilize the undercurrent and/or side runs.

An undercurrent is a flume located directly below the center run; side runs are located on either side of the main sluice run. An undercurrent's location makes observation of its riffle action and adjustment of its slope very difficult. The center run must be completely dismantled before an undercurrent can be cleaned, therefore undercurrents are not cleaned as often as they should be.

The allocation of water to the various runs is easily controlled if sluice gates are installed at the distributor's undersize discharge. If the slope of the side runs is easily adjustable, then a more shallow sluice gradient can be utilized to improve the recovery of placer gold particles.

6.3 Prescreened Sluiceboxes

When placer gravels are not screened, additional water and steeper sluice box gradients are required to move the boulders and coarse gravels down the sluice run. The high water velocity and extreme turbulence created by boulder movement causes gold migration and loss. Screens also improve washing by breaking up clumps of clay and cemented particles. Inadequate washing is a very common cause of gold losses.

Some of the Yukon's placer operations use either a stationary grizzly or a moving deck grizzly (Derocker) to eliminate large rocks from the sluice box feed. Dry grizzlie are easier to operate than wet grizzlies but they reject rock with fine gravels and gold adhered to their surfaces. The Derocker is a well known and reliable screening device which does a good job of washing and rejecting coarse rock and boulders. It can be fed with a bulldozer provided wings are added to its entrance. However, the Derocker is only capable of screening to 2.5 inches, this is too coarse for optimum gold recoveries at most placer operations.

A few other operations also screen pay gravels with vibrating deck screens, rotating trommel screens and the "Supersluice" hydraulic grizzly. Vibrating screens can screen the largest volume of gravels for a given screen area and have low capital costs. Trommels are very good at washing the pay gravels but are large and relatively inefficient screens. The long even gradient of a trommel screen also requires higher feed ramps.

Considering the size of its deck (8 by 20 feet), the Supersluice has a low capacity (reported at 250 cubic yards/hr). The Supersluice uses steel fingers to move pay gravels over three decks with bars set at a one inch spacing. It is reported to have a lower cost and to require much less maintenance than many other screens.

6.4 Oscillating Sluiceboxes

Pay gravels containing a high proportion of high specific gravity minerals such as magnetite, or a high percentage of clay are susceptible to riffle packing. Extreme gold losses occur when a sluice's riffles become packed because the gold is unable to get through to the matting. For these deposits, oscillating or live-bottom sluiceboxes may be advisable alternatives.

An oscillating sluicebox consists of a pair of sluice runs suspended from a frame with cables. A direct current electric motor is mounted in between and above the sluice runs and rotates a weighted bent shaft through an angle drive. The motor-drive combination imparts a horizontal circular "panning" motion with a 5/8 inch diameter circle oscillated at 130 to 180 rpm. Oscillating sluiceboxes should not be used for pay gravels which don't pack riffles because conventional sluiceboxes have a slightly higher recovery of fine (-0.30 mm, -48 mesh) gold with normal pay gravels.

7 MINING METHODS

Most placer mining areas in the Yukon are in continuous permafrost and the barren overburden and/or "black muck" must be stripped off with bulldozers and the ground must be left to thaw before mining can commence. Stripping is often started as early as March and can continue into November, but the period of frost free weather available for sluicing placer gravels is often as little as 100 days.

Present Yukon placer mines are relatively small by world standards, subsisting mainly on unmined remnants from the dredging era (1901-1966), extensions of existing deposits, and the reworking of historic placer creeks. Most of the present mining methods rely on the excavation and processing of relatively large volumes (60 to 250 cubic yards per hour) of low grade material. This is usually done with diesel powered earth moving equipment such as tracked dozers, rubber tired loaders, backhoes and scrapers.

8 SOME COMMON GOLD RECOVERY MISCONCEPTIONS

Testing sluiceboxes with conventional sampling is very costly, time consuming, and problematic. Some miners, geologists and engineers have tried to determine the relative recovery efficiency of a sluicebox with the following indicators which are erronous and misleading:

a) PRESENCE OF FINE GOLD - The presence or absence of fine gold in a sluicebox is not a valid recovery test because even the crudest sluicebox will recover some proportion of the fine gold present in a placer deposit;

b) PRESENCE OF NUGGETS - The presence or absence of nuggets is not a valid recovery test because some of the coarse +1 mm gold particles are recovered in even the finest expanded metal riffles. However site E (Clarkson 1989) demonstrated that angle iron riffles are much more efficient at recovering coarse gold. Expanded metal mesh is more efficient at recovering gold finer than 1 mm, however it can lose up to 70% of the gold coarser than 5 mm;

c) INITIAL CONCENTRATION - A high concentration of gold in the first few feet of sluice run is not a good indicator of recovery efficiency. Tracer tests revealed that sluiceboxes with overall recoveries of less than 30% still had most of the recovered gold in the first few feet of the sluice run;

d) TRIAL AND ERROR TESTS - False conclusions will result when the efficiency of sluicebox modifications are based on the quantity of gold recovered. This is due to the wide variations in the size distribution and quantities of gold present in different areas of a placer deposit;

e) GOLD PAN SAMPLES - A gold pan is a very small sample and prone to the "nugget" or coarse gold particle effect. Tailings piles are particularly difficult to sample due to gold segregation;

f) COMMON USAGE - Conventional sampling and radiotracer technology have indicated that many popular sluicebox designs and operating procedures are very wasteful. Often the long term survival of gold recovery devices has very little to do with their recovery efficiency;

g) LONG TERM SURVIVAL - The long term survival of a placer gold mine is dependent on many factors. Operators with high grade gold deposits will survive even if they employ poor recovery and mining practices;

h) YOU CAN'T GET IT ALL - It is generally considered impossible to recover all of the gold in a placer deposit, however that does not mean that an operator should be content with the amount of gold he is currently losing. Minor modifications doubled the overall recovery at site H and increased its profitability dramatically.

9 CONVENTIONAL SAMPLING

The magnitude and causes of gold losses from the Yukon's placer operations were not established previously due to the extreme difficulty of obtaining representative samples of the low grade placer gravels. In addition, accurate information regarding the operation and recovery efficiency of existing concentrators is usually not available. Gold losses were expected to be high due to the application of inappropriate recovery equipment; the inability to optimize equipment parameters such as screening, feed rate, and water addition; and the lack of technical expertise and industrial research.

Testing of sluiceboxes with conventional sampling and evaluation techniques is very costly, time consuming, and problematic. Most placer gold ores are of very low value and contain a very limited number of distinct gold particles in a large volume of pay gravels. The effect of a single coarse gold particle can cause large random errors (nugget effect). In addition, the uneven distribution of gold particles in a placer deposit often produces large random sampling errors.

The 1984 Placer Sampling Program collected pay gravel and tailings samples from four Yukon placer mines. Berry analyzed the content and size distribution of the gold particles. Several assay anomalies attributed to the "nugget effect" indicated that the conventional laboratory splitting and sampling procedures employed were not appropriate for placer gold.

Poling (1986) performed an excellent evaluation of a pilot scale sluice under controlled laboratory conditions. The same batch of Sulphur Creek gravels and placer gold were recombined and sluiced several times in order to assess the effect of operating variables. The study determined that 95% of placer gold as fine as 0.15 mm (100 mesh) should be recovered by following recommended optimum processing parameters (section 3).

The US $2.7 million Alaskan Placer Mining Demonstration Grant Project (Peterson) was beneficial, however many of the tests were performed without controlled conditions, over short durations, and with incomplete or faulty sampling. Despite these limitations, Peterson indicated that the most cost-effective alternative for improving fine gold recovery over a crude sluice box is to provide screening, a thorough washing of pay dirt, and even feeding to a well designed sluicebox. He determined that gold recovery devices added to the end of a sluice box, or used to replace a sluice box, including jigs, Reichert spirals, and centrifuges are usually less cost-effective compared to this proven alternative.

In 1988, Clarkson (1989) conducted a detailed tailings sampling program at six operating placer mines for the Klondike Placer Miners Association. His tests confirmed Poling's recommended gravel and water feed rates and indicated that angle iron riffles were required to efficiently recover gold particles coarser than 1 mm.

Clarkson collected hundreds of tailings sample increments in duplicate from across the full width of each sluicebox discharge over a two to four day mining period. The entire volumes (2 to 7 cubic yards each) were screened and processed on a shaking table to determine gold losses. Despite the large size, numerous increments, and extreme care taken in the design and implementation of the program, the standard errors ranged from a low of 8% for sites with low losses to 50% for sites with high and/or coarse gold losses.

Sluiceboxes lose coarse gold particles and the presence or absence of one of these in a tailings sample can lead to high unpredictable errors in conventional samples. The collection of head samples is even more impractical than tailings samples due to the more frequent occurrence of coarse gold particles.

10 NUCLEAR TRACERS

The high cost and unpredictable error levels in conventional testing led to the implementation of the 1989 radiotracer testing program. By 1949 nuclear tracers had been used extensively in mineral processing research. However as late as 1985, Walsh was one of the first to use them to evaluate the efficiency of gravity concentration devices. Most heavy minerals (except placer gold and diamonds) can be accurately sampled and assayed with conventional techniques.

When placer gold particles are placed in a nuclear reactor, some of their nucleus' absorb an extra neutron and form gold's radioactive isotope (Au198) which can be used as a tracer. If these gold tracers have sufficient radioactivit and are relatively close, scintillometers can be used to identify and isolate the tracers. The number of tracers which are salted into the feed stream of a sluicebox must be large enough to produce test results with low error levels and yet be small enough to limit the time required to separate them from a concentrate.

The standard errors from these radiotracer tests are best represented by a binomial distribution. The maximum standard error occurs if the recovery is near 50%. For 100 tracers, the maximum standard error is 5%. The overall recovery estimates will usually be within one standard error of the true value (14 times out of 20) and almost always with two standard errors (19 times out of 20). To further reduce this maximum standard error, a much higher number of tracers would be required (ie for a standard error of 1%, 2500 tracers are required).

Nuclear tracers have increased the scope and safety for the field testing of sluiceboxes while reducing errors, costs and evaluation times dramatically. Each conventional tailings sampling test performed in 1988 cost the same as five radiotracer tests in 1989. When tracers are used, it is not necessary to take continuous tailings samples from the sluicebox's discharge while dodging boulders and heavy equipment. The gold tracers need only be irradiated to mild levels and exposure to them can be reduced with distance and protective aprons. Standard hygiene and handling procedures can eliminate the possibility of ingesting a tracer. Pocket dosimeters worn by Walsh and Clarkson to measure personal exposure to radiation did not detect dosages greater than normal background levels.

Conventional samples take a lot of time, money and effort to upgrade to raw gold. Every time they are upgraded, additional errors are introduced due to the inefficiency of recovery equipment. Significant losses are often discovered several months after testing, when it is too late for modifications and more tests in the same season.

With nuclear tracers, no assaying or upgrading is required, tests can be completed in 48 hours and this allows sluiceboxes to be modified and retested in the same week. Tracers can be used outdoors and in dirty gold rooms without introducing errors or worrying about tampering because the tracers can be readily identified with a scintillometer and are available only to licensed agents.

11 PROCEDURE

Representative placer gold particles were obtained from the various operator's concentrates and sieved into four distinct size fractions including: 1.4 mm (-10+14 mesh); 0.72 mm (-20+28 mesh); 0.36 mm (-35+48 mesh); and 0.18 mm (-65+100 mesh). The 0.18 mm was the finest placer gold commonly encountered in the Klondike. The 1.4 mm mesh gold was often coarse enough to demonstrate the requirement for angle iron riffles. These particles were packaged and sent out for irradiation at a nuclear reactor.

At each operation the irradiated gold particles were thoroughly mixed with moistened pay gravels. This mixture was split into identical volumes and added to the top section (slick plate) of the various sluiceboxes. At every site the material flow rates, water flows, processing parameters, equipment dimensions and operational characteristics were measured.

Once the operator had completed sluicing, a hand-held scintillometer was used to note the location of gold tracers in the sluice runs. Then the sluicebox was cleaned up and was checked for any remaining tracers. After the operator upgraded the concentrates, these tailings would be checked for tracers. The final concentrates were sieved and weighed. The gold tracers were removed from the concentrate and counted to determine the recovery efficiency of the sluicebox. The expired tracers were stored in a lead lined container until their radioactivity was near background levels (about 2 months).

These recovery data in combination with weight and sieve data from the sluicebox concentrates allowed the determination of the gold distribution curves for the head, concentrate, and tailings (graphs 1A-1D). The metallurgical efficiency and operating parameters of the various sluiceboxes were compared with the recommendations (section 3). At two sites (G and H), the sluice runs were modified and retested to confirm the recovery improvements.

12 CALCULATIONS

12.1 PROCESSING EQUIPMENT

The following is a brief tabulation of the feeding, screening and washing equipment at each of the sites sampled in 1989 (sites G-Q). Most of the sites used bulldozer fed triple run sluiceboxes (H, I, L, O, P and Q). Only sites G, J, and K used a feeder or vibrating screen in front of their sluiceboxes. Site M used a stationary grizzly and Site N used a Derocker moving bed grizzly. Section 13 provides more information regarding the recovery equipment at each site.

TABLE 12.1 PROCESSING EQUIPMENT

FEEDING Site	G	H	I	J	K	L	M	N	O	P	Q
Bulldozer		Yes	Yes	Yes		Yes			Yes	Yes	Yes
Wheeled Loader/Backhoe					Yes	Yes	Yes	Yes			
Hopper/Feeder	Yes				Yes						

GRIZZLY Site	G	H	I	J	K	L	M	N	O	P	Q
Length ft	No	No	No	No	13	No	?	?	No	No	No
Width ft					8		?	?			
Area ft2					100		?	?			
Spacing in					6		6	2.5			

SCREEN Site	G	H	I	J	K	L	M	N	O	P	Q
Type	VB	PP	PP	VB	VB	PP	PP	DR	PP	PP	PP
Manual Monitor		Yes	Yes	Yes		Yes					
No of Screen Decks	1			2	1						
Length ft	8	12	10	12	12	14	12		6	6	8
Width (Dia) ft	8	14	14	7	5	15	8		12	10	7
Area ft2	63	133	105	83	57	96	100		49	43	41
Final Opening in	0.75	0.50	0.50	0.39	0.75	0.50	0.50	2.50	0.50	0.50	0.75
Efficiency*	100%	79%	75%	100%	100%	64%	34%		39%	14%	69%

Legend: VB - vibrating screen deck; DR - Derocker grizzly;
PP - stationary punch plate in a triple run's distributor.

Notes: * Efficiency refers to the proportion of -1/4 inch gravels which reports to the underflow of a screen. The manually monitored triple run boxes which were equipped with large distributors (100 ft2) and sluice gates (sites H, I and L) had much higher screening efficiencies than the Ross Boxes at sites O and P. None of the distributors in the triple run boxes could match vibrating screening equipment for screening efficiency and consistent feed rates and these are important factors promoting gold recovery. In many cases the poor screening efficiency of triple run boxes reduced gold recovery because they underutilized the side runs and overloaded the center run with fine pay gravels, boulders and excessive water volumes.

12.2 SLUICING EQUIPMENT

The following is a brief tabulation of the layout of the sluicing equipment at each of the sites sampled in 1989.

TABLE 12.2 SLUICING EQUIPMENT

OVERALL	G	H	I	J	K	L	M	N	O	P	Q
Total Length ft	20	20	20	59	17	18	28	17	33	25	32
Total Area ft2	120	219	222	1013	276	209	293	100	474	397	395
Matting	NM	CO	NM	NM	UN	NM	NM	CO	MO	MO	NM
Concentrate Ratio	7	22	23	4	35	29	8	?	48	?	37
DUMP BOX RECOVERY	G	H	I	J	K	L	M	N	O	P	Q
Riffle Type	No	No	No	AN	No	No	No	No	MO	MO	EX
Length ft				39					12	5	12
Width ft				4					12	10	8
Slope in/ft				1.6					2.3	2.8	1.8
DISTRIBUTOR	G	H	I	J	K	L	M	N	O	P	Q
Length ft	No	12	10	No	No	No	12	6	6	6	8
Area ft2		133	105				8	17	49	43	41
Slope in/ft		3.7	2.8				2.9	2.5	2.5	2.8	2.6
SIDE/MAIN RUN	G	H	I	J	K	L	M	N	O	P	Q
Riffle Type	EX	DE	EX	EX	EX	DE	DE	No	MO	EX/MO	EX
Length ft	8	20	20	20	18	18	16		21	20	20
Total Width ft	20	7	7	44	8	8	6		12	10	12
Slope in/ft	1.5	2.6	1.9	1.7	1.5	2.0	2.9		2.7	2.8	1.2
CENTER RUN	G	H	I	J	K	L	M	N	O	P	Q
Riffle Type	No	No	No	No	EX/AN	No	AN	FB/AN	FB	FB	AN/EX
Length ft					16		16	17	22	20	21
Total Width ft					4		3	3	4	4	3
UNDERCURRENT	G	H	I	J	K	L	M	N	O	P	Q
Riffle Type	No	DE	EX	No	EX	DE	EX	EX/AN	MO	MO	No
Length ft		20	20		16	4	16	17	22	20	
Total Width ft		4	4		4	4	3	3	4	4	
Slope in/ft		3.5	2.8		1.5	3.4	2.9	2.5	2.7	2.9	

Legend:
SR - single run sluicebox; DR - double with/undercurrent;
TR - triple run sluicebox; OS - oscillating sluicebox;

EX - expanded metal riffles; DE - doubled expanded metal;
AN - angle iron riffles; FB - flat bar riffles;

CO - cocoa matting; NM - backed Nomad matting;
UN - unbacked Nomad matting; MO - Monsanto matting.

Notes: Sites O and P used only the coarse needled Monsanto matting in their side and undercurrent runs and used flat bar riffles in the center run. Site K screened the feed to their triple run Ross Box with a vibrating screen deck and used unbacked Nomad matting.

12.3 PROCESSING PARAMETERS

The following is a brief tabulation of the pay gravel and process water flowrates compared to those recommended by Poling in 1985 and confirmed in 1988 and 1989 field sampling:

a) Feed rate of 8 loose cubic yards/hr/ft of sluice width; and

b) Water rate of 160 Imperial gpm per foot of sluice width (for expanded metal riffles). Water rate can be reduced by increasing the slope of the sluice run or by decreasing the height of the riffles.

TABLE 12.3 PROCESSING PARAMETERS

FEED RATE Site	G	H	I	J	K	L	M	N	O	P	Q
PAY GRAVELS											
Total Lyd3/hr	40	240	240	40	225	142	132	70	250	100	250
Total % of Optimum	69%	158%	177%		141%	104%	89%	101%	134%	57%	104%
Is Feed Surging?	No	No	No	No	No	No	Yes	No	Yes	Yes	Mod
Side Runs Lyd3/hr	40	109	121	26	110	45	29	No	68	9	87
Side Runs % Optimu	69%	189%	203%	7%	174%	72%	65%	No	70%	7%	34%
Center run Lyd3/hr	No			No	62		89	?	146	88	163
Center Run % Optimum					317%		389%	?	450%	291%	675%
Undercur Lyd3/hr		131	119	No	14	96	14	?	37	4	No
Undercur % Optimum		446%	394%		43%	305%	59%	?	115%	13%	

PROCESS WATER	G	H	I	J	K	L	M	N	O	P	Q
Total Igpm	1250	5000	4000	2834	4923	4500	2656	1500	6500	4000	5000
Total % Opt Width	129%	283%	222%		194%	236%	151%	162%	249%	183%	214%
Side Runs Igpm	1250	1541	1593	2834	2849	1696	619	No	2868	1358	2368
Side Speed f/s	4	7	7	4	7	8	6	No	6	7	6
Side % Opt Width	129%	131%	133%	40%	224%	134%	81%	No	149%	86%	124%
Center run Igpm	No			No	653		1468	875	3632	2642	2632
Center Speed f/s					5		10	7	11	14	13
Center % Opt Width					103%		294%	189%	528%	438%	627%
Undercur Igpm		3459	2407	No	1420	2804	569	625	996	663	No
Undercur Speed f/s		12	12		7	17	6	7	6	7	
Undercur % Opt Width		588%	399%		224%	441%	114%	135%	145%	110%	

Notes:
- The short sections of punch plate which served the undercurrent runs in sites L, O, P, and Q were almost completely ineffective.
- The excessive water volumes (400 to 600%) and velocities (10 to 17 f/s) required to move boulders down the center run of a triple run sluicebox provide few opportunities for gold particles to work through the turbulent slurry flow and be retained by a riffle. As coarse rocks pass over the riffles they scour the riffles and often become wedged between the riffles and disrupt proper riffle action.
- Triple run boxes which were washed with stationary water manifolds always experienced feed surges coinciding with the push cycle or loading cycle of the equipment which was feeding the sluicebox (sites M, O, P and Q).

12.4 SIZE DISTRIBUTIONS OF PAY GRAVELS

The following table displays the cumulative percent of pay gravel particles which are finer than the indicated sieve. These data are the result of standard sieve tests from small samples of pay gravels at each of the various sites tested.

TABLE 12.4 SIZE DISTRIBUTIONS OF PAY GRAVELS

Tyler Mes	Dia mm	G	H	I	J	K	L	M	N	O	P	Q
+4	4.760	82%	62%	72%	70%	76%	64%	76%	72%	74%	67%	69%
+8	2.380	73%	40%	57%	59%	63%	53%	57%	58%	60%	54%	50%
+14	1.190	60%	30%	43%	48%	52%	43%	39%	48%	50%	41%	32%
+28	0.595	46%	25%	34%	37%	43%	34%	26%	40%	41%	29%	15%
+48	0.297	33%	20%	27%	26%	34%	25%	18%	33%	32%	20%	4%
+100	0.149	20%	15%	19%	16%	22%	15%	9%	26%	20%	13%	4%
+200	0.074	8%	5%	9%	8%	11%	5%	1%	14%	13%	7%	2%

Notes: The gravels from sites G, I, K, N and O appear to be the finest, however gravels from sites G, H, I and N were the most difficult to wash due to a high clay content.

12.5 COREY SHAPE FACTORS

The Corey Shape Factor is a measure of the flatness of placer gold. It is the ratio of the thickness of a gold flake to the square root of its area. For example, the C.S.F. of a sphere is 1 and of a dime is 0.05. The following table displays the C.S.F. of the gold recovered by the sluiceboxes. The 1988 conventional sampling program data indicated in 5 of the 6 sites sampled that there was no significant difference in the shape factors of the recovered and lost gold.

TABLE 12.5 COREY SHAPE FACTORS OF RECOVERED GOLD

Tyler Mes	Dia mm	G	H	I	J*	K	L	M	N	O	P	Q
+4	4.760						0.2			0.3		
+8	2.380	0.3	0.5	0.4		0.3	0.4	0.1		0.2	0.1	0.4
+14	1.190	0.3	0.3	0.2	0.1	0.4	0.2	0.1	0.7	0.2	0.2	0.1
+28	0.595	0.2	0.3	0.2	0.2	0.2	0.3	0.2	0.5	0.3	0.2	0.1
+48	0.297	0.3	0.3	0.2	0.3	0.4	0.3	0.3	0.4	0.2	0.3	0.2
+100	0.149	0.4	0.4	0.3	0.3	0.4	0.2	0.4	0.5	0.3	0.4	0.2
-100			0.5	0.3		0.6	0.4	0.5		0.4		0.3

Notes: The Corey Shape Factors for gold from these Yukon placer mines are very similar, except for site N which was unusually massive and from site J* which was gold recovered only from the secondary sluice runs. Corey Shape Factors from successive tests at one site (H) commonly varied from each other by +or- 0.1 to 0.2.

12.6 SIZE DISTRIBUTIONS OF GOLD

The following table displays the percent of gold particles in the original pay gravels which are retained on the indicated sieve. This table does not provide information about gold particles coarser than 14 mesh to protect the participant's privacy.

TABLE 12.6 SIZE DISTRIBUTION OF GOLD PARTICLES
(Graphs 1A, 1B, 1C & 1D)

Tyler Mes	Dia mm	G	H	I	J*	K	L	M	N	O	P	Q
+4	4.760											
+8	2.380											
+14	1.190	40%	11%	10%	2%	2%	10%	33%	56%	34%	3%	16%
+28	0.595	41%	35%	32%	18%	25%	49%	37%	31%	35%	18%	66%
+48	0.297	18%	43%	43%	53%	58%	34%	24%	11%	22%	59%	17%
+100	0.149	1%	9%	14%	19%	14%	5%	6%	1%	7%	17%	2%
-100		0%	1%	1%	8%	1%	1%	1%	0 %	1%	2%	0 %
Total		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Notes: Sites K and P have some of the finest gold distributions while sites N and G have the coarsest gold.

12.7 SIZE DISTRIBUTIONS OF GOLD FROM SUCCESSIVE TESTS

The following table displays the percent of gold particles from pay gravels which are retained on the indicated sieve for successive tests at the same mines.

TABLE 12.7 SUCCESSIVE SIZE DISTRIBUTIONS OF GOLD PARTICLES
(Graph 2)

Tyler Mes	Dia mm	E 1	E 2	H 1	H 3	H 4	Q 1	Q 2
+4	4.760							
+8	2.380 s							
+14	1.190	28%	10%	18%	6%	10%	22%	16%
+28	0.595	56%	56%	24%	43%	39%	51%	66%
+48	0.297	15%	31%	55%	35%	39%	23%	17%
+100	0.149	1%	3%	3%	15%	11%	4%	2%
-100		0.1%	0.4%	0.2%	1.3%	1.3%	0.3%	0.1%
Total		100%	100%	100%	100%	100%	100%	100%

Notes: The size distribution of gold particles for one clean up (E1) is often different than the average for an entire season (E2). Significant variations in size distribution of placer gold can also occur for clean ups from three successive pits (H1 to H4) and over two mining seasons (Q1 and Q2). Gold recovery methods should address these significant variations in both the shape and size distributions of placer gold.

12.8 LOCATION OF RADIOTRACERS IN SLUICE RUNS

Before the sluiceboxes were cleaned up, the radiotracers were located in each sluice run with a scintillometer. The following data show how far down the sluice runs the gold traveled before it was recovered. Sluice runs with significant gold values along the full length of their run usually had poorer overall recoveries.

TABLE 12.8 RADIOTRACER RECOVERY VERSUS TRAVEL

Recovery Distance feet		G1	H1	I	J	K	L	M	N	O	P	Q
	2	51%	5%	23%	70%	36%	31%	12%	65%	6%	10%	2%
	4	42%	4%	32%	19%	41%	14%	10%	5%	13%	12%	9%
	6	3%	9%	10%	0%	11%	25%	3%	5%	4%	5%	7%
	8	0%	2%	4%	4%	8%	3%	13%	2%	16%	15%	12%
	10	0%	2%	3%	5%	0%	10%	5%	1%	12%	15%	7%
	12	0%	1%		0%	0%	4%		3%	4%	2%	7%
	14	0%	4%		0%	0%	2%	6%	0 %	16%		9%
	16	0%	1%		0%	0%		13%	2%	11%		8%
	18	0%	1%	14%	0%	1%	1%	2%		1%	4%	2%
	20	End	End	End	End	End	End	8%	2%	0%		4%
	22							5%	End	0%	6%	5%
	24							2%		1%	3%	3%
	26							4%		2%	End	
	28							End		1%		
	30									2%		1%
	32									1%		End
Overall Recovery		96%	29%	86%	98%	96%	89%	84%	85%	89%	73%	76%

12.9 CUMULATIVE RADIOTRACER RECOVERY VERSUS TRAVEL

The following table displays these data cumulatively.

TABLE 12.9 CUMULATIVE RADIOTRACER RECOVERY VERSUS TRAVEL
(Graphs 3A, 3B, 3C & 3D)

Recovery Distance feet		G1	H1	I	J	K	L	M	N	O	P	Q
	2	51%	5%	23%	70%	36%	31%	12%	65%	6%	10%	2%
	4	93%	9%	54%	89%	76%	45%	22%	70%	19%	22%	11%
	6	96%	18%	65%	89%	87%	69%	25%	75%	23%	28%	18%
	8	96%	20%	69%	93%	95%	72%	38%	77%	39%	43%	30%
	10	96%	22%	72%	98%	95%	82%	43%	78%	51%	58%	37%
	12	96%	23%	72%	98%	95%	86%	43%	81%	55%	60%	45%
	14	96%	27%	72%	98%	95%	88%	49%	81%	71%	60%	54%
	16	96%	28%	72%	98%	95%	88%	63%	83%	82%	60%	62%
	18	96%	29%	86%	98%	96%	89%	65%	83%	83%	64%	64%
	20	End	End	End	End	End	End	73%	85%	83%	64%	67%
	22							78%	End	83%	70%	72%
	24							80%		83%	73%	75%
	26							84%		85%	End	75%
	28							End		87%		75%
	30									88%		76%
	32									89%		End
Overall Recovery		96%	29%	86%	98%	96%	89%	84%	85%	89%	73%	76%

12.10 RADIOTRACER RECOVERY FOR SUCCESSIVE TESTS

The following data are the result of successive tests at sites G and H.

TABLE 12.10 CUMULATIVE RADIOTRACER RECOVERY FOR SUCCESSIVE TESTS
(Graph 4)

Recovery		G1	G2	H1	H2	H3	H4
Distance	2	51%	51%	5%	15%	17%	18%
feet	4	93%	93%	9%	41%	32%	36%
	6	96%	96%	18%	52%	32%	52%
	8	96%	96%	20%	64%	38%	56%
	10	96%	96%	22%	68%	43%	59%
	12	96%	96%	23%	69%	45%	60%
	14	96%	96%	27%	69%	47%	60%
	16	96%	96%	28%	69%	47%	60%
	18	96%	99%	29%	70%	49%	62%
	20	End	End	29%	70%	52%	62%
	22			End	End	End	End
	24						
	26						
	28						
	30						
	32						
Overall Recovery		96%	99%	29%	70%	52%	62%

12.11 RADIOTRACER RECOVERY FOR INDIVIDUAL RUNS

TABLE 12.11 RADIOTRACER RECOVERY FOR INDIVIDUAL RUNS
(Graphs 5A, 5B & 5C)

Recovery	Site H-1		Site H-4		Site I		Site K		Site O		Site O	
Distance	Side	Cent	Side	Cent	Side	Cent	Side	C&UC	Dump	Side	Cent	Under
2	5%		18%		19%	4%	34%	2%	6%			
4	4%		18%		25%	7%	38%	2%	13%			
6	6%	3%	16%		10%		9%	2%	4%			
8	2%		3%		4%		3%	4%	16%			
10	2%		3%	1%		3%			12%			
12	1%	1%		1%					4%			
14	2%	2%								14%		2%
16		1%								10%	1%	
18	1%			1%	12%	2%	1%				1%	
20												
22												
24										1%		
26												2%
28											0 %	1%
30										2%		
32											1%	
Overall Recovery		29%		62%		86%		96%				89%

NOTE: Radiotracers generally traveled further down the center and undercurrent runs of triple run boxes due to high water velocity, excessive overloading with coarse and fine pay gravels, and the difficulty of gold particles passing through stationary punch plate under these conditions.

12.12 DISTRIBUTION OF GOLD VALUES

The following table displays the proportions of gold in each size fraction (except +4 and +8 mesh) recovered by all the sluice runs at each site.

TABLE 12.12 DISTRIBUTION OF GOLD VALUES RECOVERED BY SLUICES (Graph 1D)

Tyler Mes	Dia mm	G1	H1	I	J	K	L	M	N	O	P	Q
+4	4.760											
+8	2.380											
+14	1.190	37%	10%	7%	1%	2%	10%	28%	49%	32%	2%	13%
+28	0.595	41%	11%	29%	18%	21%	43%	33%	24%	35%	15%	45%
+48	0.297	17%	7%	36%	53%	58%	30%	20%	10%	18%	45%	17%
+100	0.149	1%	1%	12%	19%	14%	5%	3%	1%	4%	10%	1%
-100		0%	0%	1%	8%	1%	1%	0 %	0 %	0 %	1%	0 %
Total		96%	29%	86%	98%	96%	89%	84%	85%	89%	73%	76%

12.13 DISTRIBUTION OF VALUES RECOVERED BY INDIVIDUAL RUNS

The following table displays the proportions of gold in each size fraction recovered by individual sluice runs at each site.

TABLE ** DISTRIBUTION OF GOLD VALUES FOR INDIVIDUAL RUNS

		SITE G		SITE H-1		SITE H-3		SITE H-4		SITE O		
Tyler Mes	Dia mm	TOP	ANGL	SIDE	CENT	SIDE	CENT	SIDE	CENT	DUMP	SIDE	CENT/
+4	4.760											
+8	2.380											
+14	1.190	37%	3%	8%	2%	2%	1%	6%	1%	18%	6%	8%
+28	0.595	41%		8%	4%	14%	1%	19%	6%	18%	7%	10%
+48	0.297	17%		4%	3%	20%	4%	17%	7%	8%	3%	7%
+100	0.149	1%		1%	1%	9%	2%	5%	1%	1%	1%	1%
-100		0.0%		0.0%	0.0%	0.6%	0.1%	0.5%	0.2%	0.1%	0.1%	0.1%
Total Recovered		96%	3%	21%	9%	46%	7%	46%	16%			89%

Notes: Overall recovery efficiency improved from 96 to 99 percent with the addition of one inch angle iron riffles to the end of site G's twin oscillating sluices. The oscillating sluices previously had only expanded metal riffles which were unable to retain all of the +1 mm radiotracers.

Overall recovery efficiency at site H improved from 29 to 62% when its doubled expanded metal riffles and cocoa matting were converted to single expanded metal riffles and Nomad matting. The double expanded metal riffles packed where they contacted the matting and the cocoa matting was unable to retain coarser (++0.60 mm, +28 mesh) gold particles effectively.

12.14 DISTRIBUTION OF GOLD VALUES LOST TO TAILINGS

The following table displays the proportions of gold in each size fraction lost to the tailings at each site.

TABLE 12.14 DISTRIBUTION OF GOLD VALUES LOST TO TAILINGS
(Graph 1D)

Tyler Mes	Dia mm	G1	H1	I	J	K	L	M	N	O	P	Q
+4	4.760											
+8	2.380											
+14	1.190	3%	8%	3%	1%	0.1%	0%	5%	7%	3%	0.2%	3%
+28	0.595	0%	12%	3%	0%	4%	6%	4%	7%	0%	4%	21%
+48	0.297	1%	48%	7%	0%	0%	4%	4%	1%	4%	14%	0%
+100	0.149	0.1%	2%	2%	1%	0%	0.4%	2%	0%	4%	8%	0.2%
-100		0.0%	0.1%	0.2%	0.7%	0.0%	0.1%	0.2%	0.0%	0.5%	1.1%	0.0%
Total Lost		4%	71%	14%	2%	4%	11%	16%	15%	11%	27%	24%

Notes: Site H and P had the highest gold losses due to inappropriate riffle and matting design.

12.15 RECOVERY OF SLUICING SYSTEMS

The recovery of the various sluiceboxes is displayed in the following chart. Unless a known amount of radiotracers was fed to each individual run, only the total system recovery could be determined.

TABLE 12.15 RECOVERY OF SLUICING SYSTEMS
(Graphs 6A, 6B, 6C & 6D)

Tyler Mes	Dia mm	G1	H1	I	J	K	L	M	N	O	P	Q
+4	4.760											
+8	2.380											
+14	1.190	92%	56%	72%	68%	96%	100%	84%	88%	92%	92%	84%
+28	0.595	100%	48%	92%	100%	84%	88%	88%	76%	100%	80%	68%
+48	0.297	96%	12%	84%	100%	100%	88%	84%	92%	80%	76%	100%
+100	0.149	84%	36%	86%	96%	100%	92%	60%	100%	49%	56%	88%
-100												
Overall Recovery		96%	29%	86%	98%	96%	89%	84%	85%	89%	73%	76%

Notes: The sluiceboxes with screened feed (G, J, and K) have the highest recovery but even these systems require small angle iron riffles to improve coarse gold recovery.

Cocoa matting (H1) and Monsanto matting (O & P) appear to be unable retain fine (0.30 mm, -48 mesh) gold particles as effectively as Nomad matting.

The recovery vs size data are a better indication of sluicebox efficiency than the overall recovery efficiency figures.

12.16 RECOVERY OF SLUICING SYSTEMS AFTER MODIFICATIONS

An additional test was performed at site G after the last six feet of the oscillating sluice runs were narrowed to half the original width and one inch angle iron riffles were installed. Due to the high losses at site H the results were checked with liberated gold particles (H2) and then the doubled expanded metal riffles and cocoa matting were replaced with single expanded metal riffles and Nomad matting (H3). The third test results were less than optimal because the expanded metal riffles were not tight against the matting. This was corrected and retested (H4).

TABLE 12.16 RECOVERY OF SLUICING SYSTEMS AFTER MODIFICATIONS

Tyler Mes	Dia mm	G1	G2	H1	H2 Side Free	H2 Cent Gold	H3	H4
+4	4.760							
+8	2.380							
+14	1.190	92%	100%	56%	64%	80%	52%	68%
+28	0.595	100%	100%	48%	76%	72%	34%	64%
+48	0.297	96%	96%	12%	84%	64%	68%	60%
+100	0.149	84%	84%	36%	60%	40%	60%	56%
-100								
Overall Recovery		96%	99%	29%	71%	69%	52%	62%

12.17 RECOVERY OF OTHER SLUICING SYSTEMS

The following data include the results from the 1988 conventional sampling program (Clarkson 1989) and Soviet literature (Zamyatin).

TABLE 12.17 RECOVERY OF OTHER SLUICING SYSTEMS
(Graphs 7A & 7B)

		1988 Conventional Test work				Soviet Literature Screened Feed to	
Tyler Mes	Dia mm	A	B	D	E	-5/8"	-5/32"
+4	4.760						
+8	2.380						
+14	1.190	100%	100%	100%	100%	97%	97%
+28	0.595	100%	100%	98%	99%	88%	93%
+48	0.297	96%	61%	93%	84%	74%	87%
+100	0.149	96%	78%	66%	34%	57%	80%

Notes:
- Site A screened its feed to 3/8" and fed at optimum parameters to a sluice run with expanded metal riffles over Nomad matting.
- Site B screened its feed to 3/4" in a trommel and operated an oscillating sluice run similar to site G (1989).
- Site D screened its feed to 2.5" with a Derocker and fed at optimum parameters to a conventional sluice with expanded metal riffles over conveyer belt matting.
- Site E operated a single run sluice at optimum parameters with sections of expanded metal and angle iron riffles over Nomad matting.

12.18 MONETARY VALUE OF GOLD LOSSES

The monetary value of gold losses in ounces per hour, dollars per hour and dollars per 1200 hour sluicing season is displayed in the following table. Raw gold is assumed to have a fineness of 800.

TABLE 12.18 MONETARY VALUE OF GOLD LOSSES
(Graph 8)

Site	G1	H1	I	J	K	L	M	N	O	P	Q
Raw Gold g/hr	2	209	11	0.1	8	10	14	2	35	15	39
$/hr @ $400/ounce	$19	2152	$111	$1	$80	$99	$145	$19	$359	$154	$397
$1000/1200 hr seas	$23	2582	$133	$1	$96	$119	$174	$22	$431	$185	$477
Overall Recovery	96%	29%	86%	98%	96%	89%	84%	85%	89%	73%	76%

12.19 RECOVERABLE LOSSES

The following estimates of recoverable gold are based on comparison with sluiceboxes operating with screened feed and under optimum processing parameters. The capital and operating costs are in $1000, negative operating costs reflect a savings where the modifications eliminate the need for some personnel or equipment.

The proposed modifications were completed at site G and some modifications resulting in a doubling of recovery at site H were completed in 1989. Sites H, O and Q are intending to install screening systems for the 1990 season. Site Q's screen will cost less than $100,000, will be operated with a diesel\hydraulic system, and will be capable of being fed with a D9 bulldozer.

TABLE 12.19 RECOVERABLE GOLD LOSSES
(Graph 9)

Site	G1*	H1*	I	J	K	L	M	N	O	P	Q
Raw Gold g/hr	2	177	7	0.03	4	6	11	1	24	14	28
$/hr @ $400/ounce	$15	1817	$76	$0.3	$44	$59	$113	$13	$245	$141	$288
$1000/1200 hr seas	$19	2180	$91	$0.3	$53	$70	$135	$16	$293	$169	$345
Capital Cost	$1	$100	$100	$1	$50	$100	$100	$60	$100	$100	$100
Operating Cost/yr	$0	($30)	($30)	$0	($5)	($80)	$10	$10	$10	$10	$10
Overall Recovery	99%	89%	95%	99%	98%	96%	96%	95%	96%	98%	93%

Notes: Virtually all of the sites without screening (H, I, L, M, O, P and Q) will payback the capital investment in screening equipment in less than one season. Many others should have additional revenue in the first season of operation.

* Site G has already reduced its gold losses following modifications after the first test. Site H has already recovered approximately half of its recoverable gold following modifications after the second and third tests.

12.20 ACCURACY OF THESE RESULTS

The experimental error from these metallurgical tests are represented by a binomial distribution. The standard error of these experiments = ((n*p*q)^0.5)/n. Where n is the total number of radiotracers added, p is the proportion recovered and q is the proportion lost. The estimated overall recovery will usually be within one standard error of the true recovery (14 times out of 20) and almost always within two standard errors of the true recovery (19 times out of 20).

TABLE 12.20 STANDARD ERRORS OF 1989 TESTING PROGRAM

Site	G	H	I	J	K	L	M	N	O	P	Q
Standard Error %	2%	5%	4%	3%	2%	3%	4%	3%	4%	4%	4%

The standard errors encountered in the 1988 conventional sampling program were much higher and ranged from 8 % for sites A and E which had relatively low gold losses to as high as 50 % for sites with much higher losses. These higher standard errors occurred despite the large volumes of tailings (2 to 7 loose cubic yards) processed and were due to the frequent occurrence of coarse gold particles in the tailings from conventional sluiceboxes.

The 1988 conventional sampling program proved that conventional sampling techniques are very expensive, time consuming and often have high errors which cannot be determined until all of the testwork and analysis is completed. Radiotracer tests are more appropriate for placer gold testwork because they have much lower standard errors which can be predicted in advance of testing. Radiotracer tests can be completed in a day, the sluiceboxes can be modified and retested immediately.

Feed rate estimates are based on sampler data, bucket counts, and on operator's estimates. Only a limited number of samples were taken with the sample cutter and variations could result from surging or varying feed rates. Water and slurry estimates are based on the speed of the slurry and their cross sectional areas.

13 DESCRIPTIONS OF SITES

13.1 SITE G

Site G is a low bench creek placer deposit with a very high clay content and very coarse gold particles. An apron feeder discharged the pay gravels evenly into a chute containing a spray nozzle and a nugget trap. The nugget trap was dilated with low pressure water from a perforated pipe suspended just above the bottom of the trap. This trap was not as effective as angle iron riffles in the recovery of coarse gold (+1 mm).

The slurry was then split into two 8 by 4 feet screen decks fitted with 3/4 inch punch plate and more spray nozzles. The clean oversize tailings were mucked away with a loader. The undersize gravels continued on to a pair of suspended oscillating sluices which were 3 feet wide and 20 feet long.

The oscillating sluices contained expanded metal riffles over backed Nomad matting. Water flow over the sluice runs was very smooth but the oscillation concentrated the bulk of the water and gravels to the central areas of the sluice runs. The sluice oscillated in a horizontal circular pattern with a diameter of 5/8 inches and a frequency of 133 rpm. The expanded metal riffles remained loose and partially full of gravels. The feed and water flow rates per foot of sluice were near optimum levels. The operator upgraded the sluicebox concentrates with a Long Tom and by hand panning. The sluiceboxes operated for 48 hours between cleanups, the tracer particles were mixed with pay gravels and added directly below the apron feeder 11 hours before cleanup. The final concentrate was weighed and screened. The operator was not satisfied with the coarse gold (+1 mm) recovery, and a second test was completed. The ends of the oscillating sluices were narrowed to half width and 1.25 inch angle iron riffles were added to this steepened section. One set of irradiated clean gold particles (1.4 mm, -10+14 mesh) was added to one of the oscillating runs one meter above the angle iron riffles 11 hours before cleanup. A few of the coarse radiotracers traveled to the end of the angle iron riffle section, but all were recovered.

Gold losses from Site G were the second lowest encountered due to the prescreened even feed. Despite the clay-rich pay gravels, the oscillating sluice runs kept the expanded metal riffles from packing. The recovery of coarse gold (+1 mm) in the oscillating runs was improved due to the addition of 1.25 inch angle iron riffles at the end of the sluice runs even though a nugget trap was already employed. The overall recovery was improved from 96 to 99%.

13.2 SITE H

Site H is a low bench river placer deposit with clay-rich pay gravels which were extremely difficult to wash. A bulldozer pushed the pay material over a gravel ramp and onto the slick plate area of the sluicebox ten times an hour. The same dozer would push tailings from the bottom of the box, only a small fraction of its time was spent feeding the sluice.

The homemade triple run "LD" sluicebox consisted of an upper slick plate area which received the pay gravels and wash water, a large (133 ft2) distributor, a center run and two adjustable side runs. The pay gravels were washed with a small stationary manifold and a manually controlled monitor which ensured that the pay gravel slurry came to a complete stop above the distributor. This triple run "LD" sluicebox had the most efficient distributor. It passed 79% of the -1/2 inch gravels passed through its punch plate holes and on to the two side run sluices. Manual control of the monitor allowed the operator to moderate the flow of pay gravels and prevent the extreme surges which are common with unmanned triple run boxes.

Coarse pay gravels and slurry which remained above the distributor were directed into the center run sluice. The center run sluice was 20 feet long and 4 feet wide and consisted of 1/2" punch plate suspended in steps above doubled expanded metal riffles over cocoa matting. The high volumes of water and extreme velocity which were required to push the large boulders down the center sluice resulted in extreme turbulence. Radiotracers traveled farther down the center run than the side runs.

The two side run sluices were each 20 feet long and 4 feet wide. Their riffles consisted of alternating sections of doubled expanded metal and 1.25 inch angle iron riffles suspended above cocoa matting. The doubled expanded metal and full width angle iron riffles were mostly packed solid with the clay-rich gravels. The operator upgraded the sluicebox concentrates with a Long Tom and by hand panning. The concentrates and tracer particles from the side runs and center run were retrieved, weighed and screened separately.

The feed rates per foot of sluice width were twice optimum levels in the side runs and four times optimum levels in the center run. The water flow rates were nearly optimal in the side runs but were almost six times optimal rates in the center run.

Four radiotracer tests were conducted at site H, the tracer particles were added to the dump box 12 hours before cleanup. The first, third and forth sets of tracers were mixed with pay gravels and buried into gravels across the full width of the dump box. For the second test, two hundred clean tracer particles were added to one side run and to the center run to help determine if the poor recovery was due to poor washing or poor riffle action. The third test detected gold losses which were due to the excessive scour under the expanded metal riffles which were bowed above the Nomad matting.

The overall recovery was improved from 30 to 62% by converting to single expanded metal riffles and Nomad matting. Doubled expanded metal riffles are not suitable for clay-rich gravels and cocoa matting does not have enough voids to retain gold particles efficiently. The overall recovery could be increased to 89% if the pay gravels were screened to 1" and the sluice runs were redesigned to the recommendations (section 3).

13.3 SITE I

Site I is a low bench river placer deposit with relatively fine sized pay gravels. A bulldozer pushed the pay material over a gravel ramp and onto the slick plate area of the sluicebox ten times an hour. The same dozer would push tailings from the bottom of the box, only a small fraction of its time was spent feeding the sluice.

The homemade triple run "LD" sluicebox was built and operated almost identically to the box at site H except that it used single expanded metal over backed Nomad matting in all of the sluice runs. Angle iron riffles were not utilized in the center or side runs (angle iron riffles are required to retain gold particles coarser than 1 mm). Site I's distributor was slightly smaller (105 square feet) and was slightly less efficient (76%) than at site H.

The operator upgraded the sluicebox concentrates with a vibrating Long Tom and by hand panning. The concentrates and tracer particles from the side runs and center run were retrieved, weighed, and screened separately. The feed rates per foot of sluice width were twice optimum levels in the side runs and nearly four times optimum levels in the center run. The water flow rates were nearly optimal in the side runs but were almost four times optimal rates in the center run.

The tracer particles were added to the dump box 18 hours before cleanup. The particles were mixed with pay gravels and buried in the gravels across the full width of the dump box. The overall recovery of 85 percent was fairly high considering that a three run sluicebox was utilized for the relatively fine sized pay gravels. The overall recovery could be increased to 95% if the pay gravels were screened to 1" and the sluice runs were redesigned to the recommendations (section 3).

13.4 SITE J

Site J is a high bench White Channel placer deposit with clay-rich pay gravels and fine flattened gold typical of White Channel deposits. Pay gravels were pushed with a dozer into a manually controlled monitor. The primary sluice run was lined with angle iron riffles over Nomad matting. The primary sluice washed the clay-rich gravels and was reported to recover 90% of the gold including all of the +1 mm gold particles.

The 12 by 7 foot double deck vibrating screen classified the primary sluicebox tailings to 3/16 of an inch. The screen undersize was then split into several secondary sluice runs lined with a single layer of expanded metal riffles on top of Nomad matting. Screen oversize and the tailings from the secondary sluices were discharged in a common launder.

The primary sluice run was 39 feet long and 4 feet wide. The secondary runs were 20 feet long and 44 feet in combined width. The concentrates and tracer particles from the secondary runs were upgraded in a centrifugal concentrator and by hand panning. Only the concentrates and tailings from one of the secondary sluice runs were evaluated because all of the final gold losses would occur in the secondary runs and all of the runs were identical.

The tracer particles were mixed with the tailings and added 24 sluicing hours before cleanup to one of the secondary sluice runs. The combined recovery of the primary and secondary sluicing systems was almost 100% even though its White Channel pay gravels were usually difficult to wash. This high recovery was due to fine screening, excellent washing in the primary sluice, adequate water flow rates, low even feed rates, and the use of both angle iron and expanded metal riffles to optimize gold recovery in all sizes.

13.5 SITE K

Site K is a wide valley creek deposit with a fine sized gold distribution and relatively fine pay gravels. A large loader fed pay gravels through a grizzly into the feed hopper. From the hopper the pay gravel was moved on a conveyer to a vibrating screen deck. Undersize gravels (-3/4") continued on to a triple run "Ross Box".

The triple run sluicebox consisted of an upper slick plate area, a distributor section, a center run with an undercurrent and two side runs. About 2/3 of the screen undersize (-3/4") passed through the small (29 ft2) distributor's punch plate holes and on to the side runs. The side runs were each 18 feet long and 4 feet wide and were fitted with a single layer of coarse expanded metal riffles on top of unbacked Nomad matting. These expanded metal riffles were partially full and loose.

Pay gravels and slurry which remained above the distributor's punch plate were directed into the center run sluice. The center run sluice was 16 feet long and 4 feet wide and consisted of an upper and undercurrent run. The upper run had two separate sections of punch plate (3/4" holes) which directed undersize to the undercurrent. It also had sections of 1" angle iron riffles, expanded metal riffles, a short slick plate and finally more expanded metal riffles all over unbacked Nomad matting. All of the riffles in the top section were full, loose, and operating freely.

The vibrating screen deck removed most of the +3/4" material which would otherwise have run down the center run sluice. Therefore the center sluice did not have the excessive turbulence typical of triple run sluices with unscreened feed. Very little of the solids in the center run sluice went through its punch plate sections to the undercurrent run. The undercurrent was 16 feet long and consisted of two sections of expanded metal riffles over unbacked Nomad matting which were separated by a short section of slick plate. These riffles appeared to be full and packed.

The sluicebox concentrates were upgraded with a jig and Gold Wheel. The tracer particles were mixed with pay gravels and added to the vibrating screen deck 30 hours before cleanup. The combined concentrate from a 56 hour period and tracer particles from the side runs and center run were retrieved, weighed, and screened.

Site K's relatively high overall recovery of 96 % was achieved because its grizzly-hopper-feeder-vibrating screen deck provided screened pay gravels (-3/4"), thorough washing and even feed. The recovery of Site K's screened sluicing system was poorer than achievable because the sluice runs needed to be widened and adapted to the recommendations (section 3). These modifications should result in a higher overall gold recovery of 98%.

13.6 SITE L

Site L is a wide valley creek deposit with readily washable coarse pay gravels. A bulldozer pushed the pay material up a gravel ramp to a hydraulic excavator which fed the sluicebox. The same dozer pushed tailings from the bottom of the box.

The homemade triple run "LD" sluicebox was built and operated almost identically to the box at sites H and I except that it was fed a lower yardage by the excavator. Site L also used doubled expanded metal riffles separated with a small (3/8") round bar and backed Nomad matting in all sluice runs. The center run had only four feet of its length fitted with a recovery section, the remainder was used as a launder to discharge the coarse gravels.

Site L's distributor was slightly smaller than site H or I's (96 ft2) and was slightly less efficient (only 64% of the fine pay gravels were directed to the side runs). Increased screen efficiency could be realized if the distributor's punch plate contained 3/4 instead of 1/2 inch holes.

The doubled expanded metal riffles worked almost as well as single expanded metal riffles. The bottom layer of expanded metal was full but remained loose enough to allow the gold particles to get through to the matting. The 3/8 inch space between the riffles filled in with particles of gravel and resulted in a normal riffle which was 3/8 of an inch taller than single expanded metal. If the pay gravels had contained clay, the bottom riffles would have been full, packed and unable to allow the transfer of gold to the matting (ie test H1).

Pay gravel and water feed rates to the side runs were near optimum values, but feed and water rates to the center run were three times optimum values. The operator upgraded the sluicebox concentrates with a mineral jig.

The tracer particles were mixed with pay gravels, added to the dump box 9 hours before cleanup and retrieved in a combined concentrate at cleanup (22 hours total sluicing hours). The particles were mixed with pay gravels and buried in the gravels across the full width of the dump box.

The overall recovery of 89 percent was very high due to the washability of the pay gravels, frequent cleanups and a well designed distributor. The tracer maps for sites H and I indicated that the overall recovery could be increased a further 4% by lining the full length of the center run with punch plate and expanded metal riffles. If the pay gravels were screened to 1" and the sluice runs were redesigned to the recommendations (section 3), the overall recovery could be increased to 96%.

13.7 SITE M

Site M is a narrow valley creek deposit with fairly coarse gold, readily washable pay gravels and frequent large boulders. Pay gravels were excavated from the valley floor and dropped into the grizzly located above the homemade triple run sluicebox. The heavy impact of the pay gravels on the grizzly and the steep slope of the slick plate caused feed surges coinciding with the loading cycle.

The grizzly diverted the +6 inch rocks to a waste dump beside the homemade sluicebox. Minus six inch pay gravels continued onto the twin dump box areas which were fitted with punch plate (total area of 100 ft2) over expanded metal riffles and Nomad matting. Occasional sets of downstream baffles flooded the expanded metal riffles with gravels, limiting their effectiveness and increasing the volume of clean up material. Only 34% of the fine pay gravels which passed through the dump box's stationary punch plates, continued on to the twin side runs.

The gravels and slurry which remained on top of the dump box's punch plate were directed to the center sluice run. The center sluice run was 3 feet wide and 16 feet long and consisted of an upper run and an undercurrent run. The upper run used a section of punch plate to direct some of the undersize gravels to the undercurrent. The last half of the upper run consisted of angle iron riffles over fine expanded metal riffles and conveyer belt matting. These riffles were full but loose. The undercurrent used single expanded metal riffles over Nomad matting which appeared to have a proper riffle action.

The side runs were 3 feet wide and 16 feet long and consisted of doubled expanded metal riffles over Nomad matting. The doubled expanded metal riffles appeared to be either full where they contacted the matting or scoured where they were spaced above the matting due to wear and warpage. Low water levels restricted the slurry flow to the middle of the side runs. The sluicebox concentrates were upgraded with a jig.

The feed rates per foot of sluice width were lower than optimum levels in the side and undercurrent runs but four times optimum levels in the center run due to the poor screening efficiency of the dump box. There was too little water in the side runs and almost three times optimal water rates in the center run.

The tracer particles were mixed with pay gravels, added at even intervals through the 65 hour mining period onto the slick plate and retrieved with the combined concentrate. The overall gold recovery was 84% and could be increased to 96% if the pay gravels were screened minus one inch and the sluice runs were redesigned to the recommendations (section 3).

13.8 SITE N

Site N is a narrow valley creek deposit with very coarse massive gold, abundant galena and a very high proportion of large rounded boulders in a clay-rich pay gravel. One front end loader was used to feed the sluicebox while another was used to move sluice tailings. The pay gravels were fed through a Derocker grizzly to a double run sluicebox.

The Derocker screened the pay gravels to 2.5 inches. Its wave action exposed many surfaces of the oversize rocks to the stationary wash manifold monitors. The double run sluicebox was 3 feet wide and 17 feet long. It consisted of a 6 feet long section of slotted punch plate which directed some of the -1/2 inch gravels and slurry into the undercurrent run. The remaining coarse gravels and some slurry flowed onto the upper sluice run.

The upper sluice run consisted of 15 feet of flat bar at 2-3.5 inches on center and 2 feet of 2.5 inch angle iron riffles at 5 inches on center. The coarse riffles were underlain by three different sizes of expanded metal mesh and cocoa matting. The Derocker allowed 2.5 inch chunks of galena onto the upper run and these rocks were lodged between the large riffles and impeded proper riffle action.

The undercurrent sluice run consisted of 2 feet of 1.25 inch angle iron riffles followed by 17 feet of expanded metal riffles. The coarse expanded metal riffles were underlain by two layers of smaller expanded metal and cocoa matting.

Water flow rates were near optimum values; the feed rates were not measured. The operator upgraded the sluicebox concentrates with a Long Tom and by hand panning. The tracer particles were mixed with pay gravels and added 11 operating hours before cleanup in the Derocker.

The overall recovery (85%) was low for a system employing coarse screening (-2.5") mainly due to the abundant galena which packed riffles. The recovery could be increased by replacing the flat bar riffles with one inch angle iron riffles, separating the undercurrent and undercurrent runs to facilitate observation and adjustment, fitting the end of the punch plate section with sluice gates to control water distribution, replacing the cocoa matting with Nomad matting for easier cleanups, and using a mineral jig with lead shot instead of a Long Tom for upgrading sluicebox concentrates.

13.9 SITE O

Site O is a wide valley creek deposit with readily washable fine pay gravels and coarse gold. A small dozer pushed the gravels over the front of a gravel ramp onto the slick plate area of the sluicebox. Even though the small dozer spent a large proportion of its cycle time feeding the steeply sloped slick plate, the pay gravels still surged down the sluice runs. The tailings were removed with a loader.

The triple run "Ross" sluicebox consisted of an upper slick plate area which received the pay gravels, a dump box recovery area, a punch plate distributor section, a center run and two side runs. The pay gravels were washed with a stationary monitor manifold at the dump box and a smaller manifold at the entrance to the center run. All of the matting used for gold retention was the very coarse Monsanto matting. The top one third of this matting remained free with coarse void spaces but the bottom was hard packed and appeared to be unable to retain fine (-0.3 mm, -48 mesh) gold as effectively as Nomad matting.

The dump box recovery area consisted of two consecutive sets of 3/4" punch plate separated by a 6 inch drop. The recovery area's punch plate was a total of 12 feet wide and 12 feet long and was suspended above the matting. At the end of each punch plate section the undersize gravels were discharged back on top of the next punch plate. At the small distributor (49 ft2 in area), only 39% of the fine pay gravels got through the punch plate holes and were distributed to the side runs.

Coarse pay gravels and slurry which remained above the distributor's punch plate were directed into the center run sluice. The center run sluice was 22 feet long and 4 feet wide and consisted of an upper run and an undercurrent located directly beneath. The upper run had two separate sections of punch plate (1/2" holes) which directed undersize to the undercurrent and were followed with flat bar riffles on top of matting. The flat bar riffles remained free but created extreme turbulence (only 3 tracers were found in the center run's flat bar even though it was heavily loaded with fine pay gravels). The undercurrent consisted of Monsanto matting retained with longitudal bars. The high volumes of water and extreme velocity which were required to push the large boulders down the center sluice resulted in extreme turbulence in the center run sluice.

The two side run sluices were each 21 feet long and 6 feet wide. Their riffles consisted of alternating sections of matting retained with longitudal flat bar, short sections of flat bar riffles above matting, and fine expanded metal mesh suspended several inches above the matting. The flat bar riffles were full, loose and caused extreme turbulence. Tracers were located above and below each section of flat bars in the side runs. The pay gravel slurry "Rooster tailed" at the end of each section of the longitudal flat bars. The sluicebox concentrates were upgraded with a spiral drum and a shaking table.

The tracer particles were mixed with pay gravels and buried in the gravels across the full width of the dump box 12 hours before cleanup. The concentrates and tracer particles from the side runs and center run were retrieved, weighed and screened separately. The overall recovery was fairly high at 89% due to the large recovery area of the dump box and the relatively coarse gold size distribution. The overall recovery could be increased to 95% if the pay gravels were screened to 1" and the sluice runs were redesigned to the recommendations (section 3).

Potential improvements to this triple run box include the following: increase the effective area of the distributor by increasing all the holes to 3/4" and by keeping the fine pay gravels which get through the dump box's punch plate underneath instead of discharging them on top of the next section; the distributor should have sluice gates where it discharges to the side runs to control the allocation of process water among the various sluice runs; the flat bar riffles utilized in the side and center runs should be replaced with one inch angle iron riffles mounted on top of Nomad matting; and most sections of the Monsanto matting should be replaced with coarse (4-6 lb/ft2) expanded metal riffles mounted directly on top of Nomad matting to enhance the retention of fine gold.

13.10 SITE P

Site P is a narrow valley creek deposit with fine sized gold. A bulldozer pushed the pay material over a gravel ramp and onto the slick plate area of the sluicebox. The same dozer would push tailings from the bottom of the box. Only a small fraction of its time was spent feeding the sluice and the pay gravels surged down the sluice runs.

The triple run "Ross" sluicebox was similar to site O's except slightly smaller. The punch plate of its small (50 ft2) dump box recovery area was suspended above expanded metal riffles and matting, and it discharged its undersize gravels back on top of the distributor. At the small distributor (43 ft2), a mere 22% of the fine pay gravels got through the punch plate holes and were distributed to the side runs.

The center run sluice was 20 feet long and 4 feet wide and very similar to site O's. The two side runs were each 20 feet long and slightly narrower at 5 feet wide. The bottom of the Monsanto matting was packed and the flat bar riffles were full, loose and caused extreme turbulence (as at site O). The sluicebox concentrates were upgraded with a shaking table.

Due to the extremely low screening efficiency of the distributor the side runs and undercurrent run were severely underutilized (only 12% of optimum feed rates) while the center run processed almost three times the optimum feed rate with over four times the optimum water flow.

The tracer particles were mixed with pay gravels and buried in the gravels across the full width of the dump box. The combined concentrates and tracer particles were retrieved, weighed and screened. The poor (73%) overall recovery can be attributed to the extremely poor screening efficiency of the distributor, inappropriate riffles and matting, and its fine gold size distribution. Site P's overall recovery could be increased to 98% if the pay gravels were screened to 1" and the sluice runs were redesigned to the recommendations (section 3).

13.11 SITE Q

Site Q is a low bench river placer deposit with relatively coarse and readily washable placer gravels. A bulldozer pushed the pay material over a gravel ramp and onto the slick plate area of the sluicebox. This bulldozer spent only a small fraction of its cycle time feeding the dump box. Another bulldozer was used for pushing tailings.

The homemade triple run sluicebox consisted of an upper slick plate area which received the pay gravels, a dump box recovery area, a punch plate distributor section, a center run and two adjustable side runs. Wash water was sprayed into the feed gravels from two stationary manifolds.

The 12 feet long by 8 feet wide dump box recovery area consisted of two consecutive sets of punch plates suspended above coarse expanded metal riffles and Nomad matting. A small step separated each of the two recovery sections and forced large rocks to roll over to allow better washing. At the end of each punch plate section the undersize gravels were discharged back on top of the next punch plate. At the small (41 ft2) distributor, 69% of the fine pay gravels got through the 3/4 inch punch plate holes and were distributed to the side runs.

Boulders and entrained pay gravels which remained above the distributor plate were directed to the center run sluice. The center run sluice was 21 feet long and 3 feet wide. The first 12 feet of the run was lined with 2 inch angle iron riffles over expanded metal and Nomad matting. The remaining 8 feet consisted of punch plate with 3/4 inch holes suspended well above expanded metal riffles and Nomad matting. At the top of the center run, the angle iron riffles were free in the middle but were full on the edges and at the bottom of the center run.

The two side runs were each 20 feet long and 6 feet wide and were underlain with Nomad matting. Their riffles consisted mainly of expanded metal and a short section of full width 1 inch angle iron riffles. The expanded metal riffles were full and loose but the full width angle iron riffle sections were packed.

The feed and water flow rates per foot of sluice width were near optimum levels in the side runs but over six times optimum levels in the center run due to its narrow width and the amount of coarse gravels in the feed. The sluicebox concentrates were upgraded with a mineral jig.

The tracer particles were mixed with pay gravels and buried in the gravels across the full width of the dump box 30 hours before cleanup. The combined concentrates and tracer particles from the side runs and center run were retrieved, weighed and screened. The overall recovery was fairly low at 76% due to extreme overloading of the center run and the absence of effective angle iron riffles. The overall recovery could be increased to 94% if the pay gravels were screened to 1" and the sluice runs were redesigned to the recommendations (section 3).

14 REFERENCES

BERRY, T.F., 1985. Concentration of Gold from Yukon Placers. Mineral Sciences Laboratories, Canada Center for Minerals and Energy Technology, Ottawa, Ontario.

CLARKSON, R.R., 1988. Gold Recovery Project Feasibility Analysis. Prepared for the Klondike Placer Miners Association, P.O. Box 4427, Whitehorse, Yukon Y1A 2R8

CLARKSON, R.R., 1989. Gold Losses at Klondike Placer Mines, (1988 Conventional Sampling Program). Prepared for the Klondike Placer Miners Association. Available at Northern Affairs Program, 200 Range Road, Whitehorse, Yukon Y1A 3V1.

PETERSON, L.A., 1987. Placer Mining Demonstration Grant Project Final Repot. Prepared for State of Alaska Department of Environmental Conservation.

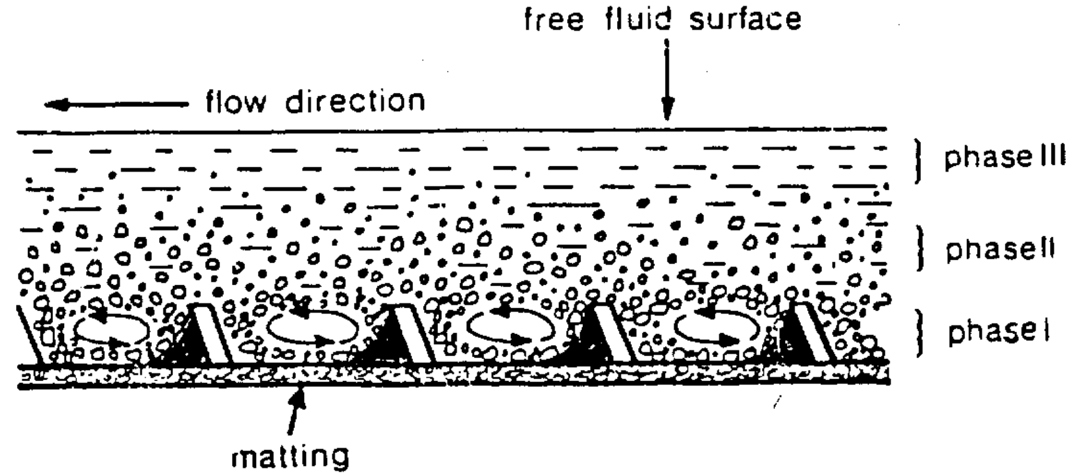
POLING, G.W. and HAMILTON, J.F., 1986. Fine Gold Recovery of Selected Sluicebox Configurations. Available at Northern Affairs Program, 200 Range Road, Whitehorse, Yukon Y1A 3V1.

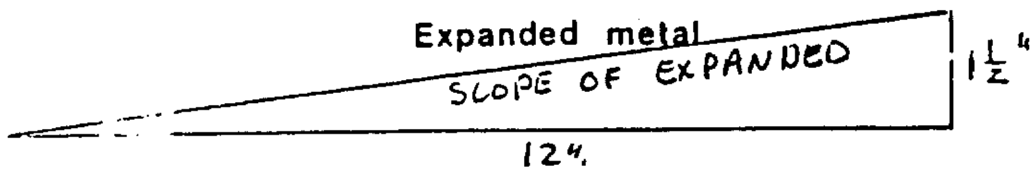
MERKS, J.W., 1987. Procedures for Sampling Tailings from Placer Gold Sluice Operations. Prepared for the Klondike Placer Miners Association, P.O. Box 4427, Whitehorse, Yukon Y1A 2R8

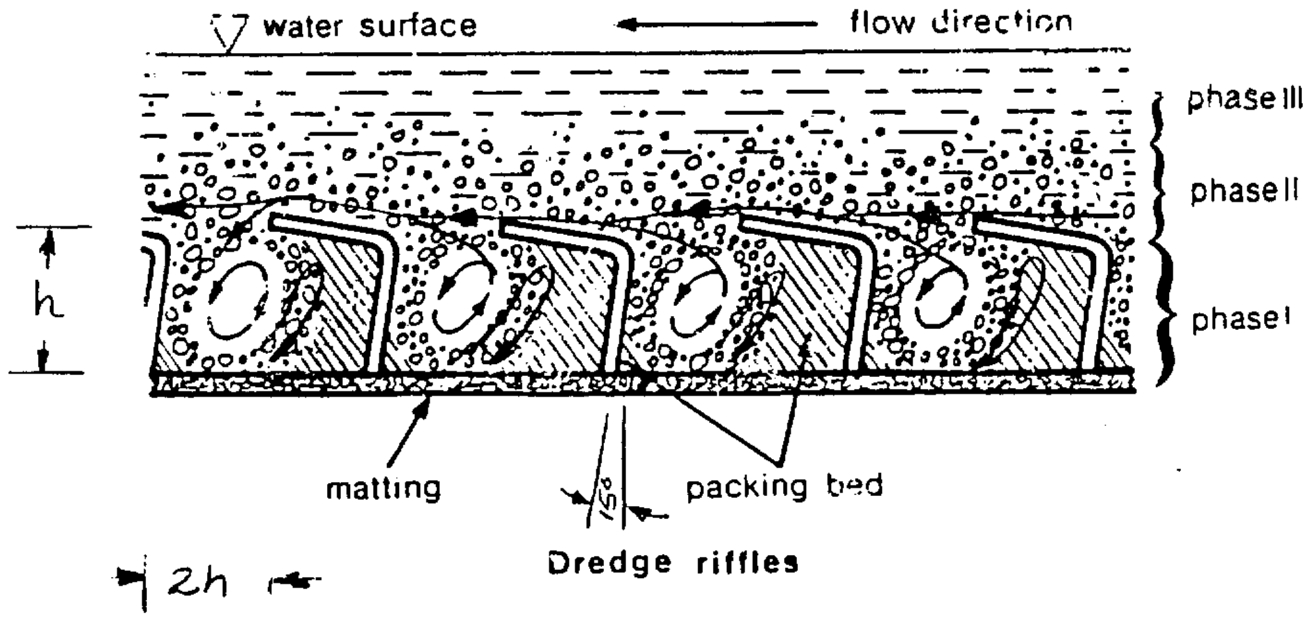
WALSH, D.E., 1985. Evaluation of the Four Inch Compound Water Cyclone as a Fine Gold Concentrator Using Radiotracer Techniques. Mineral Industry Research Laboratory, University of Alaska, Fairbanks 99775-1180

ZAMYATIN, O.V., et all, 1975. The Concentration of Auriferous Sands and Conglomerates. English translation available from the Geological Survey of Canada, Ottawa, Ontario.

FIGURE 1 RIFFLE ACTION







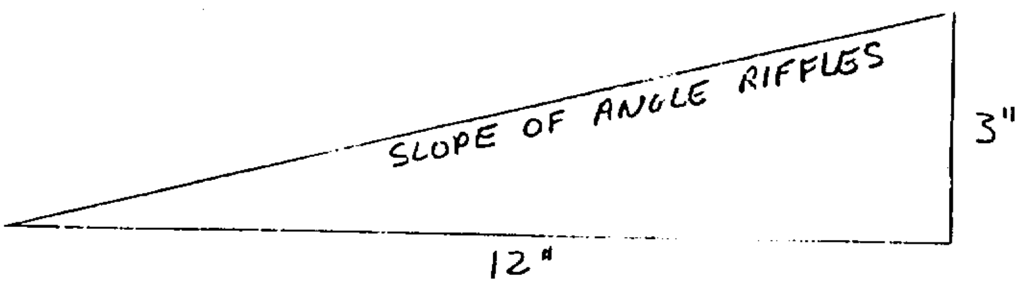
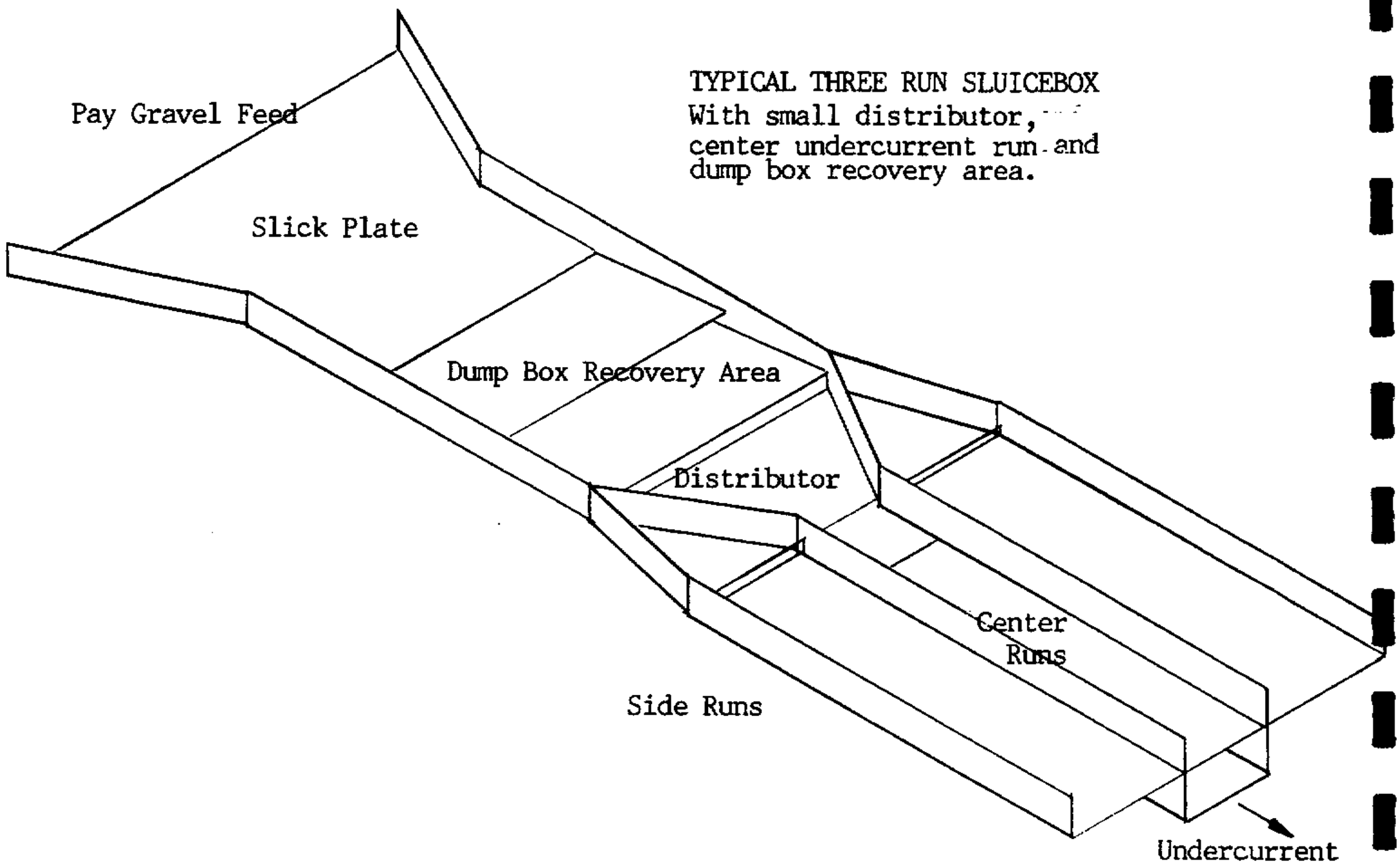
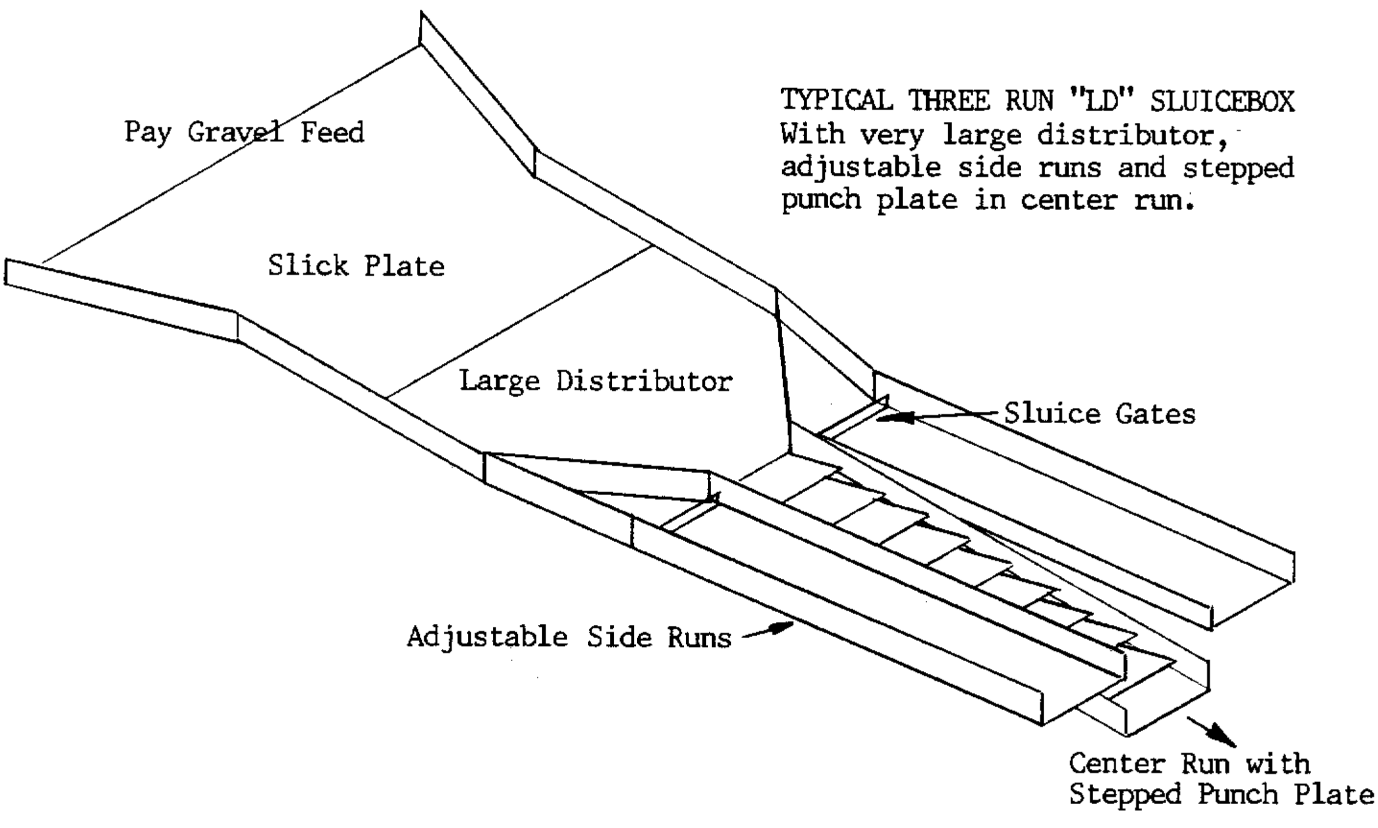
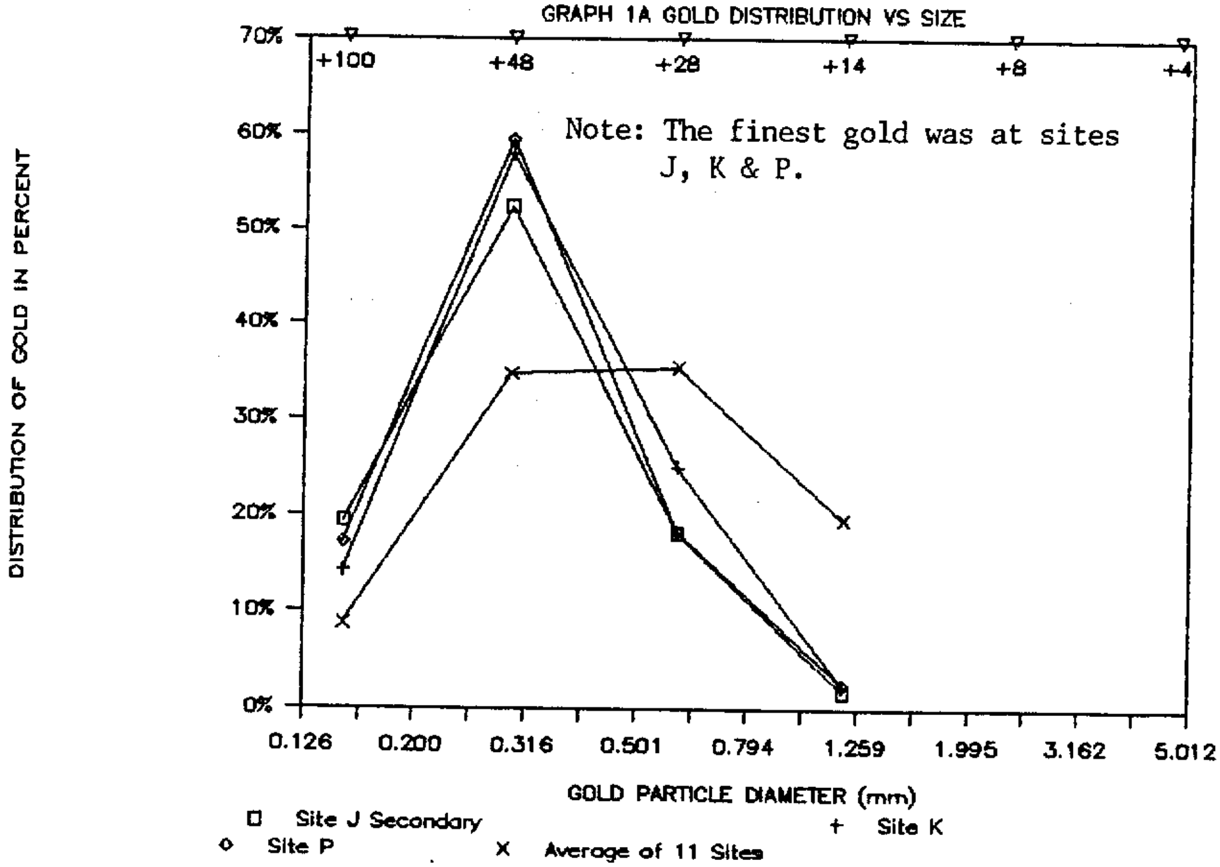


FIGURE 2 COMPONENTS OF A TRIPLE RUN SLUICEBOX





DISTRIBUTION OF GOLD VALUES (HEADS)



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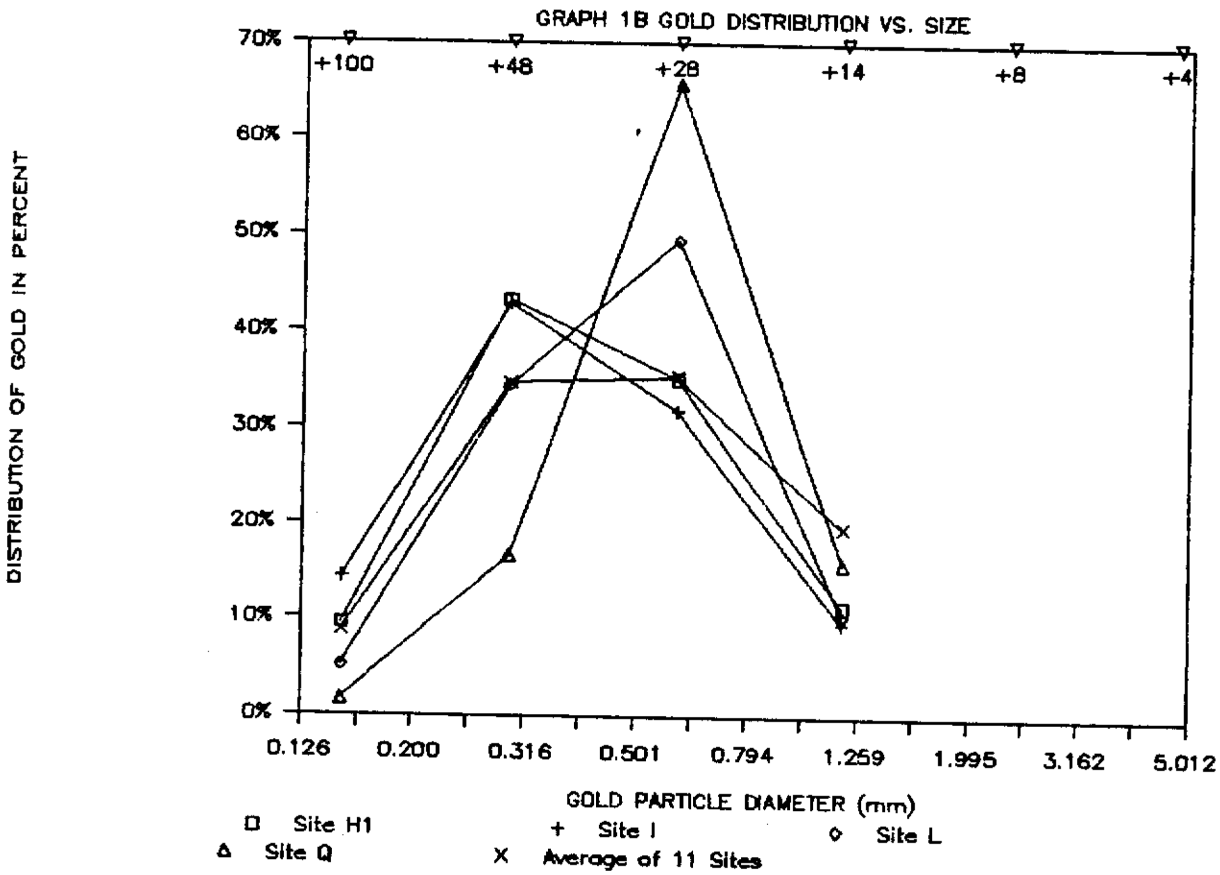

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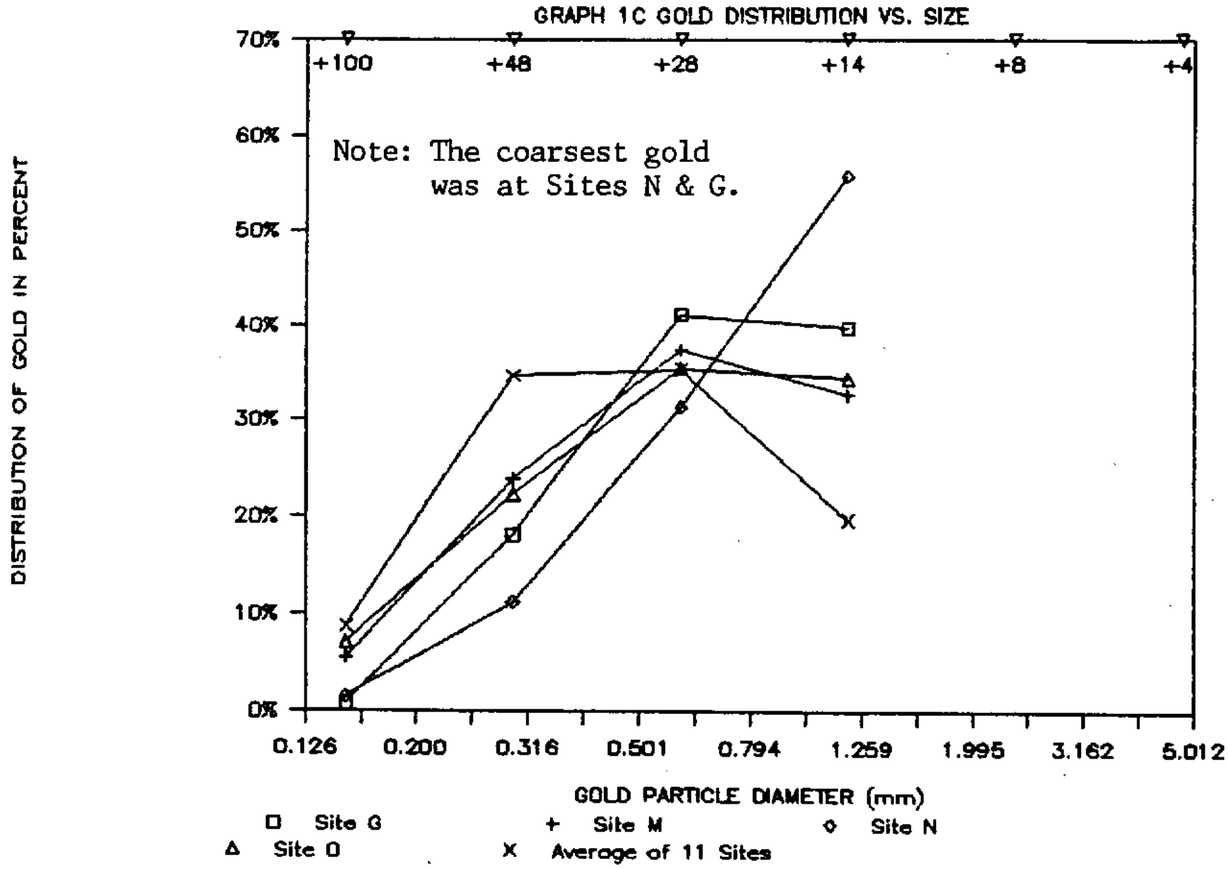
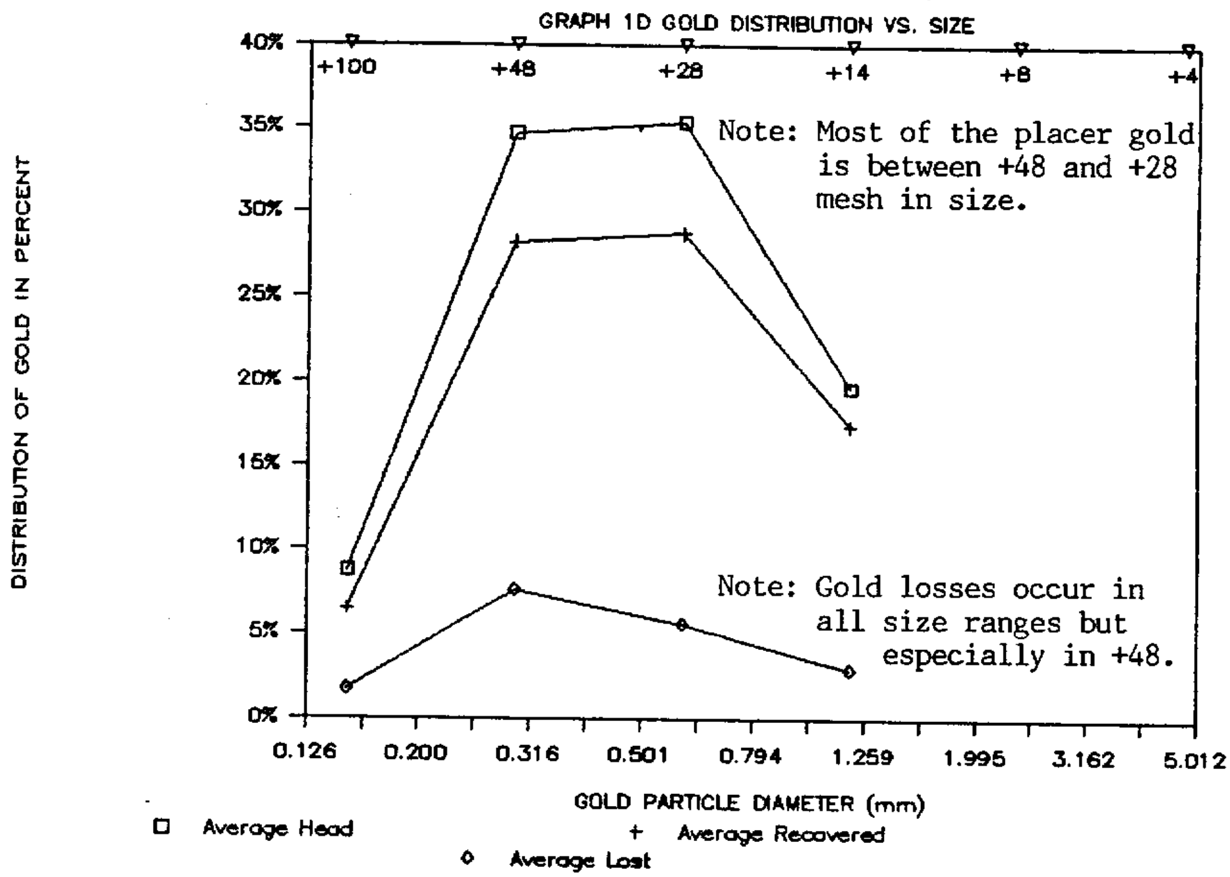
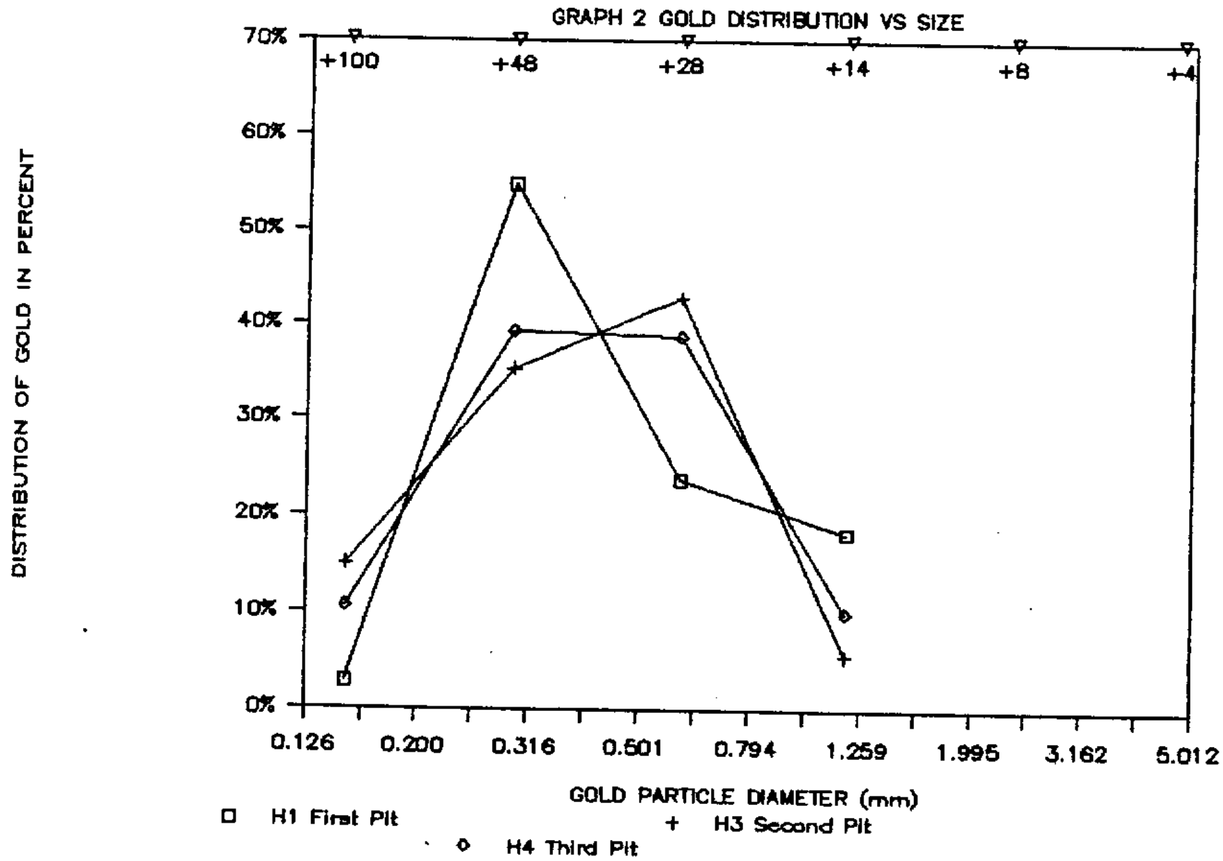


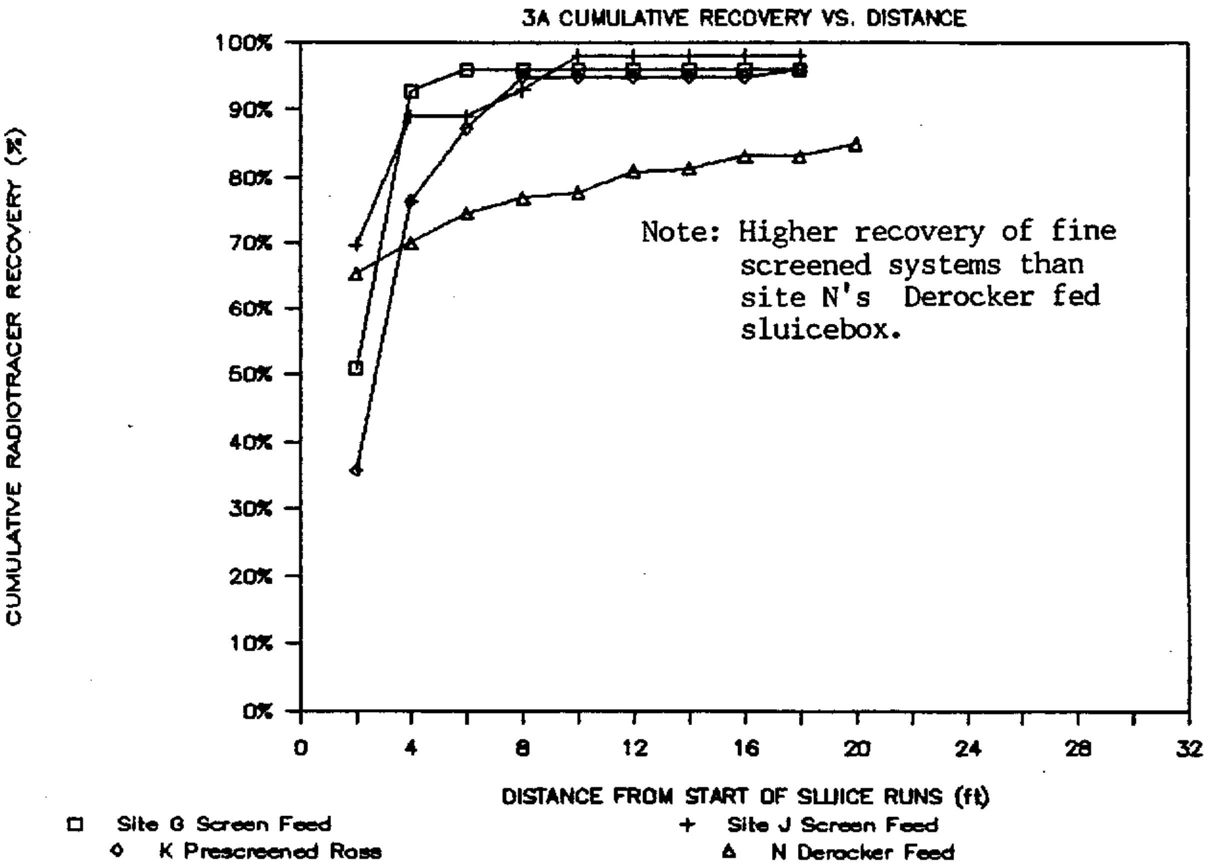
DISTRIBUTION OF GOLD VALUES (AVERAGES)



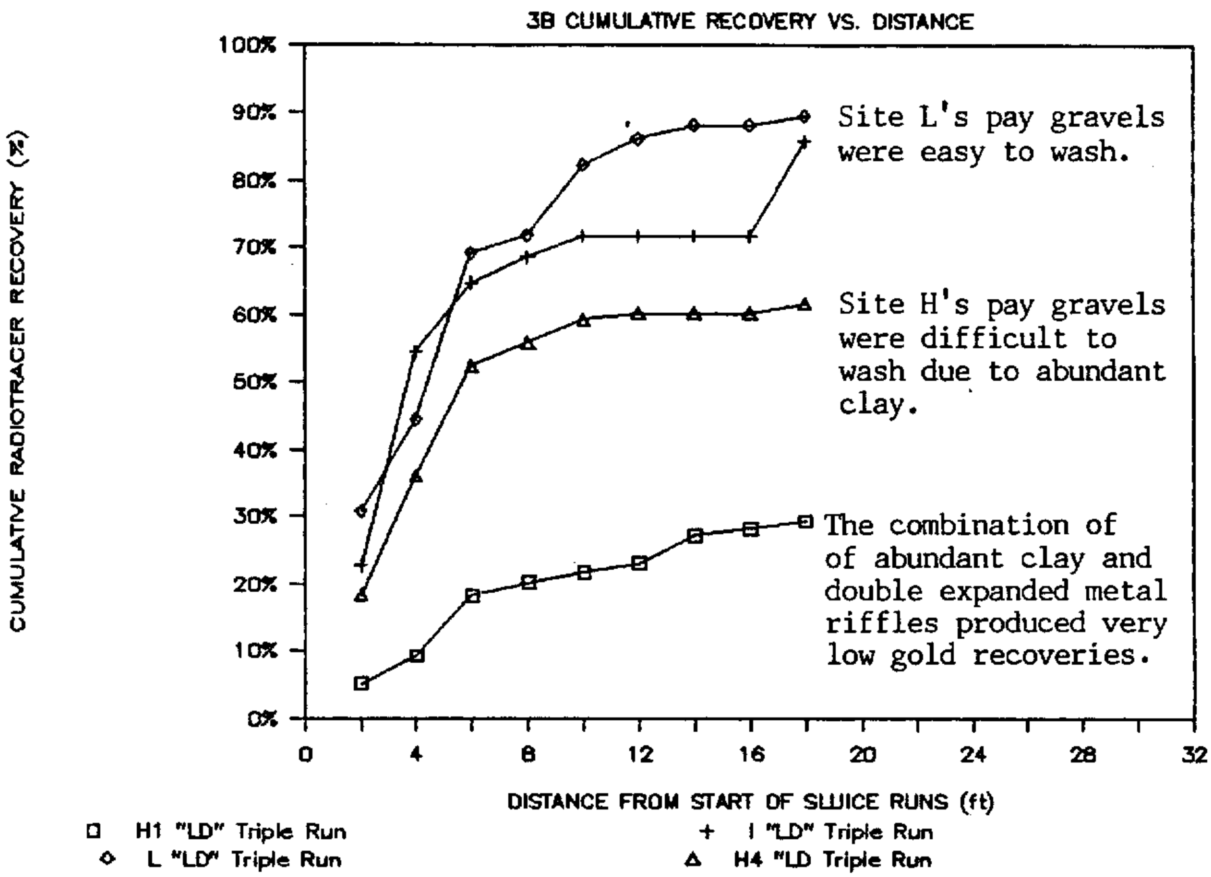
DISTRIBUTION OF GOLD VALUES (SUCCESIVE)



LOCATION OF RADIOTRACERS IN SLUICE RUNS

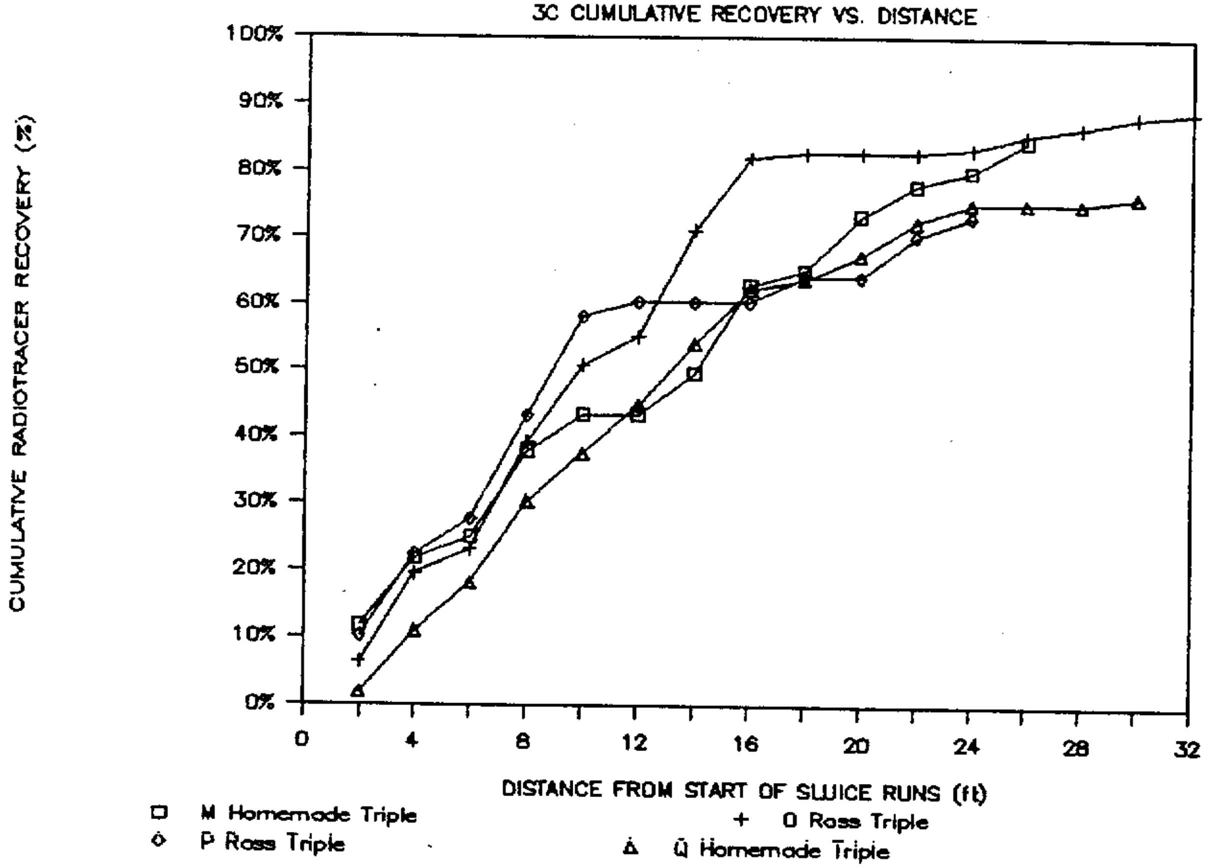


LOCATION OF RADIOTRACERS IN SLUICE RUNS



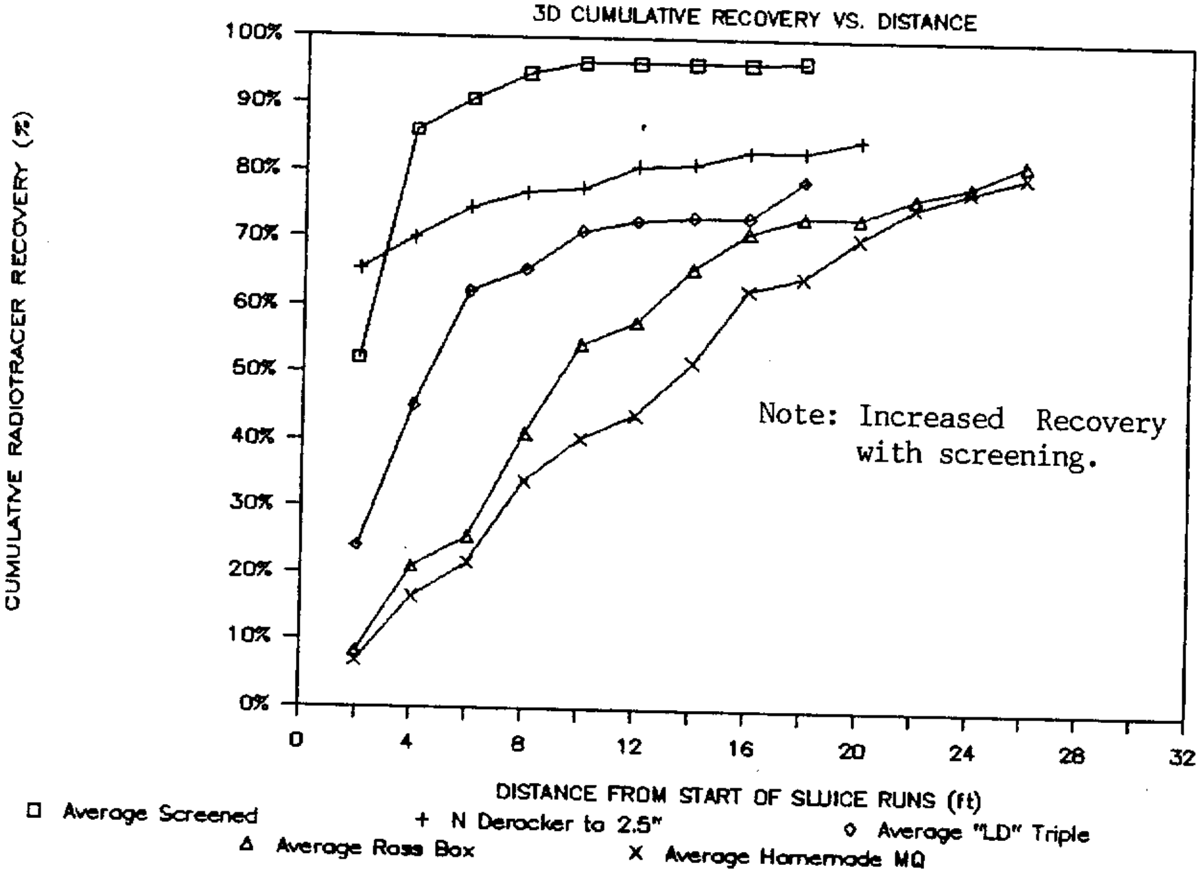
LOCATION OF RADIOTRACERS IN SLUICE RUNS

3C CUMULATIVE RECOVERY VS. DISTANCE

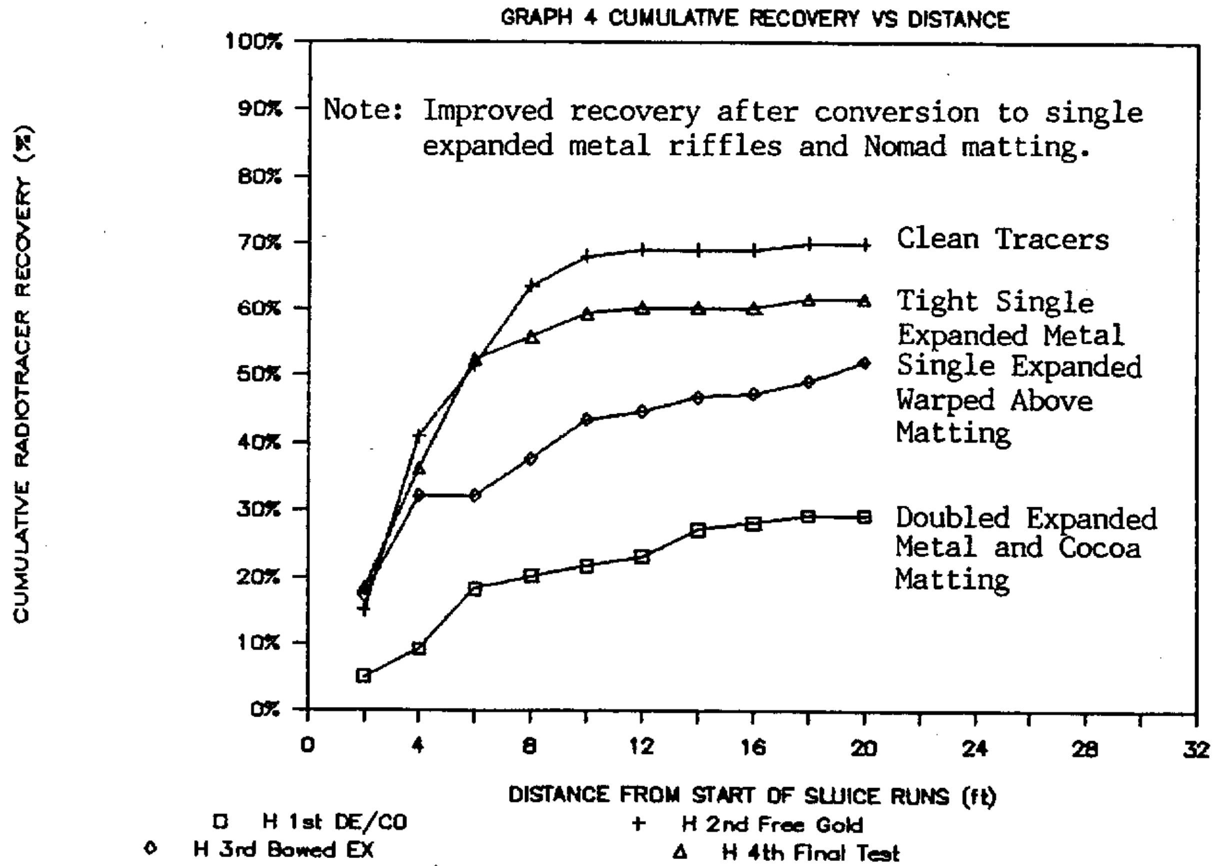


LOCATION OF RADIOTRACERS IN SLUICE RUNS

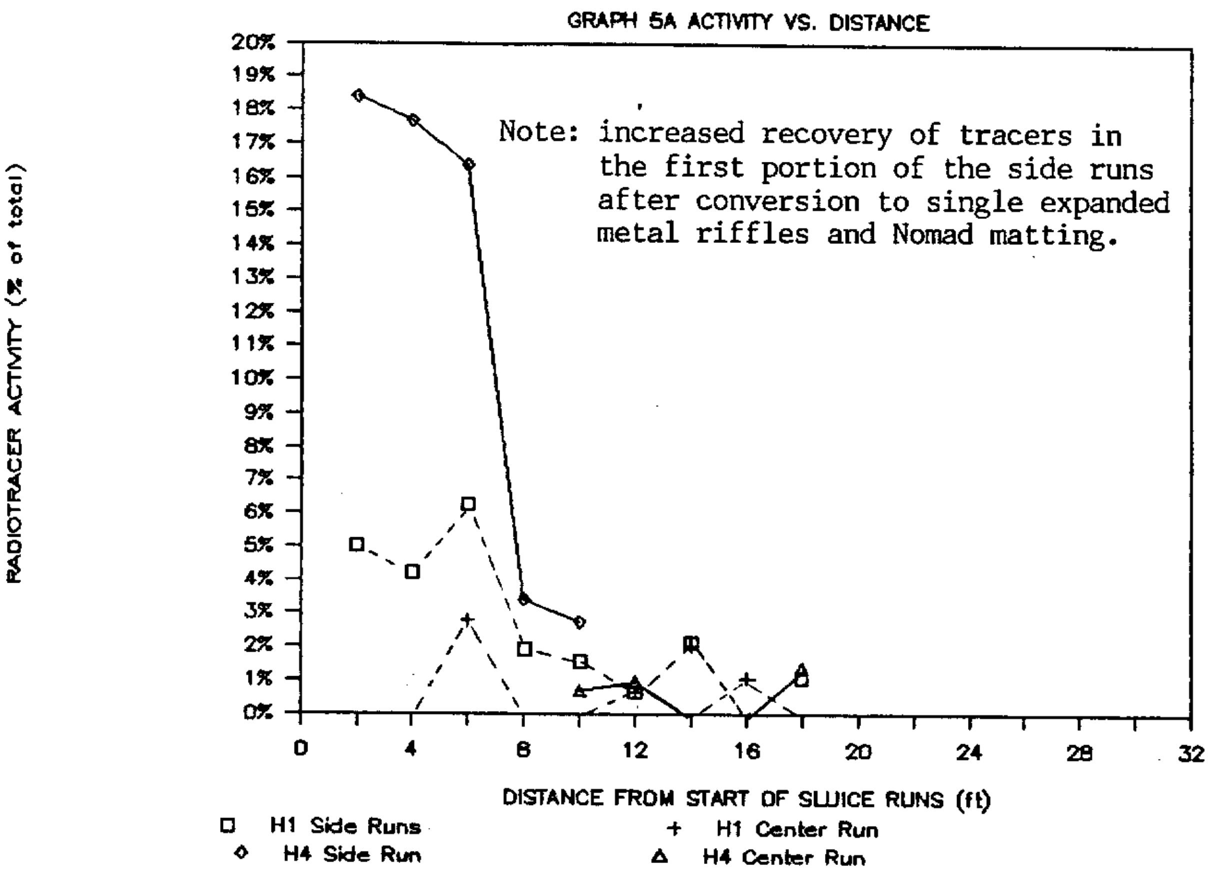
3D CUMULATIVE RECOVERY VS. DISTANCE



RADIOTRACERS IN SUCCESSIVE TESTS

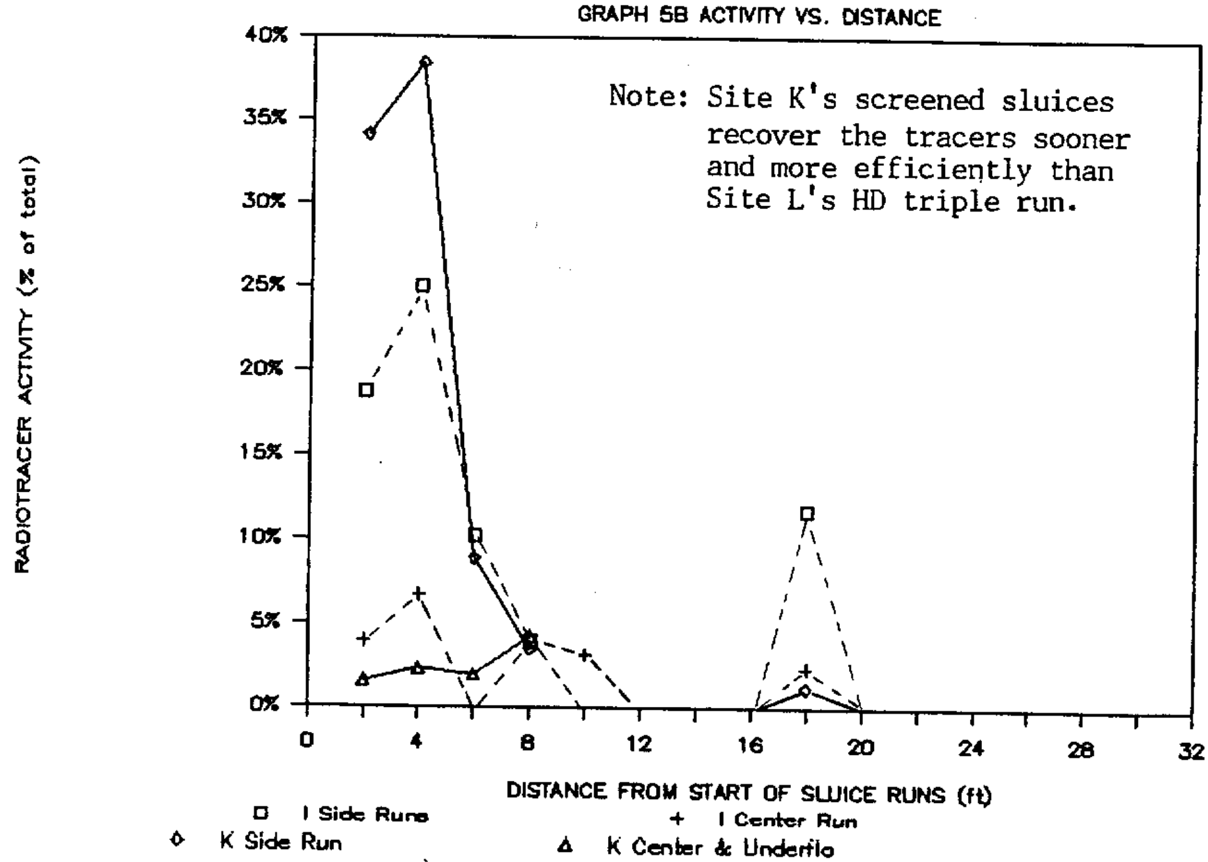


RADIOTRACERS IN INDIVIDUAL RUNS



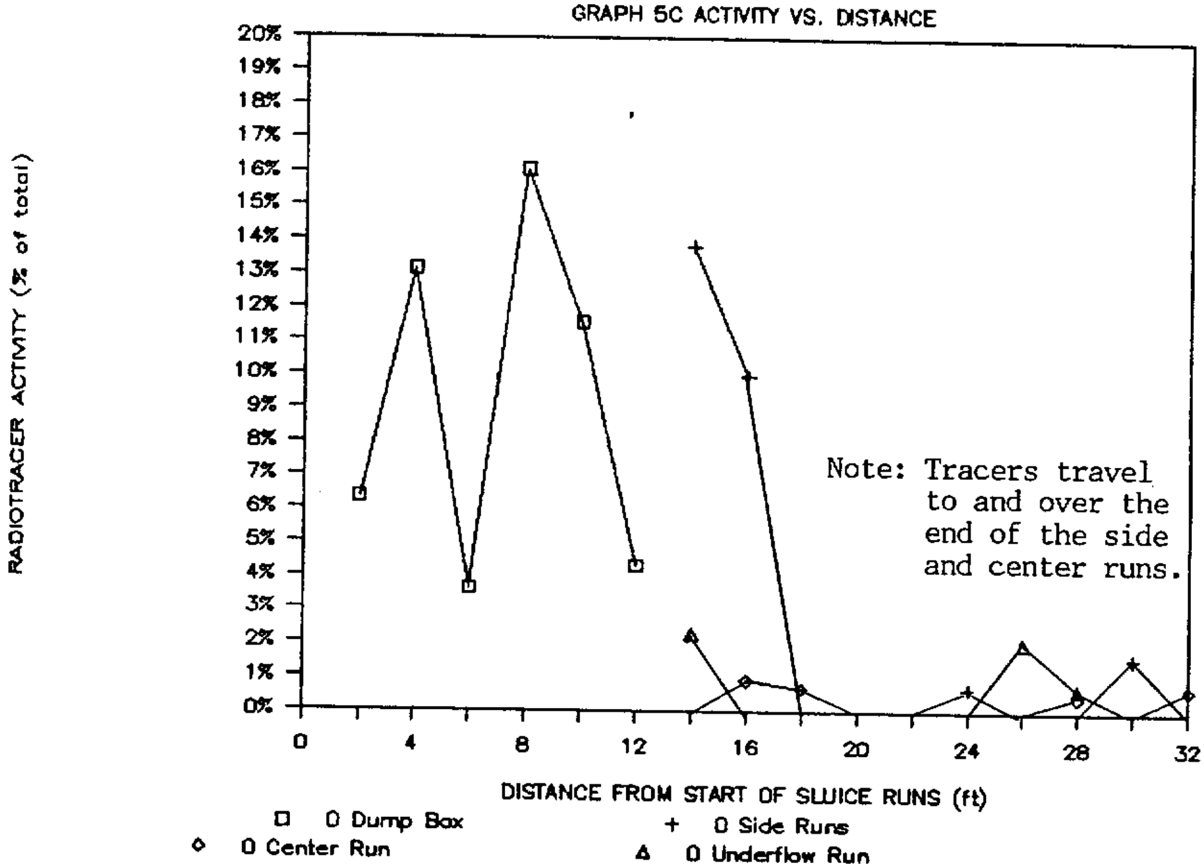
RADIOTRACERS IN INDIVIDUAL RUNS

GRAPH 5B ACTIVITY VS. DISTANCE

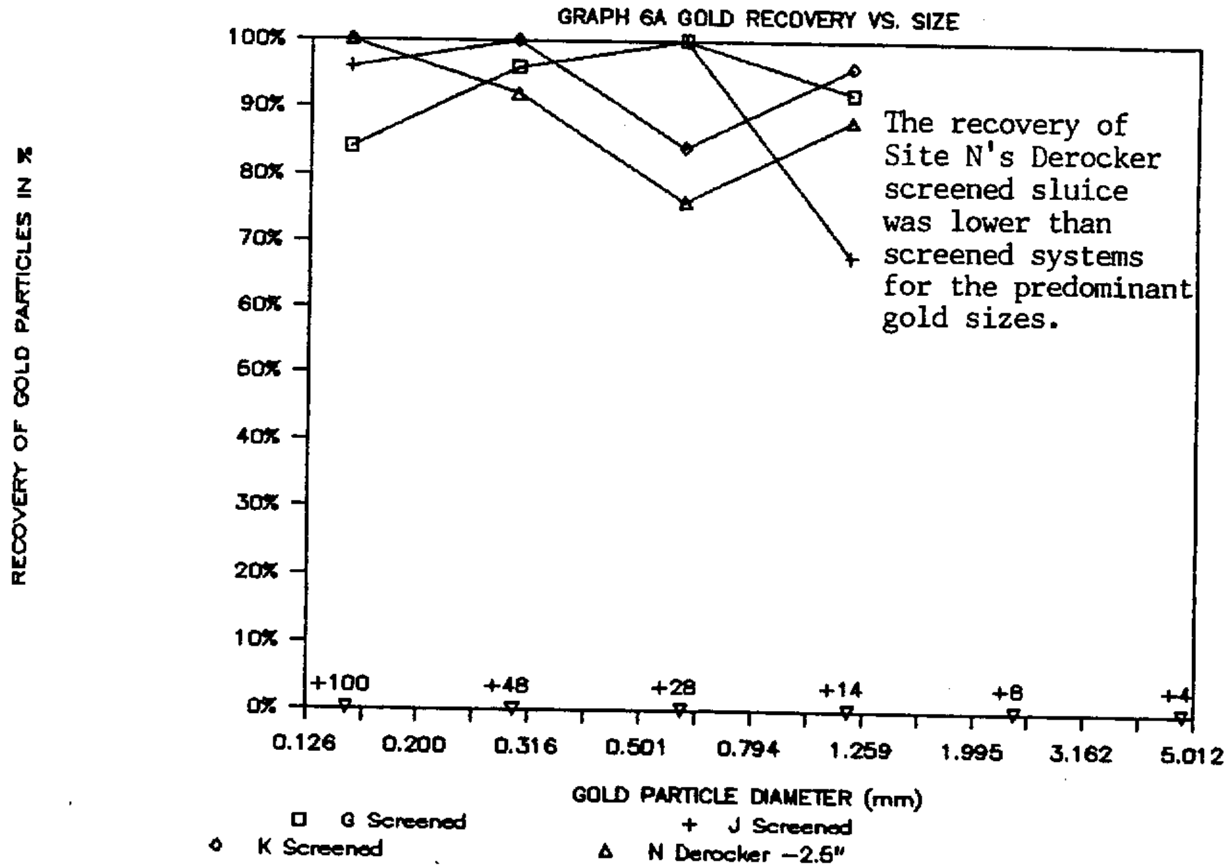


RADIOTRACERS IN INDIVIDUAL RUNS

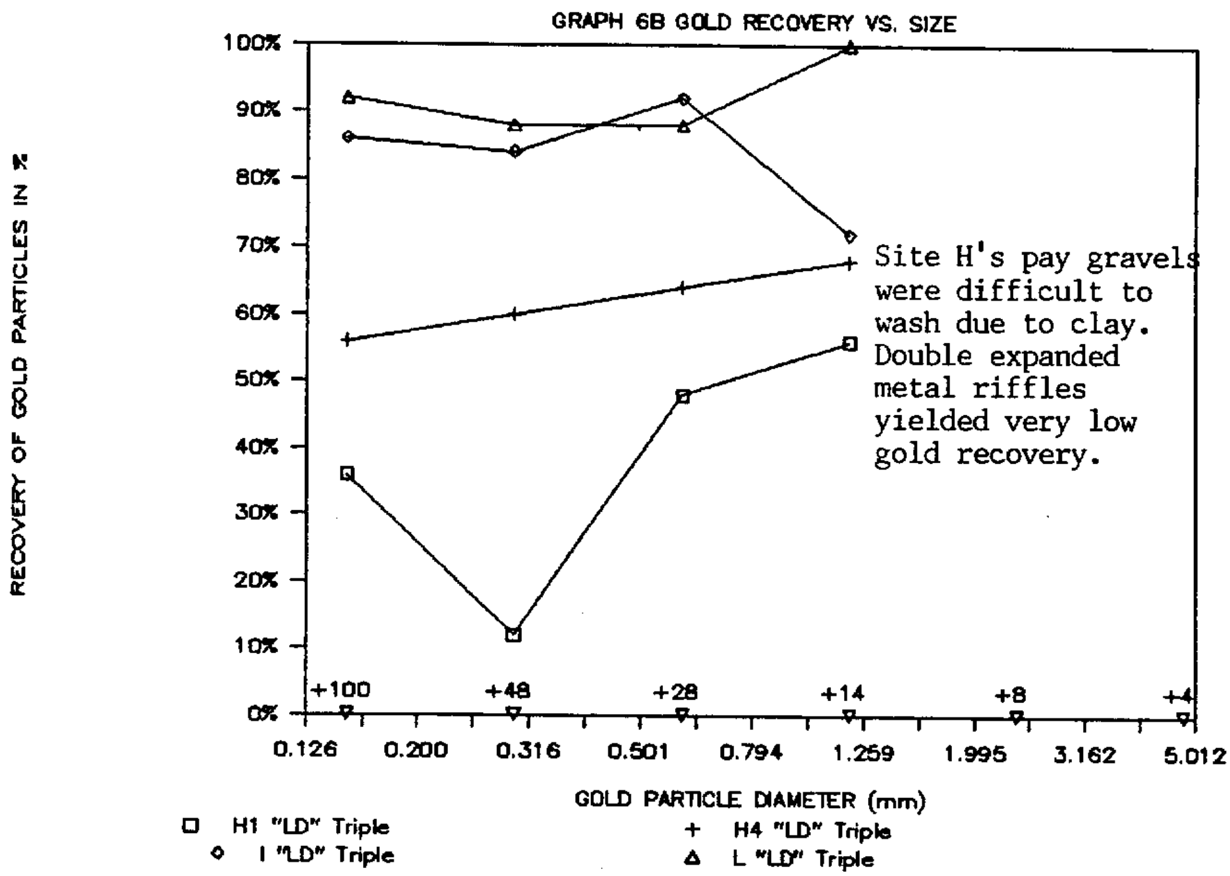
GRAPH 5C ACTIVITY VS. DISTANCE



GOLD RECOVERY (G, J, K & N)

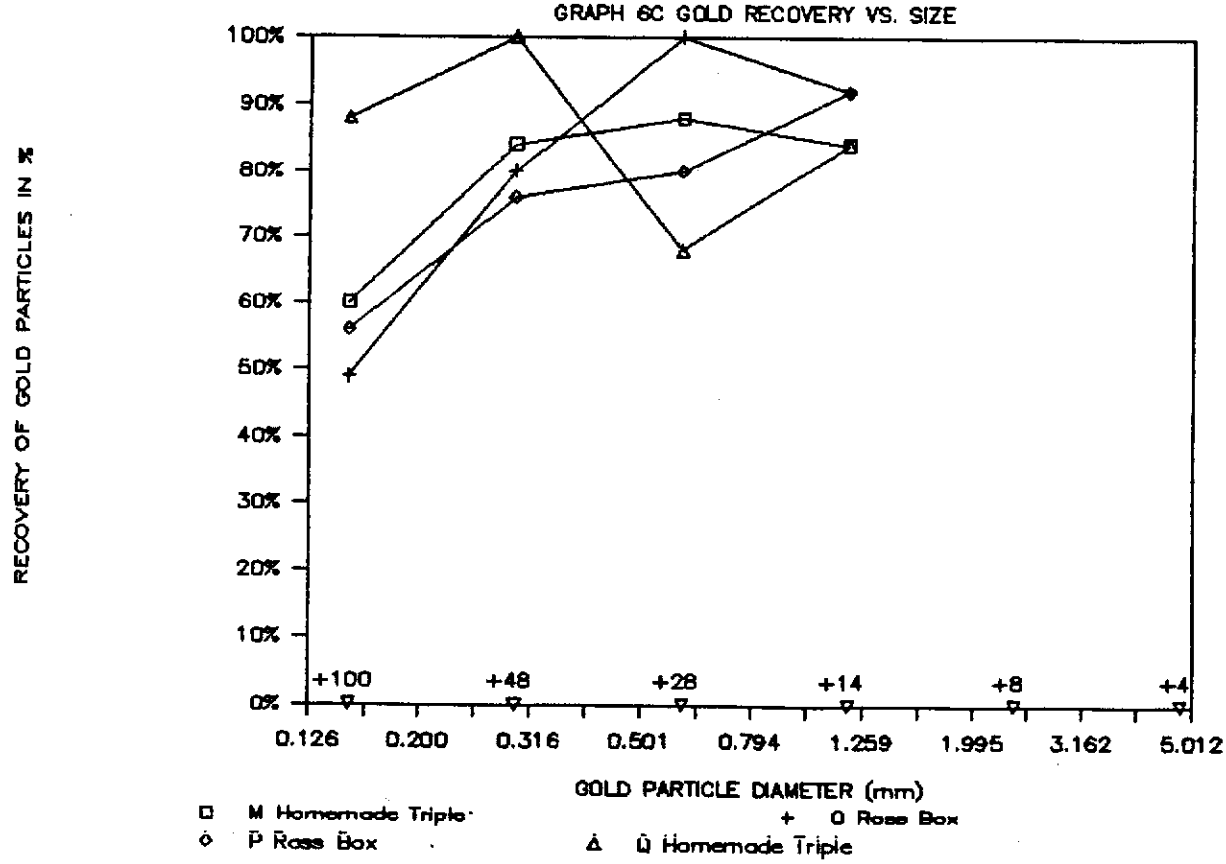


GOLD RECOVERY (H, I & L) "LD"



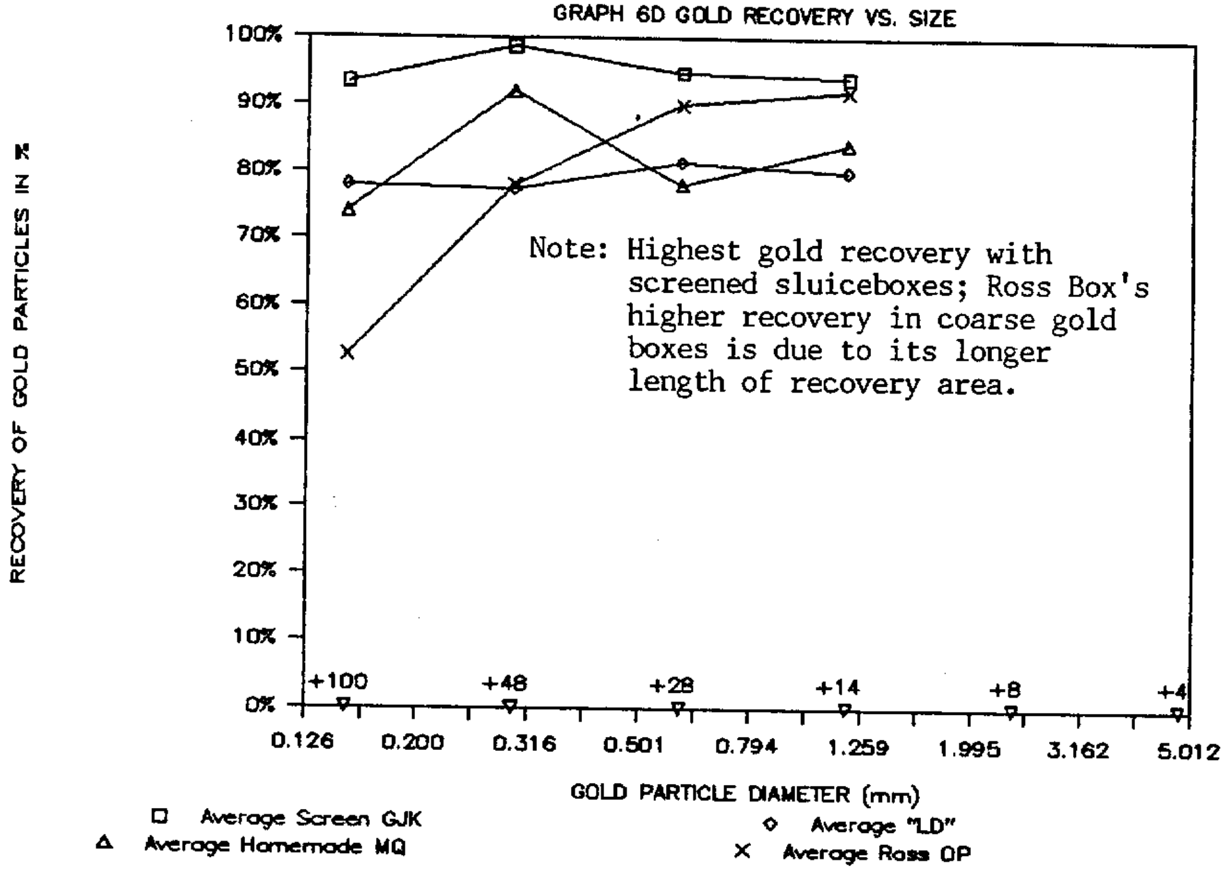
GOLD RECOVERY (M, O, P & Q)

GRAPH 6C GOLD RECOVERY VS. SIZE

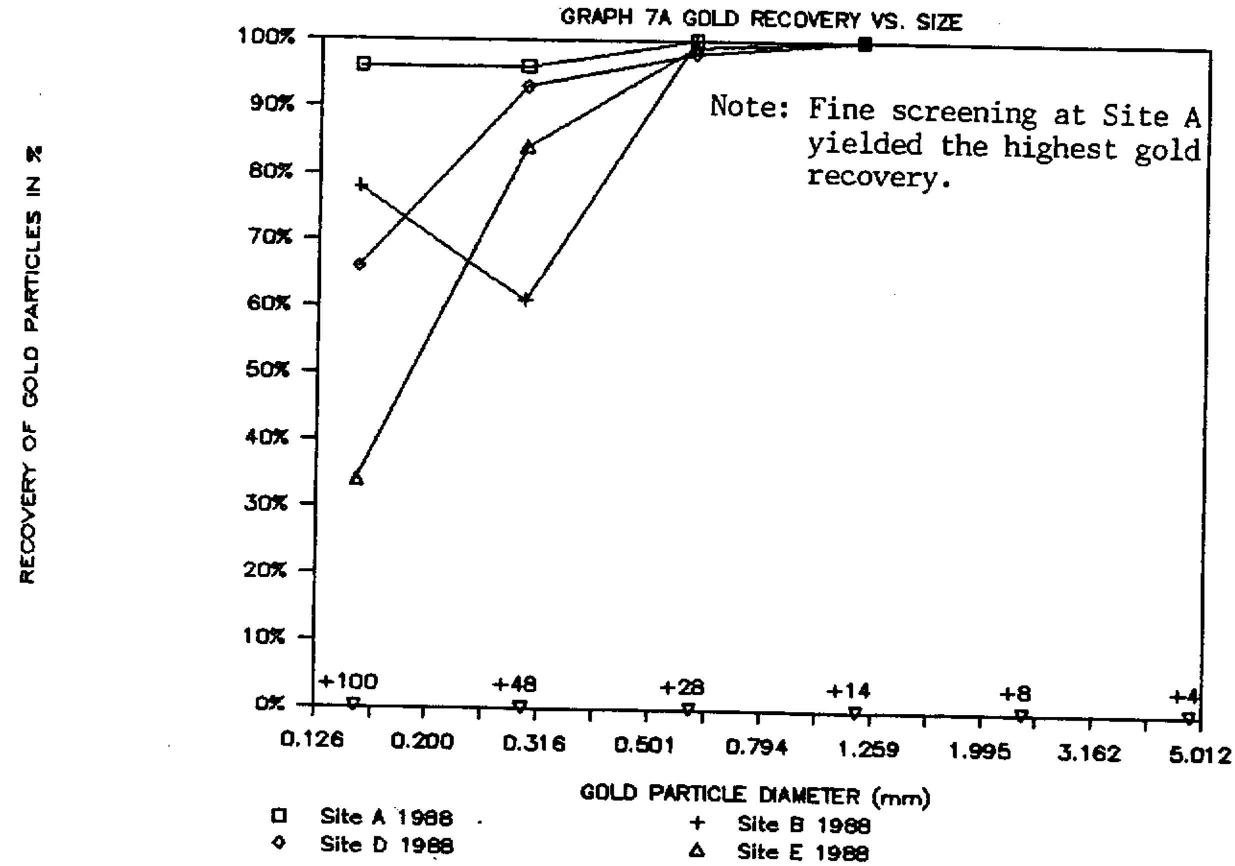


GOLD RECOVERY (Averages)

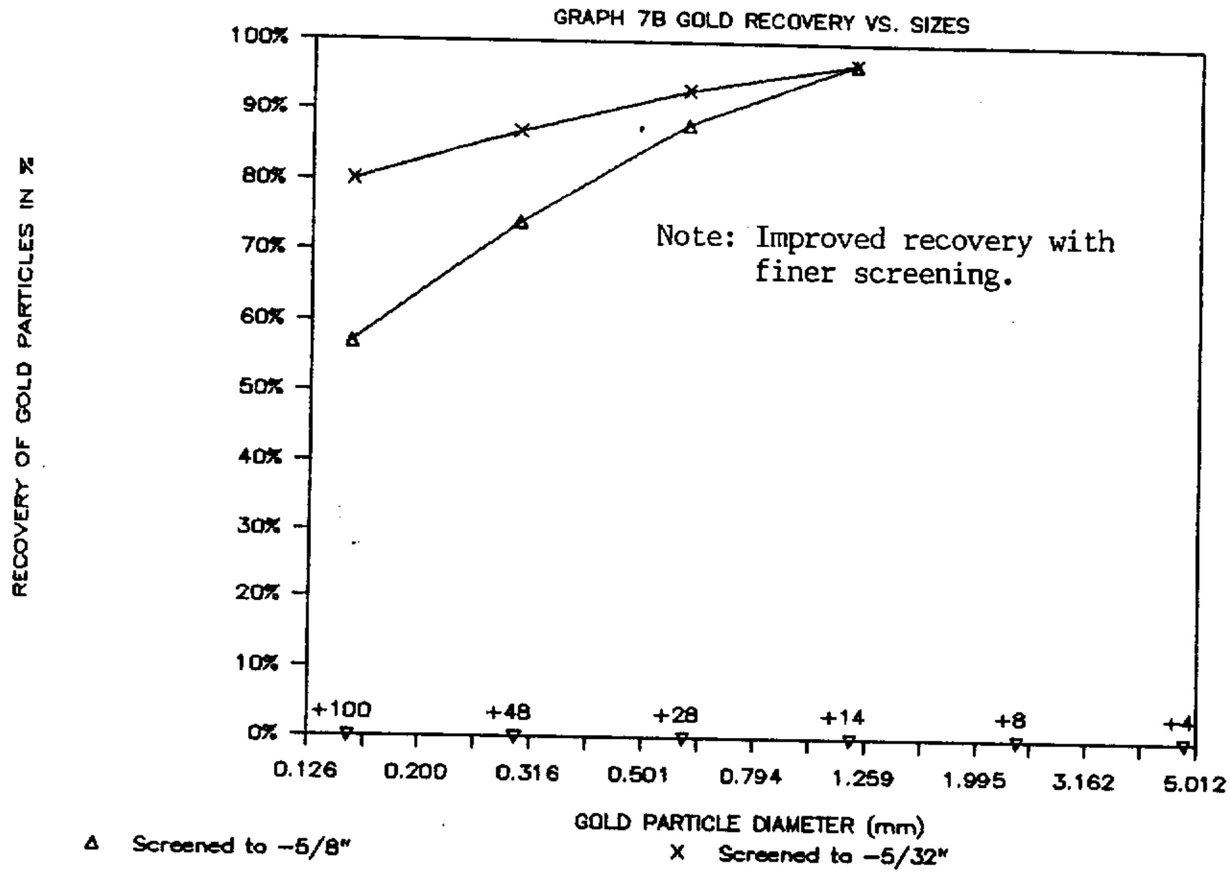
GRAPH 6D GOLD RECOVERY VS. SIZE



GOLD RECOVERY AT SITES SAMPLED IN 1988

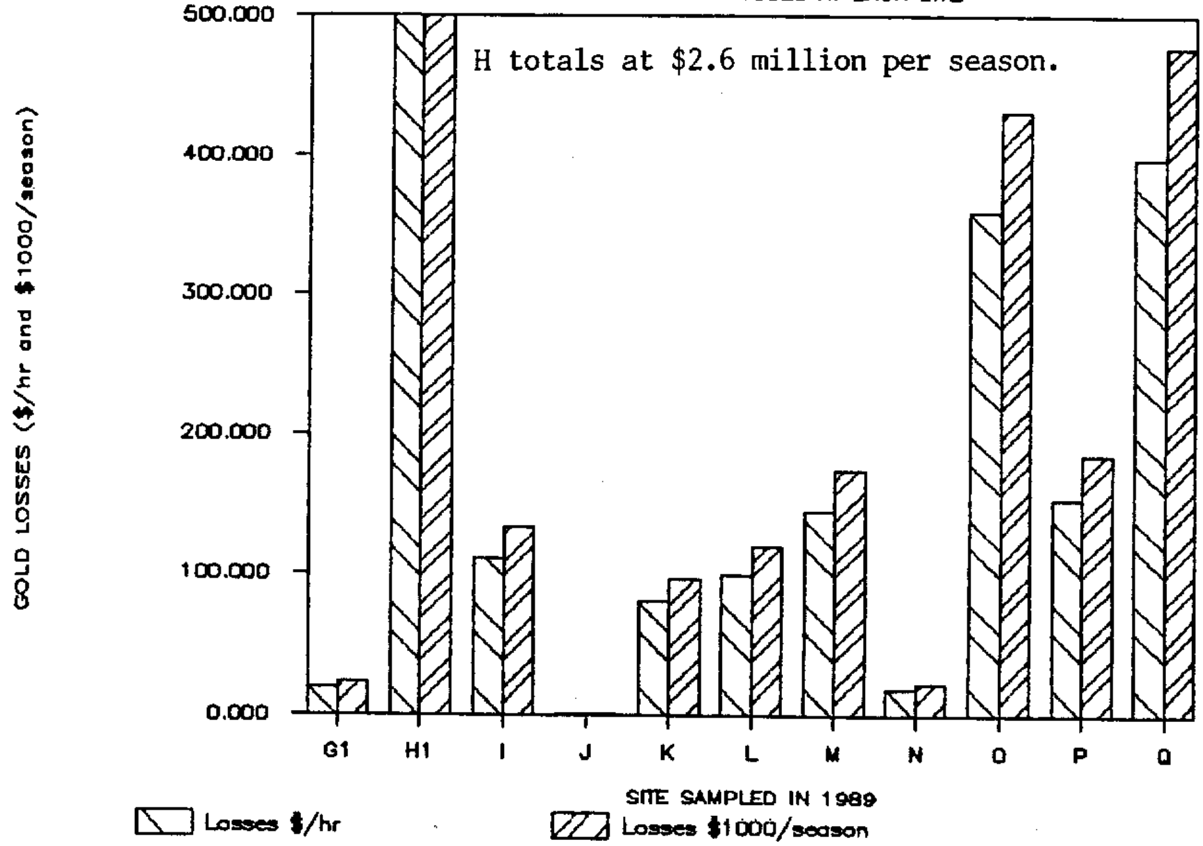


GOLD RECOVERY FROM SOVIET LITERATURE



VALUE OF GOLD LOSSES

GRAPH 8 GOLD LOSSES AT EACH SITE



VALUE OF RECOVERABLE GOLD LOSSES

GRAPH 9 RECOVERABLE GOLD AT EACH SITE

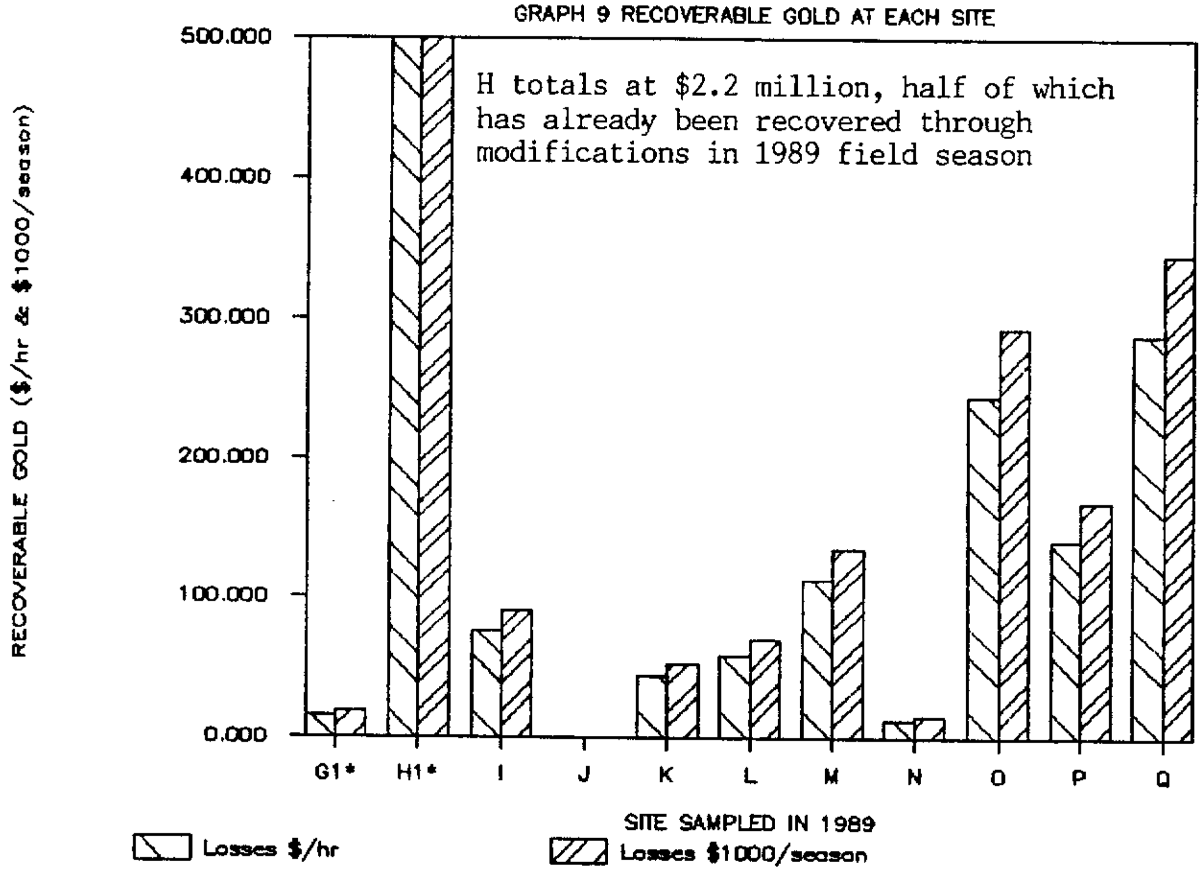


Table 1
A Comparison of Standard Sieve Sizes

Tyler mesh	National Bureau of Standards inches	A.S.T.M. Sieve Opening mm	A.S.T.M. Sieve Opening inches
	4	101.60	4.00
	3	76.10	3.00
	2	50.80	2.00
	1	25.40	1.00
	3/4	19.00	0.75
	1/2	12.70	0.50
1/4	1/4	6.35	0.25

Tyler mesh	N.S.B. number	A.S.T.M. open mm	inches
3		6.730	0.2650
4	4	4.760	0.1874
6	6	3.360	0.1323
8	8	2.380	0.0937
10	12	1.680	0.0661
14	16	1.190	0.0469
20	20	0.841	0.0331
28	30	0.595	0.0234
35	40	0.420	0.0165
48	50	0.297	0.0117
65	70	0.210	0.0083
100	100	0.149	0.0059
150	140	0.105	0.0041
200	200	0.074	0.0029
270	270	0.053	0.0021
400	400	0.037	0.0015

Table 2
Placer Mining Measurement Conversions

WEIGHT EQUIVALENTS

Milligram mg	Gram g	Kilogram kg	Pound lb	Metric Tonne t	Short Ton ton
1	0.001	1.000E-06	2.205E-06	1.000E-09	1.102E-09
1000	1	0.001	0.002205	0.000001	1.102E-06
1000000	1000	1	2.205	0.001	0.001102
453600	453.6	0.4536	1	0.0004536	0.0005
1.0E+09	1000000	1000	2205	1	1.102
9.1E+08	907200	907.2	2000	0.9072	1

LENGTH EQUIVALENTS

Micron u	Millimeter mm	Meter m	Inch "	Foot '	Yard yd
1	0.001	1.000E-06	3.937E-05	3.281E-06	1.094E-06
1000	1	0.001	0.03937	0.0032808	0.001094
1000000	1000	1	39.37	3.2808	1.094
25400	25.4	0.0254	1	0.08333	0.02778
304800	304.8	0.3048	12	1	0.33333
914400	914.4	0.9144	36	3	1

VOLUME EQUIVALENTS

Milli-liter ml	Liter l	Cubic Meter m3	U.S. Gallon USg	Imperial Gallon g	Cubic Yard yd3
1	0.001	0.000001	0.0002642	0.0002200	0.0000013
1000	1	0.001	0.2642	0.2200	0.001308
1000000	1000	1	264.2	220.0	1.308
3785	3.785	0.003785	1	0.8327	0.004951
4546	4.546	0.004546	1.201	1	0.005946
764600	764.6	0.7646	201.99	168.19	1

FLOWRATE EQUIVALENTS

Liter/second l/s	Cubic Meter/second m3/s	U.S. Gallon/minute USgpm	Imperial Gallon/minute gpm	Cubic Feet/second cfs
1	0.001	15.85	13.20	0.03531
1000	1	15851	13198	35.31
0.06309	0.00006308	1	0.8327	0.002228
0.07577	0.00007576	1.201	1	0.002676
28.32	0.02832	448.9	373.8	1