

# **Placer Gold Recovery Research**

## **Final Summary**

**Prepared for the**

**Klondike Placer Miners Association**

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**by**

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## **Dedication**

This work is dedicated to the men and women of Yukon who endured hardship and depravation in their quest for gold and who through their hard work, resourcefulness and determination have helped develop this remarkable frontier. May they continue to mine and prosper.

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## 1 SUMMARY

Sluiceboxes can provide a much higher concentration ratio than most other gravity concentrators at very high overall placer gold recoveries (as much as 99.9%, K90). They are also very reliable, inexpensive and simple to operate. This combination is very difficult to beat and explains why the sluicebox is still the most important placer gold concentrator in the Yukon.

A sluicebox is a rectangular flume containing riffles on matting, through which a dilute slurry of water and alluvial gravel flows. Sluiceboxes operating under ideal conditions are actually centrifugal concentrators whose riffles overturn ribbons of slurry to form vortices. At the bottom of these vortices, centrifugal and gravitational forces combine to drive placer gold particles into matting. The standard recommendations (section 3) which have been developed over three years of field and laboratory testing ensure sluicing conditions which optimize gold recovery.

Testing sluiceboxes with conventional sampling and evaluation techniques is very costly, time consuming and problematic. The effect of a single gold particle can cause large unpredictable errors (nugget effect) even when large sample volumes are processed with care. Nuclear tracer tests are more accurate, faster, cheaper and safer than conventional sampling. In 1989 and 1990 the recovery efficiency at several sluicing systems was determined by mixing radioactive gold particles (tracers) into the feed streams of 24 placer mines 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.

Of the mines which were tested in 1989 and 1990, ten used bulldozer-fed triple-run sluiceboxes, nine used fine screening equipment, two used Derocker moving-deck grizzlies and two used raised stationary screen decks. Two operators installed screening equipment which increased their gold recovery by 20% and three made significant modifications to their sluicing systems and increased their gold recovery by 4 to 44%.

Many of the miners tested in 1990 had already implemented recommendations from the 1989 test program including the use of unbacked Nomad matting, coarse expanded metal and one inch angle iron riffles. None were using doubled expanded metal riffles and few were using cocoa matting or Monsanto matting.

This paper presents a summary of the existing and potential gold recoveries, and recommends sluicebox designs and operating parameters based on the results of nuclear tracer testwork in 1989 and 1990, conventional sampling in 1988 and laboratory investigation in 1989/90.

## 2 CONCLUSIONS

## 2.1 OVERALL LOSSES

Overall gold losses ranged between 71 and 0 percent or from \$2.5 million (mine H) to less than \$1000 (mines G2, J and K90) per 1200 hour season (graph 12). Unscreened single and triple-run sluiceboxes were the biggest losers with average losses of \$516,000 per 1200 hour season. Sluiceboxes using Derockers or raised stationary decks for coarse (2.5 inch) screening had much lower losses averaging \$98,000 per season. The fine (minus 1 inch) screened sluiceboxes had the lowest losses of all, averaging only \$47,000 per season.

One of the triple-run boxes (H) and a single-run box (Z) lost more gold than they recovered, while three of the fine screened systems with recommended sluicebox designs (mines G2, J and K90) recovered 99% of their placer gold.

## 2.2 RECOVERABLE LOSSES

These gold losses could be reduced to a maximum of 10% (mine H) and an average of 2% by screening the pay gravels to minus one inch and modifying the sluiceboxes according to recommendations detailed in section 3. This would result in an average increase in revenue of \$210,000 per mine (graph 13). In many cases screening systems would also lower operating costs by reducing labour, water pumping and/or heavy equipment requirements.

Virtually all of the mines without screening equipment (I, L, M, O, P, U and Z) would pay back their capital investment in screening equipment in less than one season. Many others should have additional revenue in the first season of operation. The installation of screens and/or relatively minor sluicebox modifications at mines H, Q, G and K resulted in gold recovery increases of 54, 20, 3 and 4 percent respectively (graph 14).

In 1989 the overall recovery at mine H was increased from 29% to 62% (graphs 7 and 10) 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. In 1990 mine H had constructed a raised stationary screen and recommended sluice runs. Its recovery increased a further 21% to an overall total of 83%.

In 1990 mine Q constructed recommended sluice runs and a finger grizzly which screened its pay gravels to minus one inch. These changes increased its overall gold recovery from 76 to 96% while increasing its throughput by 50% (graphs 8 and 11). These two improvements will extend its mine life by allowing it to profitably mine low grade reserves it has recently delineated with auger drilling.

The sluiceboxes with screened pay gravels (A, B, G, J, K and R) had the highest recoveries but even these systems required modifications to improve their gold recovery. In 1989, the addition of one inch angle iron riffles to mine G's oscillating sluice runs increased its overall recovery from 96 to 99% (graph 6). When mine K replaced its triple-run sluicebox in 1990 with a recommended design, its overall recovery increased from 96 to 100%. Mine K's new sluicebox is much easier to clean up than its old triple-run sluicebox.

Almost all of the mines tested have or are planning to install screening equipment or construct recommended sluice runs. Mine M constructed a stationary screening platform in 1990. Mine O has purchased fine screening equipment to replace its triple-run sluicebox. Mines W and X are planning to replace their triple-run sluiceboxes with recommended designs in 1991. Mine Z intends to purchase screening equipment and modify its single-run sluicebox extensively. Both mines I and L constructed minor modifications to their sluice runs in 1990.

Estimated recovery improvements were based on comparisons between screened operations from the field research programs. There is very little 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 except for deposits with extremely fine gold.

### 2.3 SIZES AND SHAPES OF KLONDIKE PLACER GOLD

The most common gold size in the pay gravels was +0.30 mm (+48 mesh) but ranged from the finest at 0.15 mm (+100 mesh) at mine R to greater than +1.2 mm (+14 mesh) at mines V and N. The tracer testwork indicated that there is very little gold (less than 2% 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 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.

On average, the Corey Shape Factors for gold from these Yukon placer mines were fairly similar. However the gold size distribution and Corey Shape Factors in any given placer deposit were variable even within successive pits of the same deposit. There was no significant difference in the shape factors of the recovered and lost gold at 5 of the 6 mines sampled in 1988.

#### 2.4 EFFECT OF SCREENING ON GOLD RECOVERY

The data on graphs 5 to 9 clearly demonstrate the effect of screening on gold recovery. The averaged gold losses of mines with unscreened single-run and triple-run boxes were ten times higher than those with screening equipment. When pay gravels are screened before sluicing, gold recovery is improved dramatically, barren gravels are eliminated from the feed, and riffle wear is reduced. Screens also improve washing by breaking up clumps of clay and cemented particles.

#### 2.5 EFFECT OF RIFFLE TYPE AND MATTING

Coarse (10 H and 4-6 lb/ft<sup>2</sup>) expanded metal riffles are effective at recovering gold particles finer than 1 mm, however one inch angle iron riffles are required to efficiently recover gold coarser than 1 mm. Coarse gold (+1 mm) losses with expanded metal can be very dramatic as the particle size increases.

Angle iron riffles require higher water flows (320 lpm), steeper gradients (3 in/ft) and specified gaps (1.5 to 2.5 inches) and inclinations (-15 degrees) for optimum gold recovery (figures 2 to 4). One inch angle iron riffles do not tend to pack as readily as larger angle iron riffles.

Doubled expanded metal riffles are not recommended due to their susceptibility to riffle packing. Flat bar riffles are not recommended because they create extreme turbulence and deflect most of the pay gravels to the top of the slurry flow.

Unbacked Nomad matting appears to be the best matting in common use because it does not interfere with riffle operation, most of its volume is available for gold storage, it does not release entrained gold particles in a sluicebox and it is easy to clean. Cocoa matting, astro-turf and Monsanto matting are not recommended.

Stationary punch plate is a very inefficient screen and limits effective riffle action. Riffles which are located too close to punch plate are susceptible to packing and once packed are difficult to clear.



## 2.6 EFFECT OF FEED RATE ON GOLD RECOVERY

Pay gravel feed rates which exceed 100% of recommended values (8 loose cubic yards per hour per foot of sluice width for expanded metal riffles, 16 for one inch angle iron riffles) are one of the greatest factors contributing to gold losses. Water flow rates which are less than 100% of recommended values (160 lpgm/ft of sluice width for expanded metal riffles) or more than 250 % of recommended values also reduce gold recovery. These recommended rates have been confirmed in three years of field testing by Clarkson and in laboratory testing by Poling and Clarkson.

## 2.7 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.

## 2.8 HYDRAULIC RIFFLES

Hydraulic riffles consist of alternating two inch flat bar riffles and one inch square tubing which is perforated on the bottom. Low pressure water introduced into the square tubing keeps full riffles loose. Unlike conventional riffles which rely on the formation of vortices, hydraulic riffles appear to rely only on the settling velocity of gold.

Two hydraulic riffle tests at mines V and Y yielded both relatively low and high gold recoveries. The higher recovery was achieved with extremely low feed rates and water flows. These results indicate the need for more testing to determine optimum operating parameters before hydraulic riffles receive widespread application in the Yukon.

## 2.9 LIMITATIONS OF TRIPLE-RUN SLUICEBOXES

Triple-run sluiceboxes rely on the ability of their distributor's stationary punch plate to screen fine pay gravels to the side runs. Most of the water entering the distributor has 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 water and are swept off with the boulders at high speed (10-17 ft/s) down the center run.

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

Triple-run sluiceboxes fabricated with large distributors (greater than 100 ft<sup>2</sup>) which contain large holes (+3/4 inch) in their punch plate, sluice gates to control flows to the side runs, adjustable side run slopes and manually controlled wash monitors are the most efficient triple-run sluiceboxes. However, on the average, triple-run sluiceboxes lose ten times as much gold (average losses of over \$500,000 per 1200 hour season) as sluiceboxes of a recommended design using prescreened pay gravels. Almost all of the unscreened triple-run sluiceboxes tested to date would return the cost of a screening system in less than a season.

Mines H and Q increased their gold recoveries by 20% when they replaced their triple-run sluiceboxes with pre-screened sluice runs and mine Q increased its feed rate by 50%. The high volume portable screening/sluicing plant that mine Q constructed in 1990 would find wide application in the Yukon as a replacement for triple-run sluiceboxes.

Mines Q's prototype screens to minus one inch and regulates the feed rate with unmanned wash manifolds. Its screen deck can be fed directly and skidded with a bulldozer. It requires the same feed ramp and mining layout as triple-run sluiceboxes. The prototype had a number of design problems with its Super Sluice finger-grizzly. However these problems would be eliminated by replacing the finger-grizzly with a very heavy duty vibrating screen deck.

## 3 STANDARD RECOMMENDATIONS

The highest percentage gold recoveries occurred at mines which screened their feed to minus one inch, used both expanded metal and angle iron riffles on top of Nomad matting for every sluice run and fed their runs at recommended 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.

Pilot scale and field testwork (Clarkson 1989 and 1990) has indicated that sluice runs should be designed and operated at the following specifications for optimum recovery levels:

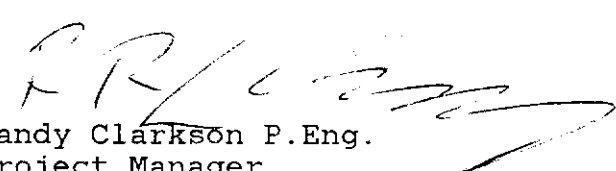
- a) Pay gravels should be prescreened to at least minus one inch, washed thoroughly prior to sluicing and feed rates should be controlled with mechanical feeders, vibrating screen decks or manually operated wash monitors;
- b) Every sluice run should have a sixteen foot long section of coarse expanded metal riffles (4-6 lbs/ft<sup>2</sup>) which is wide enough to process 8 loose cubic yards/hr/ft with at least 160 lpgm 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 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 a steeper gradient of 3 inches/foot to avoid packing. At least 360 lpgm 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 sluicebox's vertical towards the top of the box, located with a gap of 2 inches between each riffle and mounted tightly on top of Nomad matting;
- f) 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 at least four feet long should be placed in front of riffle sections to allow gold segregation in the slurry.

Mines A, G2, J and K90 demonstrated that a sluicebox can recover almost all of the placer gold in a Klondike deposit when feed control, adequate washing and fine (-3/4 inch) screening are provided to a sluicebox. Mines G2 and B 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 expand the knowledge of gold recovery at a greater variety of deposit types and recovery equipment such as hydraulic riffles.



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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 1990 research program is the development of nuclear tracing technology as a cost-effective method of determining gold losses.

## 6 GOLD RECOVERY TESTING PROCEDURES

## 6.1 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 erroneous 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. Expanded metal mesh is more efficient at recovering gold finer than 1 mm, however it may lose up to 70% of the gold coarser than 5 mm (Clarkson 1989);
- 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 estimates of 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 mine H and increased its profitability dramatically.

## 6.2 CONVENTIONAL SAMPLING

In 1988, Clarkson conducted a detailed tailings sampling program (Clarkson 1990) at six operating placer mines. He collected hundreds of tailings sample increments in duplicate from across the full width of each sluicelox discharge over a two to four day mining period. The entire volumes (2 to 7 cubic yards each) were screened and processed several times 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% to unacceptable values as high as 50% when high and/or coarse gold losses were encountered.

Testing sluiceloxes 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 small number of gold particles in a large volume of pay gravels. Sluiceloxes lose coarse gold particles and the presence or absence of one of these in a tailings sample can lead to high unpredictable errors (nugget effect). The collection of head samples is even more impractical than tailings samples due to the more frequent occurrence of coarse gold particles.

Every time conventional samples 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.

## 6.3 NUCLEAR TRACERS

In 1989 and 1990 Clarkson conducted 30 radiotracer tests at 24 placer mines. For each test, 100 placer gold particles from four size ranges (1.4, 0.72, 0.36 and 0.18 mm or +14 to +100 mesh) were irradiated in a nuclear reactor. These tracers were thoroughly mixed with pay gravels and salted into the sluicelox's feed hopper 12 to 24 hours before clean-up. At clean-up, scintillometers were used to detect the very low level X-ray and gamma ray radiation emitted by these tracers to locate them in the sluice runs.

At every mine the gravel feed rates, water flows, equipment dimensions and riffle performance were measured. After the gold tracers were removed from the final concentrate and counted, the concentrate was sieved and weighed. These gold recovery, weight and sieve data were used to calculate the quantities and size distributions of the gold particles in the original pay gravels and those lost in the tailings. The expired tracers were stored in a lead lined container until their radioactivity was near background levels (about 2 months).

The standard errors from these radiotracer tests were estimated from binomial probability theory. Each overall recovery estimate would be within one standard error of the true recovery value 14 times out of 20. The maximum standard error with 100 tracers was 5% and occurs when the recovery approached 50%. With higher recoveries, standard errors usually ranged from 2 to 3%.

Nuclear tracers have increased the scope and safety for the field testing of sluiceboxes while reducing errors, costs and evaluation times dramatically. 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 are irradiated to extremely low levels and create personal exposure levels several times lower than nuclear industry standards.

Each 1990 radiotracer test was only 10% of the cost of a conventional tailings sampling test carried out in 1988. 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 concerns about tampering. The tracers can be readily identified with a scintillometer and are available only to licensed agents.

#### 6.4 LABORATORY ANALYSIS OF RIFFLE PERFORMANCE

During the winter of 1989/90, a pilot scale testing facility was constructed at the Yukon College in Whitehorse. It used a gravel pump and cyclone to continuously cycle -1/2 inch placer gravels through an 8 foot by 6 inch wide sluice run. The sluice run was constructed with Plexiglas sides to allow visual interpretation. Several sizes, types, spacings and orientations of riffles were tested under a variety of feed rates, water rates and sluice run slopes to determine the optimum scour and deposition patterns.

Once the optimum conditions had been observed, the feed was salted with irradiated gold particles to confirm the riffle's effectiveness. In addition, the effects of Monsanto matting, suspended punch plate and the screening efficiency of stationary punch plate were also investigated.



## 7 DISCUSSION

## 7.1 PLACER MINING

Yukon placer mines 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. Most placer mining areas in the Yukon are in continuous permafrost and the barren overburden and/or organic "black muck" must be stripped off with bulldozers and the ground 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.

## 7.2 THE SLUICEBOX

The sluicebox has been used for the recovery of placer gold since ancient Greece (Jason's golden fleece) and it is still the most important placer gold concentrator in the Yukon. Sluiceboxes provide a much higher concentration ratio than most other gravity concentrators such as jigs and spirals. Sluices are also very reliable, inexpensive and simple to operate.

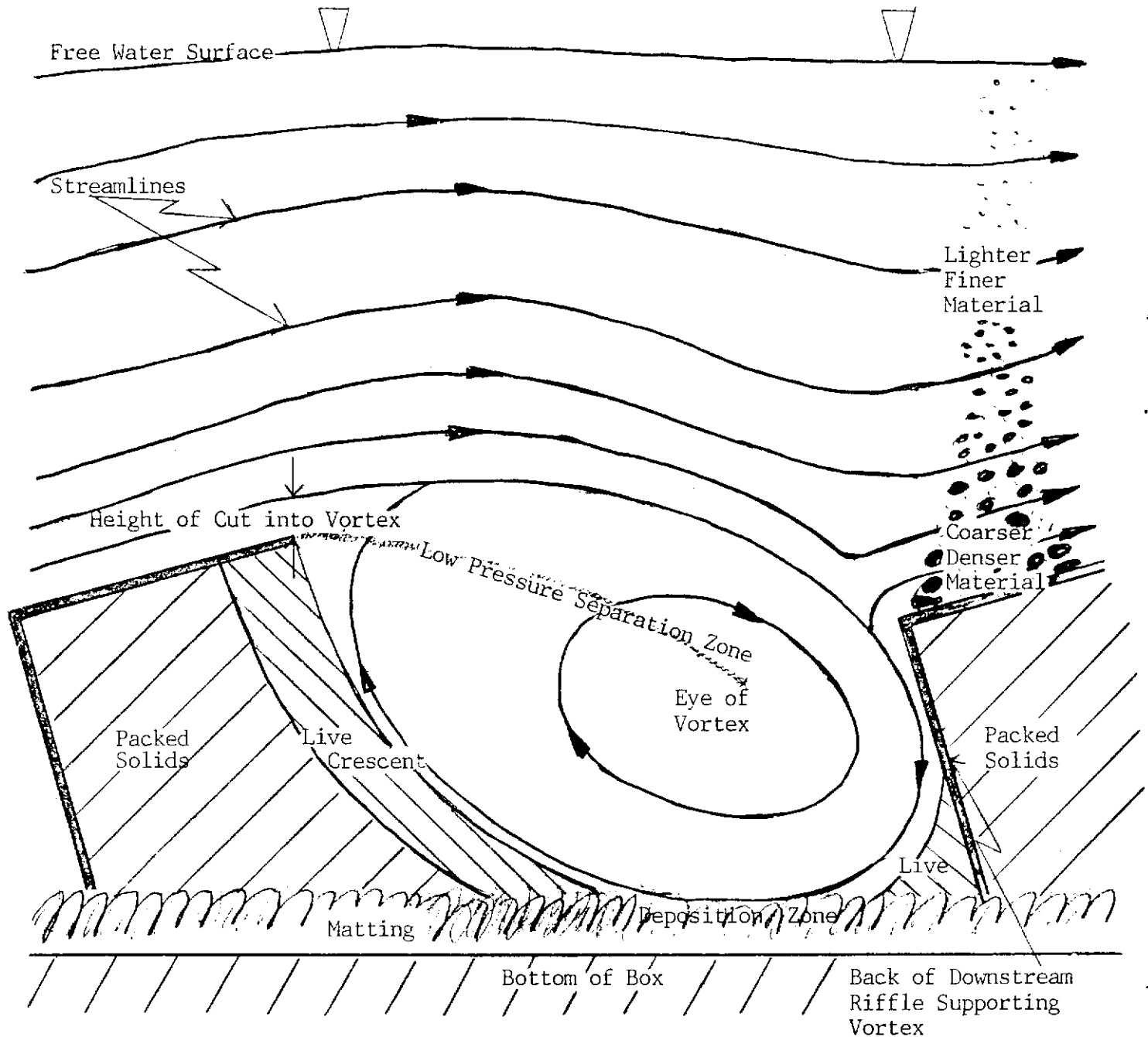
A sluicebox is a rectangular flume containing riffles through which a dilute slurry of water and alluvial gravel flows. The most common sluice riffles include expanded metal, angle iron (Hungarian) and flat bar. Matting is usually placed under the riffles to help retain the gold particles. To remove the gold concentrates, sluiceboxes are shut down and the riffles and matting are taken apart and cleaned.

## 7.3 GOLD RECOVERY MECHANISM

Previous researchers disagreed on the exact mechanism of gold recovery in a sluicebox but most related it to settling velocity (Peterson, MacDonald). Sluiceboxes are actually centrifugal concentrators and settling velocity plays a minor role in the gold recovery mechanism of a riffle. Gold's greater settling velocity allows a gold particle to descend to the bottom of the slurry column where it is preferentially cut into the streamline feeding a riffle's vortex (figure 1).

As the segregated slurry flow approaches the open space between the riffles it encounters a low pressure zone which draws a ribbon of the slurry column down into the riffle. Under ideal conditions, this ribbon of slurry will be overturned as it flows down the rear of the following riffle and will continue flowing in a circular path to form a vortex.

FIGURE 1 DETAILED CROSS SECTION OF RECOVERY MECHANISM



The energy of this vortex is derived from the velocity of the slurry above the riffle and is slowly reduced due to friction as it flows down the back of the riffle, across the matting and up the live sorting crescent in its oval path. The gold contained in the streamline is driven by centrifugal force to the outside of the vortex. At the bottom of the vortex, centrifugal and gravitational forces combine to drive the gold particles into (or through) the matting.

If a gold particle cannot enter the matting it continues to a crescent of loose gravels which are continually being sorted by the reduced upward velocity of the vortex. Lighter weight particles continue flowing up and along the surface of this crescent and are ejected into the slurry flow above the vortex. Gold and heavier minerals which were not previously driven into the matting tend to remain near the bottom and inside of this sorting crescent.

When a sluicibox is shut down the sorting crescent slumps into the area previously occupied by the vortex. This material is very well washed, loose and composed of heavier minerals. The volume under the riffle's horizontal lip which is not occupied by the vortex and sorting crescent is comprised of packed mineral particles which rarely contain gold. Gold particles are usually unable to penetrate into the packed solids under a riffle or under a raised vortex.

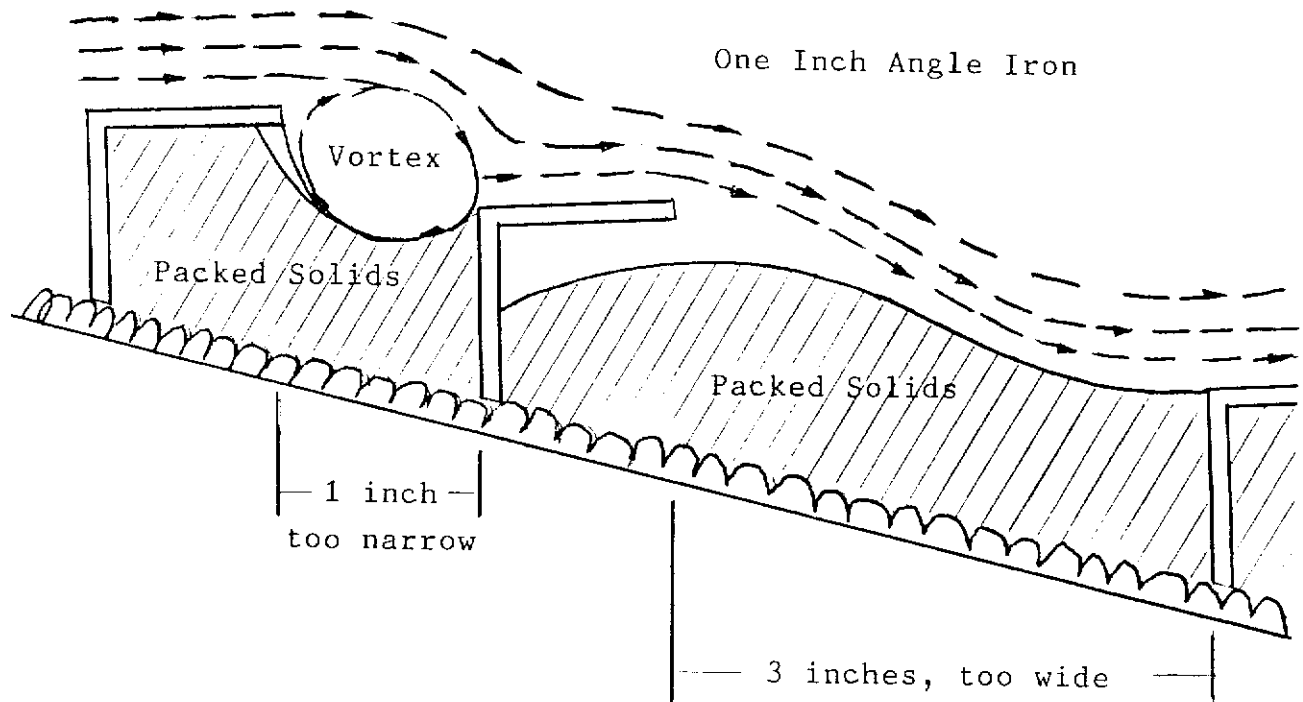
The slurry velocity provides the energy which powers the vortex. If the velocity of the slurry is reduced through overloading with solids, insufficient water flow or shallow gradients it may not sustain a vortex. If the riffles are too close, too far apart, too tall, or if there is not enough energy available to the vortex, the vortex will not be formed properly.

#### 7.4 RIFFLE SPACING

If the riffles are located too close, there is not a long enough contact between the slurry flow and the vortex to transfer the required energy. Under these conditions, the backside of the downstream riffle will begin to collect material and the bottom of the vortex will rise off the mat and isolate the gold concentrating vortex from the matting (figure 2). When the riffles are spaced too far apart, the streamline which is drawn down into the riffle is not overturned and continues up and over the back of the next riffle. Under these conditions the space between the riffles fills up to form a shallow depression. Gold which is deposited in this depression is very sensitive to loss from scouring (figure 3).

FIGURE 2 RAISED VORTEX

FIGURE 3 WIDE RIFFLES



In a typical sluicing environment the maximum sized vortex which can be sustained is approximately one inch in diameter. If the riffles are taller than one inch, then the vortex will readily rise off the mat and pack the riffles with material.

#### 7.5 RECOMMENDED FEED RATES

Poling recommended pay gravel feed rates of 8 loose cubic yards/hr and water flow rates at 160 Igpm per foot of sluice width. Field experience in 1989 and 1990 indicates that this feed rate should not be exceeded for expanded metal riffles but can be doubled for angle iron riffles. Water flow rates were less critical and could range from a minimum value of 160 Igpm/foot (angle iron riffles require at least 320 Igpm/foot) and can be increased up to 2.5 times without gold loss.

Pay gravel feed rates which exceed 100% of recommended values are one of the greatest factors contributing to gold losses. Pay gravel feed rates below 100% of recommended values may improve gold recovery slightly.

## 7.6 ANGLE IRON RIFFLES

Clarkson recommended the use of angle iron riffles to retain gold particles coarser than 1 mm (14 mesh) and expanded metal riffles to retain gold finer than 1 mm (Clarkson 1989). Angle iron riffles required much steeper slopes (3 inches/ft), higher water flow rates (at least 320 lpgm per foot of width) and can tolerate higher feed rates (16 loose cubic yards/ft of sluice width) than expanded metal riffles. Modified one inch angle iron riffles (top leg reduced from 1 to 1/2 inch in length) and ordinary one inch angle iron riffles were the most consistently efficient coarse riffles. The modified riffle had a much smaller deposit of packed gravels and therefore higher proportion of clear matting because of its shorter top leg (figure 4).

Regular or modified angle iron riffles should have a two inch gap and be tilted at 15 degrees upstream of the sluicebox's vertical in a sluice run with a slope of 3 inches/foot. The riffles have better performance at this steep slope because the increased slurry velocity provides more energy for the vortex. The efficiency of the vertically aligned riffles is slightly lower.

## 7.7 FLAT BAR RIFFLES

Flat bar riffles are not recommended for the recovery of gold particles smaller than 2.4 mm (8 mesh) because they create excessive turbulence and reduce the vertical segregation of gold particles. The material rejected by a flat bar's vortex is launched up to the top of a turbulent slurry column instead of on to the next riffle. This severely reduces the opportunity for gravels and anything except very coarse gold nuggets to enter the riffles. Flat bar riffles may be suitable for a coarse (+1/2 inch) nugget trap, however more research would be required to confirm this application.

## 7.8 EXPANDED METAL RIFFLES

Expanded metal riffles are recommended (Clarkson 1989) to retain gold particles finer than 1 mm (14 mesh). Expanded metal riffles create vortices similar to those in the angle iron riffles but they cut a shorter height of the slurry column into their vortices (figure 5). Due to its small size and shallow live sorting crescent, the expanded metal riffle is very sensitive to changes in slurry density such as those caused by surging.

FIGURE 4  
MODIFIED ANGLE IRON RIFFLES

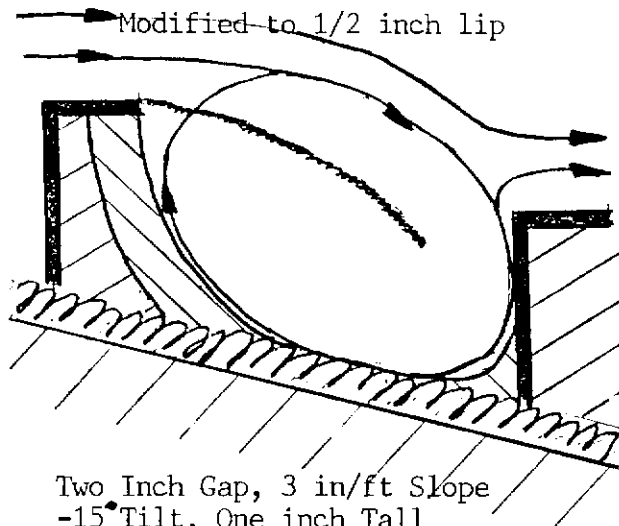
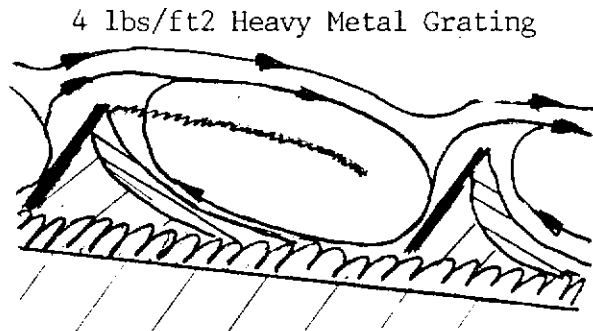


FIGURE 5  
EXPANDED METAL RIFFLES



Therefore expanded metal riffles require lower feed rates (8 loose cubic yards/hr per foot of sluice width) and shallower gradients (1.5 to 2.5 in/ft) than angle iron riffles. Expanded metal riffles must be kept tight to the matting to prevent high gold losses caused by excessive scour above the matting (i.e. use heavy weight expanded metal [4 to 6 lb/ft<sup>2</sup>] and flip over warped sections at each cleanup).

Doubled expanded metal riffles are not recommended because the bottom layer of expanded metal fills up and hardens with use. This prevents the gold particles from penetrating into the matting and makes the riffles even more sensitive to surging than single expanded metal riffles. When the doubled sections were separated with a 3/8 inch bar, the space eventually became clogged with gravels or they created erratic hydraulic patterns which lowered recovery.

#### 7.9 MATTING

Unbacked Nomad matting appears to be the best matting in common use because it does not interfere with vortex formation, most of its volume is available for gold storage, it does not release entrained gold particles in a sluicebox and it is easy to clean. Cocoa matting and Astro Turf are not recommended because of their limited storage capacity and difficulty in cleaning. Monsanto matting is not recommended because its bottom sections pack hard and its long needles protrude between the expanded metal riffles and disrupt the formation of regular large vortices.

## 7.10 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 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 between and above the sluice runs and rotates a weighted bent shaft through an angle drive. The motor-drive combination creates 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 have a tendency to pack riffles because conventional sluiceboxes have higher gold recoveries when processing normal pay gravels.

## 7.11 HYDRAULIC RIFFLES

Hydraulic riffles have recently been introduced into the Yukon from New Zealand. These riffles consist of alternating two inch flat bar riffles and one inch square tubing perforated on the bottom. Low pressure water is introduced into the square tubing from a manifold on the side. The pressure of the water must be controlled so that it keeps the riffles loose but does not eject fine gold particles (about 10 psi). Even with a screened water intake, the manifolds and tubing must be cleaned periodically to ensure that water flows evenly throughout the riffles.

At mine Y, gold recovery was relatively high. Its hydraulic riffles operated with feed rates and water flows at less than half of recommended values for conventional riffles. The riffles remained full and relied on settling velocity to lower gold particles through the low velocity water flows into the loose bed of material. Its hydraulic riffles did not develop the scouring vortices common to conventional riffles and therefore required a trommel scrubber unit to ensure that gold particles were washed free of clays and other waste minerals. Matting was not used and was probably unnecessary due to the absence of turbulence in the tall riffles.

Mine V used a trommel screen but had very low gold recovery with hydraulic riffles. This low recovery occurred even though its feed and water addition rates were at recommended values (for conventional riffles) and the riffles remained loose. This extreme variability in gold recovery for two very similar systems indicate the need for detailed testing to determine the optimum operating parameters for this type of riffle.

## 7.12 PUNCH PLATE

Stationary punch plate is not recommended because it is a very inefficient screen and it reduces the velocity of the slurry above the riffles. Its efficiency is even lower at steeper (3 in/ft) slopes and/or high slurry velocities. Sections of punch plate shorter than two feet (in common use) are almost completely useless.

If punch plate is too close to riffles, the slurry velocity becomes too slow to power a vortex and the riffles will fill and pack. Riffles located below punch plate are much more sensitive to changes in slurry velocity and once filled (i.e. due to surging), take a long time to clear. It is impossible to check how well the riffles are operating when they are located below punch plate.

## 7.13 TRIPLE-RUN SLUICEBOXES

Several large Yukon placer operations use triple-run sluiceboxes consisting of some combination of a slick plate, dump box recovery area, distributor, center run, undercurrent run and side runs (figure 6). 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.

Triple-run sluiceboxes rely on the ability of their distributor's stationary punch plate to screen and distribute fine pay gravels to the side runs. Most of the water entering the distributor has to stay above the punch plate to push large rocks along. Fine pay gravels and gold are inevitably trapped in these turbulent excessive water flows (300% to 600% of recommended values) and are swept down the center run with the boulders at high speed (10 to 17 ft/s).

Distributors are often too small (less than 100 ft<sup>2</sup>), are fitted with punch plates with small holes (less than 3/4 in) and pass the slurry over at very high velocities. These distributors are often so inefficient that they reduce gold recovery by underutilizing the side runs (7-70% of recommended values) and overloading the center run with boulders and fine pay gravels (300-700% of recommended values). Additional gold losses occur in the center runs when rocks are wedged between the riffles and disrupt proper vortex formation in the riffles.

The short sections of punch plate which are installed in some center runs to direct fine gravels to an undercurrent run are even less effective. The center runs have to be completely dismantled before an undercurrent can be cleaned, and consequently are not cleaned as often as they should be. It is also impossible to observe the riffle action and adjust the slope of an undercurrent run.



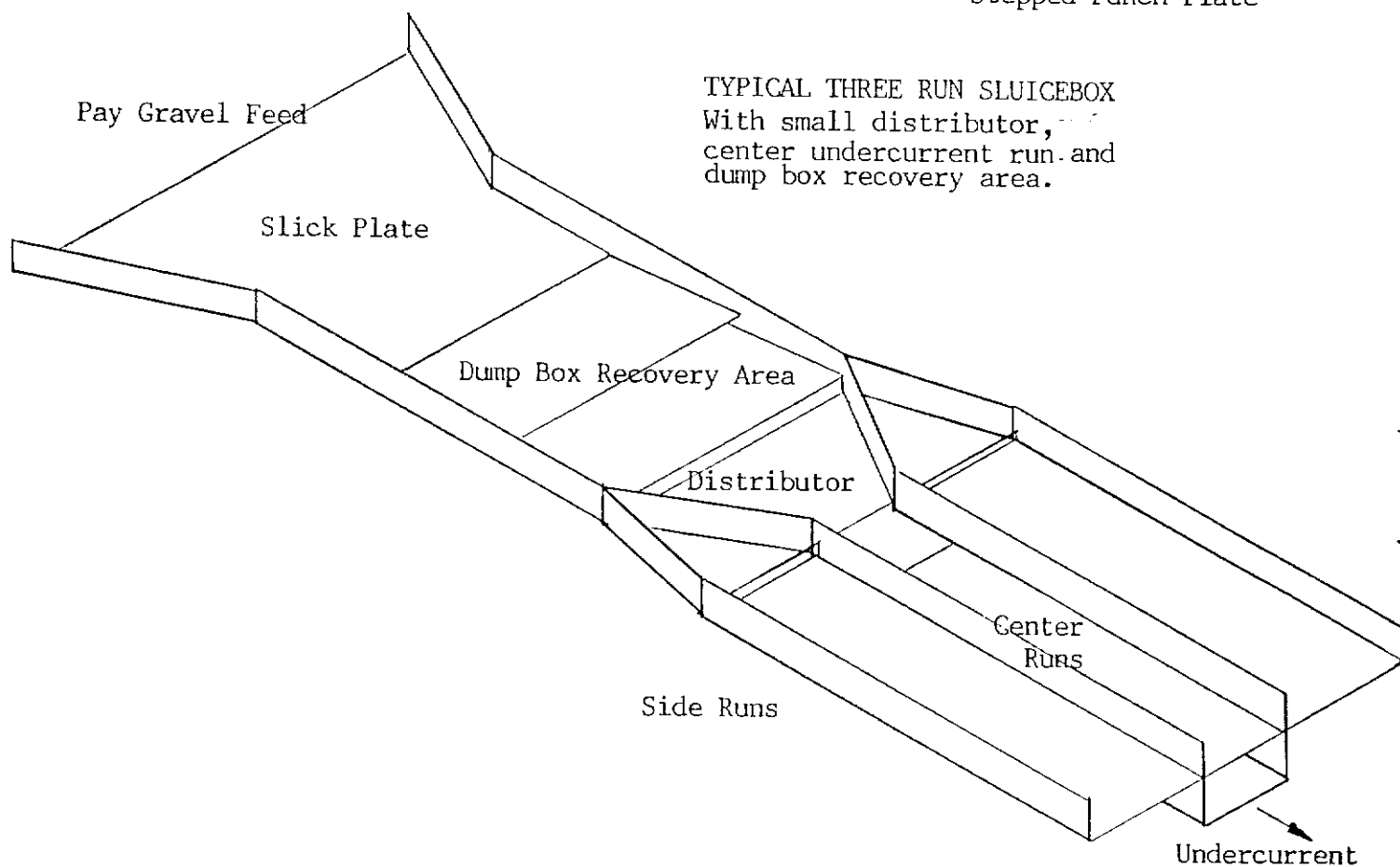
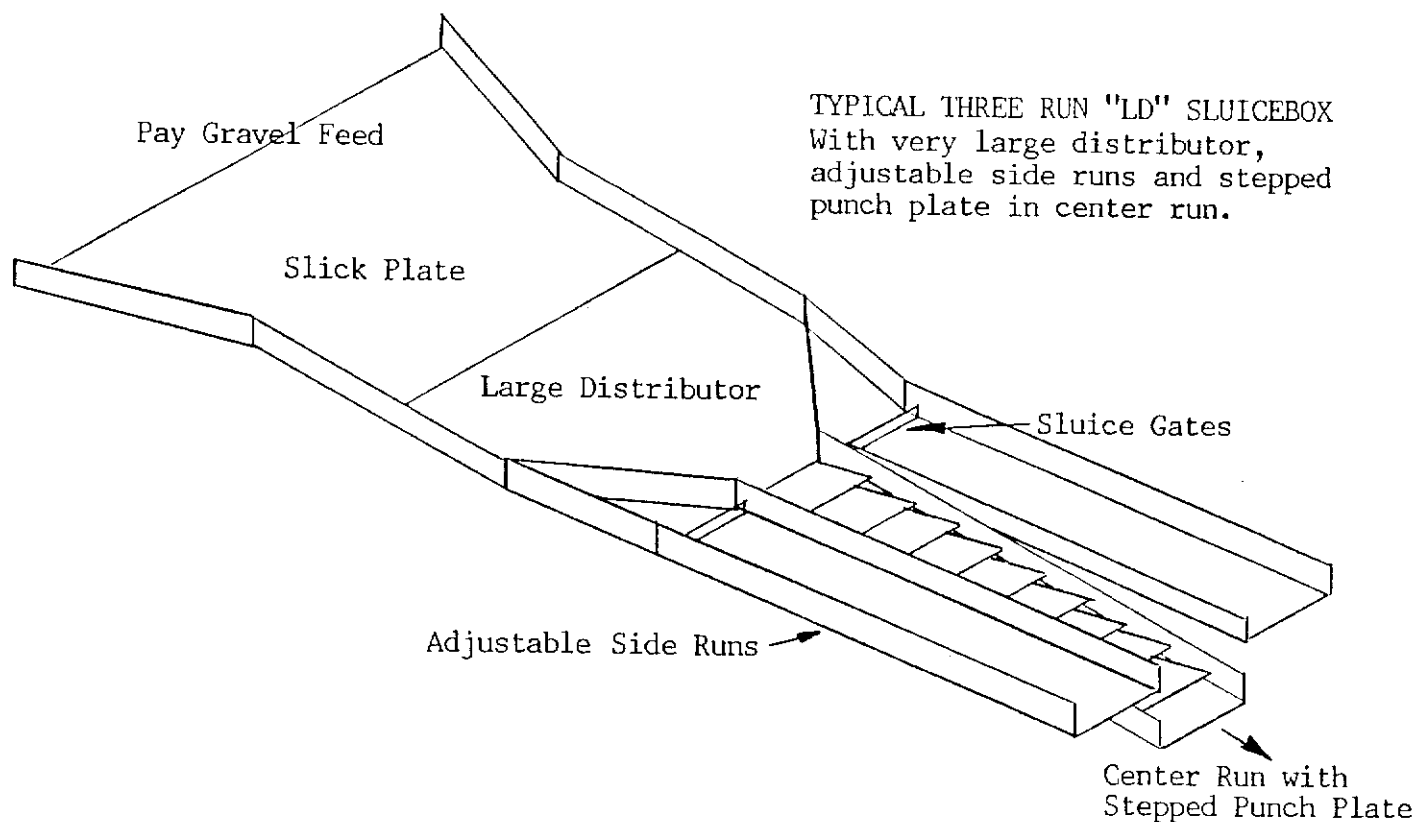
Some mines (M, O, P, Q, O90, W and X) improved their gold recovery significantly by installing riffles under punch plate in the dump box area in front of their inefficient distributors. At mines O, P, Q, W and X the dump box's undersize gravels were not distributed to the side runs but were discharged back on top of the distributor to be screened once again. The heavy sections of punch plate above the riffles in a dump box had to be raised before its riffles and matting could be cleaned.

The mines using the Ross Box (mines K, O, P, O90, W and X) had their side runs fixed at the same steep slopes as the center run, underflow and dump box recovery area. The operators attempted to control pay gravel and process water flows to the side runs by blocking or opening holes in the punch plate distributor. It was virtually impossible to control the allocation of water and pay gravels to the various runs if the gravel sizes changed with depth or from pit to pit.

In a Pearson Rock Box (mine U) and the homemade "LD" boxes (large distributor, mines H, I, L and T), the allocation of water to the various runs was more easily controlled with sluice gates located at the distributor's discharge. These mines also were able to adjust their side run slopes to optimize riffle performance. The "LD" boxes also had a much larger punch plate distributor and a manned wash monitor. This combination resulted in more efficient screening and helped to control pay gravel surging.

The other homemade triple-run sluiceboxes had features from both the Ross and Pearson sluiceboxes. The homemade sluicebox at mine M had a stationary four inch grizzly, a large dump box gold recovery area and side runs with fixed slopes. Mine Q's homemade sluicebox had a gold recovery area in the dump box and adjustable side runs.

FIGURE 6 COMPONENTS OF A TRIPLE-RUN SLUICEBOX



## 7.14 PRE-SCREENING

When pay gravels are screened before sluicing, gold recovery is improved dramatically, much less water is required for sluicing, barren gravels are eliminated from the sluicebox feed and riffle wear is significantly reduced. Pre-screening eliminates the need for a triple-run box and the corresponding problems in allocating fine gravels and water to the various sluice runs.

Screens also improve washing by breaking up clumps of clay and cemented particles. Inadequate washing is a very common cause of gold losses. When triple-run boxes are replaced with pre-screened sluiceboxes constructed in accordance with the recommendations in Section 3 (i.e. mine K and Q) these capital costs are usually recovered within the first mining season and often in a few weeks of operation.

The Derocker is a well known and reliable moving deck grizzly-feeder which does a good job of washing and rejecting coarse boulders. It can be fed with a dozer providing additional wings are added to its entrance. Its main limitation is its feed rate (generally less than 150 loose cubic yards/hour) and its coarse undersize (2.5 inch).

Trommel screens are very good at scrubbing pay gravels but can be large and relatively inefficient screening devices. The feed rate must be controlled with a manned monitor or by short feeding cycle times. Large boulders must be sorted out of the feed to reduce impact damage. The long gradient required of a trommel screen also requires high feed ramps.

A vibrating screen has a higher throughput, lower height requirements and lower capital costs than a trommel. Two or three decks can be stacked on top of each other and result in very efficient, high volume screening. Very large boulders should be sorted from the feed or removed by stationary grizzlies constructed above a hopper. Mine Q90 constructed a very efficient, high volume, portable sluicebox which is fed directly with a bulldozer. This prototype could be fitted with a vibrating screen deck.

Super Sluice finger grizzly-feeders are not recommended for high volume applications due to their low throughput (100 loose cubic yards/hour) and the extensive down time experienced at mine Q90. The design of the hydraulic controls and the layout of the grizzly bars required extensive modifications at mine Q90. Other mines with lower throughputs have reported low operating costs and satisfactory service with a Super Sluice.

## 8 CALCULATIONS

## 8.1 SCREENING EQUIPMENT

The following is a brief tabulation of the screening equipment at each of the mines. Mine Z used a bulldozer fed single-run sluicebox. Several other mines used different homemade and manufactured versions of triple-run boxes including the homemade "LD" (or large distributor) boxes with sluice gates and adjustable side runs. Mines H90 and W used raised stationary screening platforms lined with punch plate. Mines D, N and X used Derocker moving-bed grizzly-feeders while mine Q90 used a moving finger-grizzly. Mines B, S, V and Y used rotary trommel screens and mines A, G, J, K and R used vibrating screens.

TABLE 8.1 SCREENING EQUIPMENT

	Single Run	Homemade Triple		Homemade "LD" -----Triple Run-----				Pearson Triple
DISTRIBUTOR	Z	M	Q	H	I	L	T	U
Length ft	None	12	8	12	10	14	11	6
Area ft <sup>2</sup>		100	41	133	105	96	149	63
Slope in/ft		2.9	2.6	3.7	2.8		3.8	3.5
Opening in		0.5	0.75	0.5	0.5	0.5	0.5	0.5
Efficiency*		34%	69%	79%	75%	64%	61%	62%

	Ross Box -Triple Run--			Stationary --Decks--		---Derocker---			Finger Grizzly
DIST/GRIZZLY	O	O90	P	H90	W	D	N	X	Q90
Length ft	6	8	6	8	15	18		20	12
Width (Dia) ft	12	12	10	18	13	10		14	8
Area ft <sup>2</sup>	49	97	43	88	203	182		280	96
Slope in/ft	2.5	2.7	2.8	3.0	5.7			2.5	-0.5
Opening in	0.5	0.5	0.5	0.5	2.0	2.5	2.5	2.0	1.0
Efficiency*	39%	62%	14%	92%	95%	100%	100%	100%	100%

	--Rotating Trommel--				---Vibrating Screen Decks---					
SCREENS	B	S	V	Y	A	G	J	K	K90	R
Length ft	4	24	18		4	8	12	12	12	12
Width (Dia) ft	4	5	4		5	8	7	5	5	4
Area ft <sup>2</sup>	N/A	N/A	N/A	N/A	20	63	83	57	57	48
Opening in	1.00	0.50	1.4	0.5	0.19	0.75	0.39	0.75	0.75	0.38
Efficiency*	100%	100%	98%	100%	100%	100%	100%	100%	100%	100%

Notes: \* Efficiency refers to the proportion of -1/4 inch gravels which got through a screen. The operator at mine O90 effectively enlarged his distributor by keeping more of the gravels screened in the dump box recovery area under his distributor. The manually monitored "LD" triple-run boxes had much higher screening efficiencies than other triple-run boxes. Screening efficiency also increases with the size of the distributors. The stationary decks were fairly efficient screens but were not as good at washing pay gravels and regulating feed as conventional screens and grizzly-feeders.

## 8.2 SLUICING EQUIPMENT

The following is a brief tabulation of the layout of the sluicing equipment at each of the mines.

TABLE 8.2 SLUICING EQUIPMENT

	Single Run	Homemade Triple		Homemade "LD" -----Triple Run-----				Pearson Triple
	Z	M	Q	H	I	L	T	U
SLUICE RUNS				20	20	18	22	24
Length ft	45	28	32	219	222	209	224	237
Area ft2	196	293	395	CO	NM	NM	NM	NM
Matting Type	CO/NM	NM	NM	No	No	No	No	No
DumpBox Riffle	EX	No	EX	DE	EX	DE	EX	EX
Center Riffle	EX/AN	AN	AN/EX	3.5	2.8	3.4	3.0	2.3
Center Slope	4.0	2.9		No	No	No	No	No
Under Riffles	No	EX	No	DE	EX	DE	EX/AN	EX/AN
Side Riffles	No	DE	EX	2.6	1.9	2.0	1.8	1.3
Side Run Slope	No	2.9	1.2	22	23	29	32	17
Conc. Ratio	8	8	37					
(x 1000)								

	Ross Box -Triple Run--			Stationary --Decks--		---Derocker---			Finger Grizzly
	O	090	P	H90	W	D	N	X	Q90
SLUICE RUNS				23	29	30	17	30	21
Length ft	33	31	25	216	222	200	100	200	203
Area ft2	474	489	397	NM	UN	BELT	CO	UN	UN
Matting Type	MO	NM/MO	MO	No	AN	No	No	AN	No
DumpBox Riffle	MO	EX/AN	MO	FB	AN	No	FB/ANAN/EX	No	No
Center Riffle	FB	EX/FB	FB	4.1	2.4	No	2.5	1.9	No
Center Slope	2.7	2.7	2.9	No	EX	No	EX/ANEX/AN	No	No
Under Riffles	MO	EX	MO	EX/ANEX/AN		EX/AN	No	EX/ANEX/AN	
Side Riffles	MO	EX/ANEX/MO		1.8	2.4	1.5	No	2.5	2.0
Side Run Slope	2.7	2.7	2.8	7	8	N/A	N/A	21	2
Conc. Ratio	48	12	N/A						
(x 1000)									

	--Rotating Trommel--				---Vibrating Screen Decks---					
	B	S	V	Y	A	G	J	K	K90	R
SLUICE RUNS					15	20	59	17	30	20
Length ft	24	40	16	8	27	120	1013	276	340	236
Area ft2	172	349	54	86	NM	NM	NM	UN	UN	NM
Matting Type	NM	NM/CO	NM	No	No	No	AN	No	No	No
DumpBox Riffle	No	No	No	No	No	No	No	EX/AN	No	No
Center Riffle	No	No	No	No	No	No	No	1.5	No	No
Center Slope	No	No	No	No	No	No	No	EX	No	No
Under Riffles	No	No	No	No	No	No	No	EX	AN/EX	EX
Side Riffles	OS/EX	EX	HY/EXHY/FB		EX	OS	EX	EX		
Side Run Slope	1.1	1.5	2.4	1.5	3.0	1.5	1.7	1.5	2.5	1.5
Conc. Ratio	N/A	13	8	5	N/A	23	4	35	49	21
(x 1000)										

Legend: EX - expanded metal riffles;  
AN - angle iron riffles;  
HY - hydraulic riffles;

DE - doubled expanded metal;  
FB - flat bar riffles;  
OS - oscillating expand metal

CO - cocoa matting;  
UN - unbacked Nomad matting;

NM - backed Nomad matting;  
MO - Monsanto matting.

Notes: Many of the miners tested in 1990 had implemented recommendations from the 1989 test program including the use of Nomad matting, coarse expanded metal and one inch angle riffles. There were no doubled expanded metal riffles and few using cocoa and Monsanto matting or flat bar riffles.

Both mines V and Y used hydraulic riffles and small amounts of gold (7 and 3% respectively) were recovered in the extremely overloaded (mine V) and packed riffles (mine Y) following the hydraulic riffles. The oscillating riffles used at mines B and G yielded high recoveries with the clay rich gravels which would have packed conventional riffles.

### 8.3 PAY GRAVEL FEED RATES

Pay gravel feed rates are compared to the recommended 8 loose cubic yards/hr/ft of sluice width (for expanded metal riffles). Excessive pay gravel feed rates are one of the greatest factors contributing to gold losses.

TABLE 8.3 PROPORTION OF RECOMMENDED FEED RATES

	Single Run Z	Homemade Triple M Q	Homemade "LD" -----Triple Run----- H I L T				Pearson Triple U
FEED RATE							
Total Lyd3/hr	70	132 250	240	240	142	110	170
% Recommended	254%	89% 104%	158%	177%	104%	135%	210%
% Center Run	338%	389% 675%	446%	394%	305%	336%	567%
% Undercurrent	No	59% No	No	No	No	No	No
% Side Runs	No	65% 34%	189%	203%	72%	53%	84%
Feed Surging?	Yes	Yes Mod	Mod	Mod	Mod	Yes	Yes

	Ross Box -Triple Run-- O O90 P			Stationary --Decks-- H90 W		---Derocker--- D N X			Finger Grizzly Q90
FEED RATE									
Total Lyd3/hr	250	200	100	200	196	69	70	185	200
% Recommended	134%	118%	57%	169%	85%	103%	101%	85%	76%
% Center Run	450%	468%	291%	554%	211%	No	N/A	286%	No
% Undercurrent	115%	20%	13%	No	21%	No	N/A	35%	No
% Side Runs	70%	40%	7%	41%	54%	103%	No	85%	76%
Feed Surging?	Yes	Yes	Yes	No	Mod	No	No	No	No

	--Rotating Trommel-- B S V Y				---Vibrating Screen Decks--- A G J K K90 R					
FEED RATE										
Total Lyd3/hr	57	240	69	60	28	40	40	225	218	81
% Recommended	87%	186%	100%	37%	98%	69%	7%	141%	112%	46%
% Center Run	No	No	No	No	No	No	No	317%	No	No
% Undercurrent	No	No	No	No	No	No	No	43%	No	No
% Side Runs	87%	186%	100%	37%	98%	69%	7%	174%	112%	46%
Feed Surging?	No	Min	Min	No	No	No	No	No	No	No

Notes: In triple-run boxes, the poor screening efficiency of the distributors always overloaded the center runs with water and fine pay gravels and underutilized the side runs. Surging feed rates were common with unscreened sluicing systems.

## 8.4 PROCESS WATER FLOW RATES

The following is a brief tabulation of the process water flow rates compared to the recommended 160 Imperial gpm per foot of sluice width (for expanded metal riffles). Water flows less than recommended values or greater than 2.5 times recommended values usually reduce gold recoveries.

TABLE 8.4 PROPORTION OF RECOMMENDED WATER FLOWS

WATER FLOW	Single	Homemade		Homemade "LD"				Pearson
	Run	Triple		-----Triple Run-----				Triple
	Z	M	Q	H	I	L	T	U
Total Igpm	3247	2656	5000	5000	4000	4500	5000	4774
% Recommended	451%	151%	214%	283%	222%	236%	307%	296%
% Center Run	814%	294%	627%	588%	399%	441%	756%	828%
% Undercurrent	No	114%	No	No	No	No	No	No
% Side Runs	No	81%	124%	131%	133%	134%	124%	107%

WATER FLOW	Ross Box			Stationary		Finger		
	-Triple Run--			--Decks--		---Derocker---		
	O	O90	P	H90	W	D	N	X Q90
Total Igpm	6500	6500	4000	3603	4449	1923	1500	4545 5000
% Recommended	249%	201%	183%	124%	174%	198%	162%	216% 268%
% Center Run	528%	394%	438%	193%	494%	No	189%	526% No
% Undercurrent	145%	188%	110%	No	79%	No	135%	78% No
% Side Runs	149%	138%	86%	107%	61%	198%	No	99% 268%

WATER FLOW	--Rotating Trommel--				---Vibrating Screen Decks---					
	B	S	V	Y	A	G	J	K	K90	R
Total Igpm	1089	3001	700	1078	85	1250	2834	4923	4400	2116
% Recommended	123%	173%	99%	61%	35%	129%	40%	194%	183%	110%
% Center Run	No	No	No	No	No	No	No	103%	No	No
% Undercurrent	No	No	No	No	No	No	No	224%	No	No
% Side Runs	123%	173%	99%	61%	35%	129%	40%	224%	183%	110%

Notes: 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 (mines M, O, P and Q).

Trommel Screens commonly surge more than vibrating screens.

The short sections of punch plate which directed undersize gravels to the undercurrent runs in mines O, P, and Q were almost completely ineffective.

## 8.5 SIZE DISTRIBUTIONS OF GOLD PARTICLES

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 participating mines' privacy.

TABLE 8.5 SIZE DISTRIBUTION OF GOLD PARTICLES IN PAY GRAVELS

Tyler Mesh	Single Dia mm	Run Z	Homemade Triple M Q		Homemade "LD" -----Triple Run----- H I L T				Pearson Triple U
+4	4.76								
+8	2.38								
+14	1.19	1%	33%	16%	11%	10%	10%	2%	8%
+28	0.59	13%	37%	66%	35%	32%	49%	19%	28%
+48	0.29	66%	24%	17%	43%	43%	34%	46%	44%
+100	0.14	20%	6%	2%	9%	14%	5%	29%	18%
-100		0.9%	0.5%	0.1%	0.9%	1.2%	0.7%	3%	3%
Total		100%	100%	100%	100%	100%	100%	100%	100%

Tyler Mesh	Dia mm	Ross Box -Triple Run-- O O90 P			Stationary --Decks-- H90 W		---Derocker--- D N		Finger Grizzly X Q90	
+4	4.76									
+8	2.38									
+14	1.19	34%	17%	3%	13%	40%	0%	56%	36%	25%
+28	0.59	35%	44%	18%	39%	36%	18%	31%	36%	44%
+48	0.29	22%	31%	59%	37%	20%	57%	11%	22%	23%
+100	0.14	7%	8%	17%	11%	3%	21%	1%	5%	7%
-100		0.8%	0.7%	2%	0.6%	0.4%	4%	0.1%	0.7%	0.3%
Total		100%	100%	100%	100%	100%	100%	100%	100%	100%

Tyler Mesh	Dia mm	--Rotating Trommel-- B S V Y				---Vibrating Screen Decks--- A G J K K90 R Avg					
+4	4.76										
+8	2.38										
+14	1.19	0%	6%	65%	42%	7%	40%	2%	2%	8%	0.2% 18%
+28	0.59	35%	28%	27%	50%	39%	41%	18%	25%	33%	5% 33%
+48	0.29	38%	41%	7%	8%	24%	18%	53%	58%	49%	37% 34%
+100	0.14	21%	23%	1%	0.4%	25%	1%	19%	14%	10%	47% 13%
-100		5%	2%	0.0%	0.0%	5%	0.0%	8%	0.6%	0.0%	10% 2%
Total		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Notes: There is a wide variation in the size distributions of placer gold in the Yukon. However there is usually not much gold (average of 2%) finer than 0.14 mm (100 mesh).

Mines R and Z have some of the finest gold distributions while mines V and N have the coarsest gold.



## 8.6 SIZE DISTRIBUTIONS OF GOLD FROM CONSECUTIVE TESTS

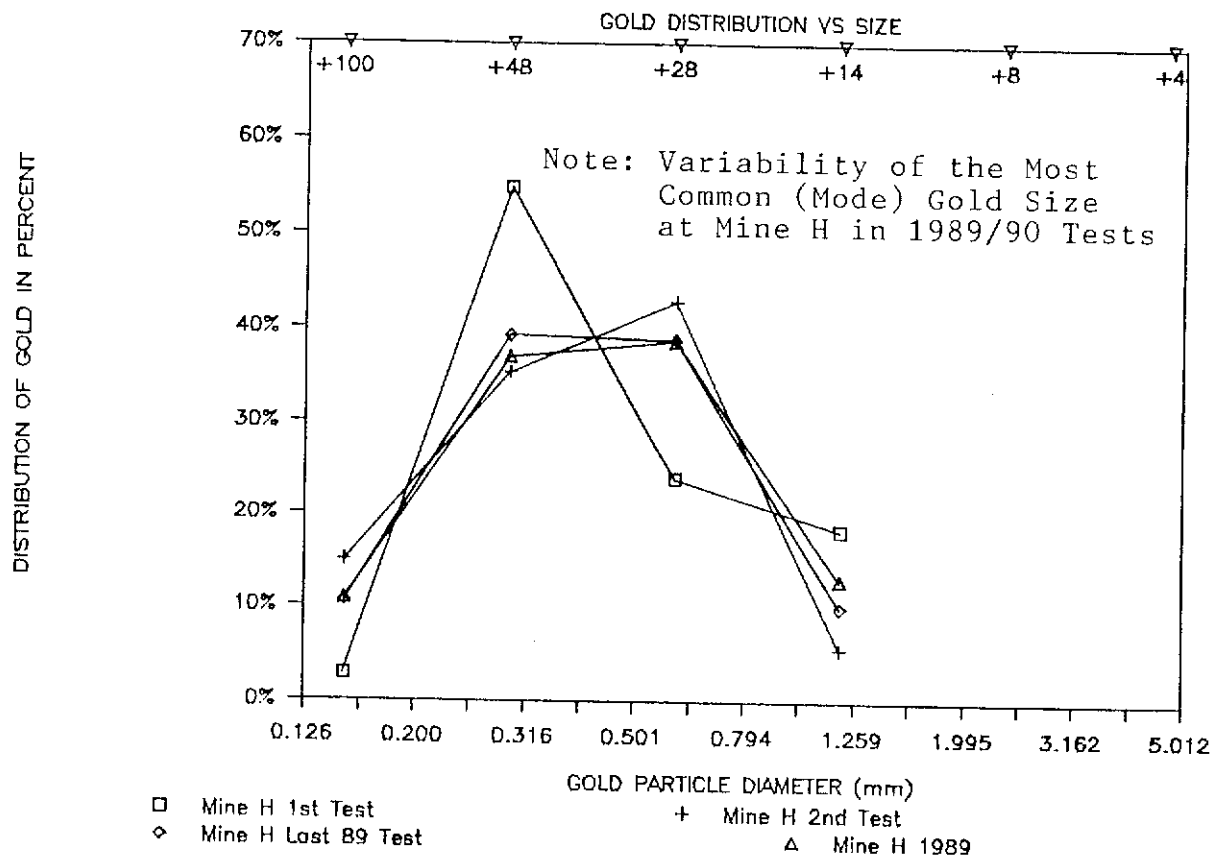
The following table displays the percent of gold particles from pay gravels which are retained on the indicated sieve for consecutive tests at the same mines.

TABLE 8.6 CONSECUTIVE SIZE DISTRIBUTIONS OF GOLD PARTICLES (Graphs 1 and 2)

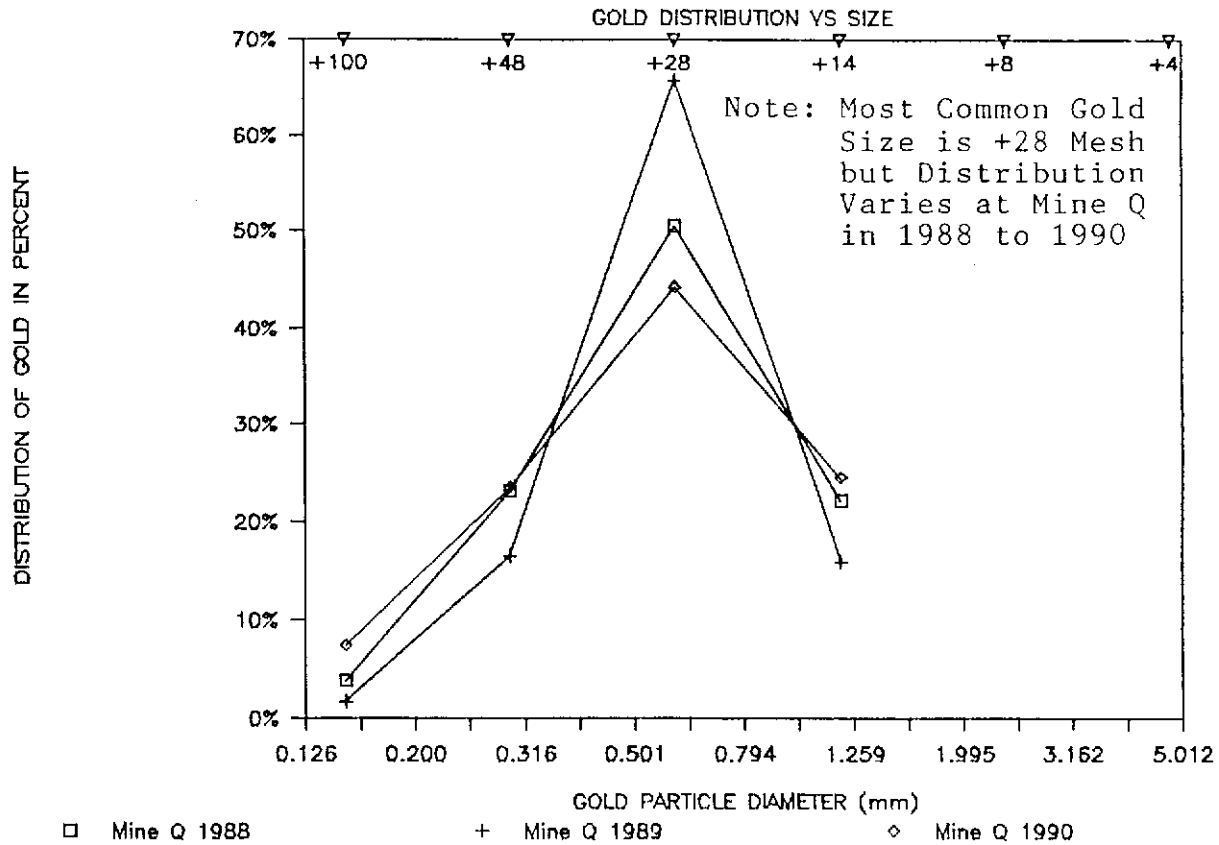
Tyler Mesh	Dia mm	H1	H3	H4	H90	K	K90	Q1	Q2	Q90
+4	4.76									
+8	2.38									
+14	1.19	18%	6%	10%	13%	2%	8%	22%	16%	25%
+28	0.59	24%	43%	39%	39%	25%	33%	51%	66%	44%
+48	0.29	55%	35%	39%	37%	58%	49%	23%	17%	23%
+100	0.14	3%	15%	11%	11%	14%	10%	4%	2%	7%
-100		0.2%	1.3%	1.3%	0.6%	0.6%	0.0%	0.3%	0.1%	0 %
Total		100%	100%	100%	100%	100%	100%	100%	100%	100%

Notes: Significant variations in size distribution of placer gold can occur for clean ups from three successive pits (H1 to H4), over two mining seasons (H1 versus H90 and K versus K90) and over three mining season (Q1, Q2 and Q90).

GRAPH 1 CONSECUTIVE SIZE DISTRIBUTIONS OF GOLD FROM MINE H



GRAPH 2 CONSECUTIVE SIZE DISTRIBUTIONS OF GOLD FROM MINE Q



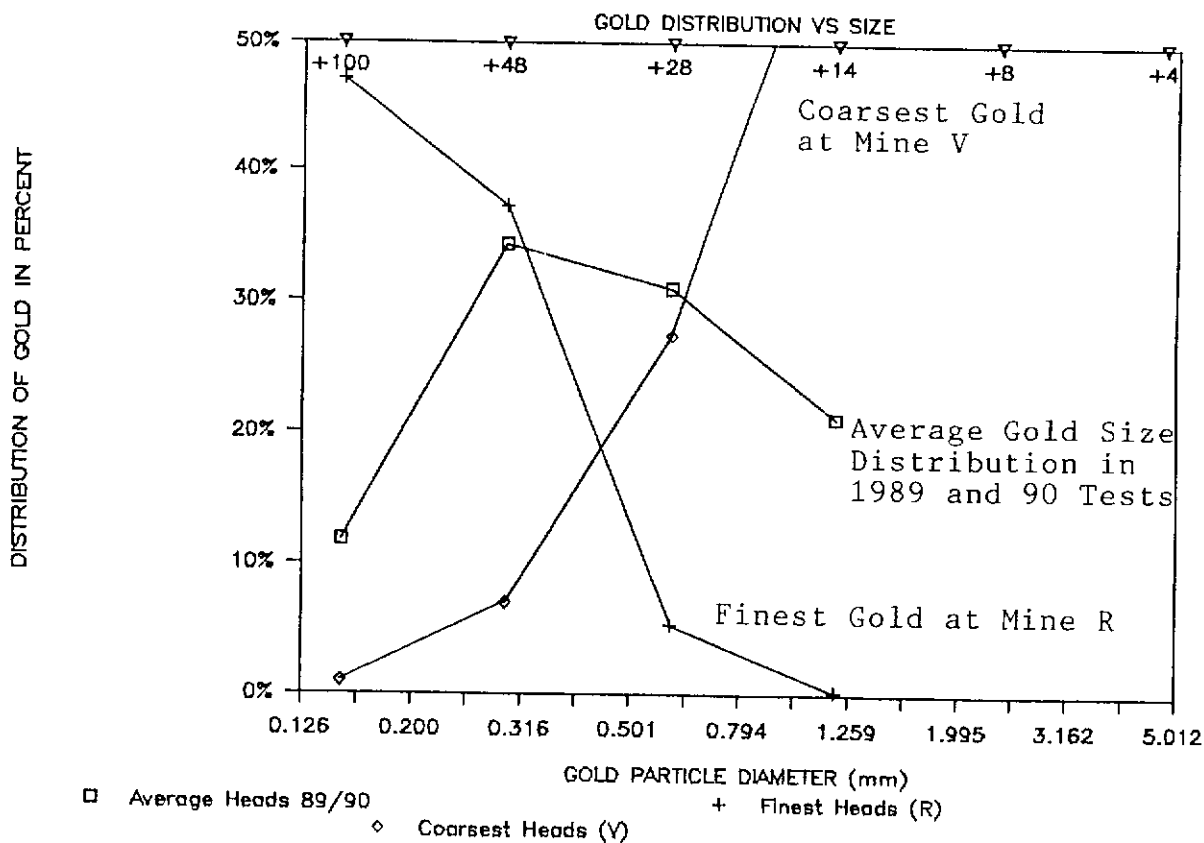
## 8.7 DISTRIBUTION OF GOLD VALUES

The following table displays the average, finest and coarsest distributions of gold in pay gravels as well as the averaged distributions of recovered and lost gold particles.

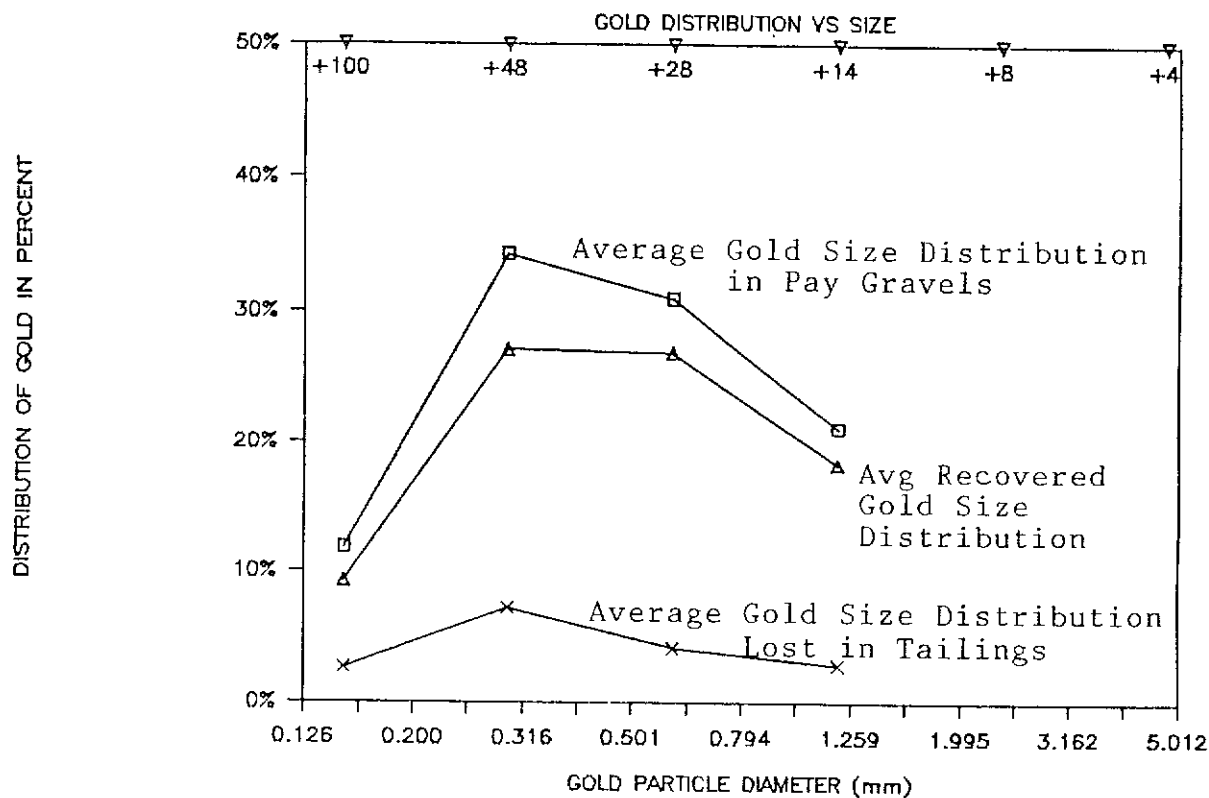
TABLE 8.7 DISTRIBUTION OF AVERAGE GOLD VALUES  
(Graphs 3 and 4)

Tyler Mesh	Dia mm	Average Of All	Finest Mine R	Coarsest Mine V	Average Recovered	Average Lost
+4	4.76					
+8	2.38					
+14	1.19	21.1%	0.2%	64.6%	18.3%	2.8%
+28	0.59	31.0%	5.3%	27.4%	26.9%	4.1%
+48	0.29	34.3%	37.2%	7.0%	27.2%	7.1%
+100	0.14	11.8%	47.1%	1.0%	9.2%	2.6%
-100		1.7%	10.1%	0.0%	1.4%	0.4%
Total		100%	100%	100%	83.0%	16.9%

GRAPH 3 AVERAGE AND EXTREME GOLD DISTRIBUTIONS IN PAY GRAVELS



GRAPH 4 DISTRIBUTIONS OF RECOVERED AND LOST GOLD



## 8.8 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 ball or cube is 1 and of a dime is 0.05. The following table summarizes the C.S.F. of the gold recovered by the sluiceboxes. The 1988 conventional sampling program data indicated that in 5 of the 6 mines sampled there was no significant difference in the shape factors of the recovered and lost gold.

TABLE 8.8 COREY SHAPE FACTORS OF RECOVERED GOLD

Mesh Dia mm	Average	Minimum	Maximum	Standard Error
+4 4.76	0.30	0.20	0.40	0.07
+8 2.38	0.28	0.05	0.53	0.11
+14 1.19	0.24	0.10	0.70	0.12
+28 0.60	0.25	0.10	0.50	0.12
+48 0.30	0.28	0.10	0.40	0.09
+100 0.15	0.32	0.15	0.50	0.10
-100	0.39	0.20	0.60	0.12

Notes: The Corey Shape Factors for gold from these Yukon placer mines are fairly similar as noted by the low standard errors. Corey Shape Factors can only be estimated to the nearest 0.1 and often varied in successive tests at each mine (H, Q, O and K) by plus or minus 0.1 to 0.2.

## 8.9 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 tracers traveled before they were recovered.

TABLE 8.9 CUMULATIVE RADIOTRACER RECOVERY VERSUS TRAVEL  
(Graph 5)

Recovery Distance feet	Single Run		Homemade Triple		Homemade "LD" -----Triple Run-----				Pearson Triple
	Z		M	Q	H1	I	L	T	U
2	0%		12%	2%	5%	23%	31%	26%	17%
4	2%		22%	11%	9%	54%	45%	42%	35%
6	6%		25%	18%	18%	65%	69%	52%	48%
8	9%		38%	30%	20%	69%	72%	72%	50%
10	12%		43%	37%	22%	72%	82%	84%	57%
12	14%		43%	45%	23%	72%	86%	84%	59%
14	15%		49%	54%	27%	72%	88%	87%	60%
16	15%		63%	62%	28%	72%	88%	87%	61%
18	22%		65%	64%	29%	86%	89%	87%	62%
20	22%		73%	67%	End	End	End	87%	67%
22	27%		78%	72%				87%	72%
24	31%		80%	75%				87%	End
26	33%		84%	75%				End	
28	36%		End	75%					
30	38%			76%					
32	38%		End						
Overall Recovery	48%		84%	76%	29%	86%	89%	87%	72%

Recovery Distance feet	Ross Box -Triple Run--			Stationary --Decks--		---Derocker---		Finger Grizzly	
	O	O90	P	H90	W	D	N	X	Q90
2	6%	14%	10%	29%	1%	N/A	65%	1%	37%
4	19%	17%	22%	55%	12%		70%	4%	62%
6	23%	23%	28%	63%	21%		75%	13%	74%
8	39%	30%	43%	72%	29%		77%	25%	76%
10	51%	52%	58%	77%	54%		78%	39%	81%
12	55%	59%	60%	78%	61%		81%	44%	84%
14	71%	65%	60%	84%	67%		81%	59%	89%
16	82%	70%	60%	84%	88%		83%	72%	89%
18	83%	72%	64%	84%	88%		83%	84%	91%
20	83%	76%	64%	84%	88%		85%	87%	92%
22	83%	79%	70%	84%	88%		End	87%	94%
24	83%	80%	73%	84%	88%			96%	96%
26	85%	84%	End	End	90%			97%	End
28	87%	84%			90%			97%	
30	88%	87%			90%			97%	
32	89%	End			90%			97%	
Overall Recovery	89%	87%	73%	83%	92%	87%	85%	98%	96%

Notes: Sluice runs with significant numbers of tracers along the full length of their run usually had poorer overall recoveries.

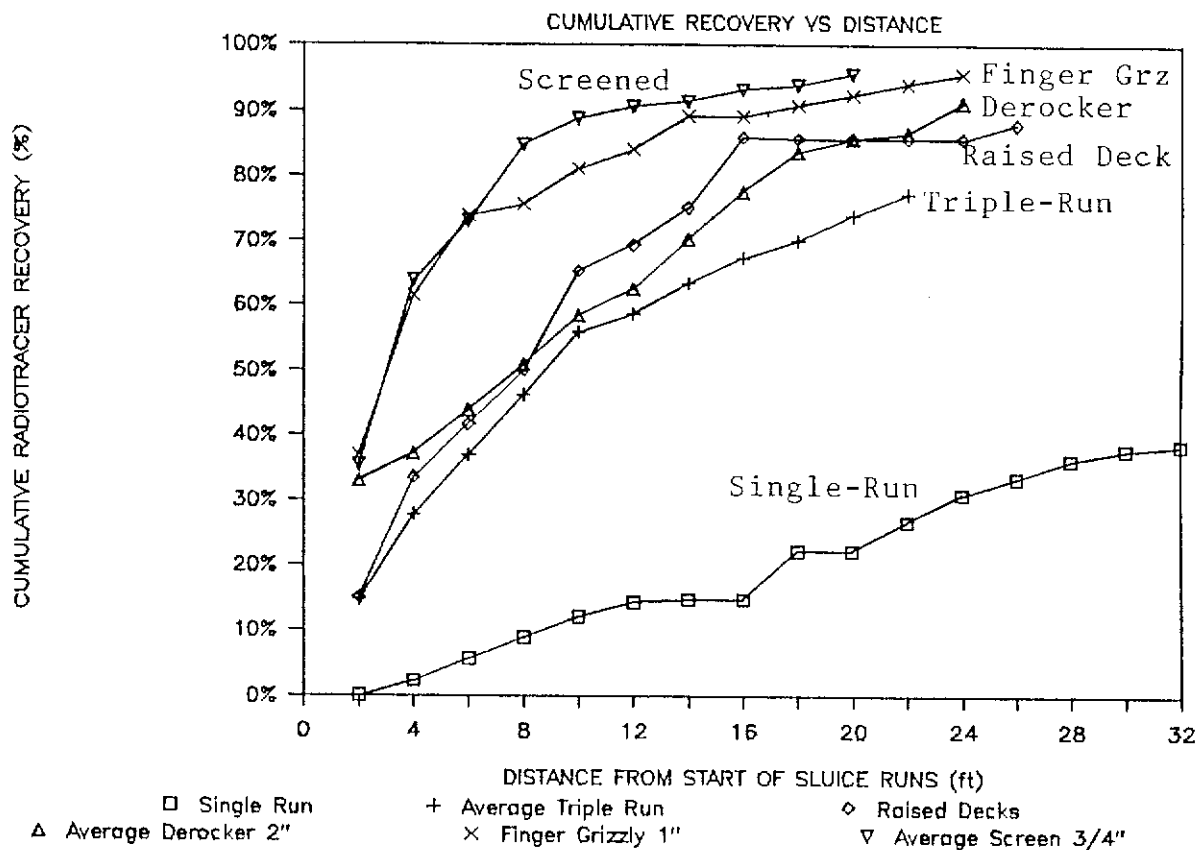
Radiotracers generally travelled further down the center runs of triple run boxes due to high water velocity and excessive overloading with water and coarse pay gravels. It is very difficult for gold particles to pass through stationary punch plate under these conditions.

TABLE 8.9 Continued

	--Rotating Trommel--				---Vibrating Screen Decks---						
Recovery Distance feet	B	S	V	Y	A	G	J	K	K90	R	
2	N/A	17%	N/A	87%	N/A	51%	70%	36%	24%	19%	
4		45%		93%		93%	89%	76%	40%	45%	
6		54%		94%		96%	89%	87%	52%	62%	
8		76%		97%		96%	93%	95%	61%	77%	
10		82%		97%		96%	98%	95%	69%	81%	
12		84%		End		96%	98%	95%	74%	86%	
14		84%				96%	98%	95%	76%	89%	
16		88%				96%	98%	95%	83%	92%	
18		90%				96%	98%	96%	87%	92%	
20		90%				End	End	End	89%	92%	
22		91%							91%	End	
24		93%							97%		
26		95%							97%		
28		97%							99%		
30		97%							100%		
32		97%							End		
Overall Recovery		79%	97%	77%	98%	98%	96%	98%	96%	100%	92%

Notes: The screened systems recovered more of the gold tracers sooner than the single or triple run boxes due to superior pay gravel washing and riffle operation.

GRAPH 5 LOCATION OF RADIOTRACERS IN SLUICING SYSTEMS  
AVERAGE RADIOTRACER TRAVEL



## 8.10 RADIOTRACER RECOVERY FOR CONSECUTIVE TESTS

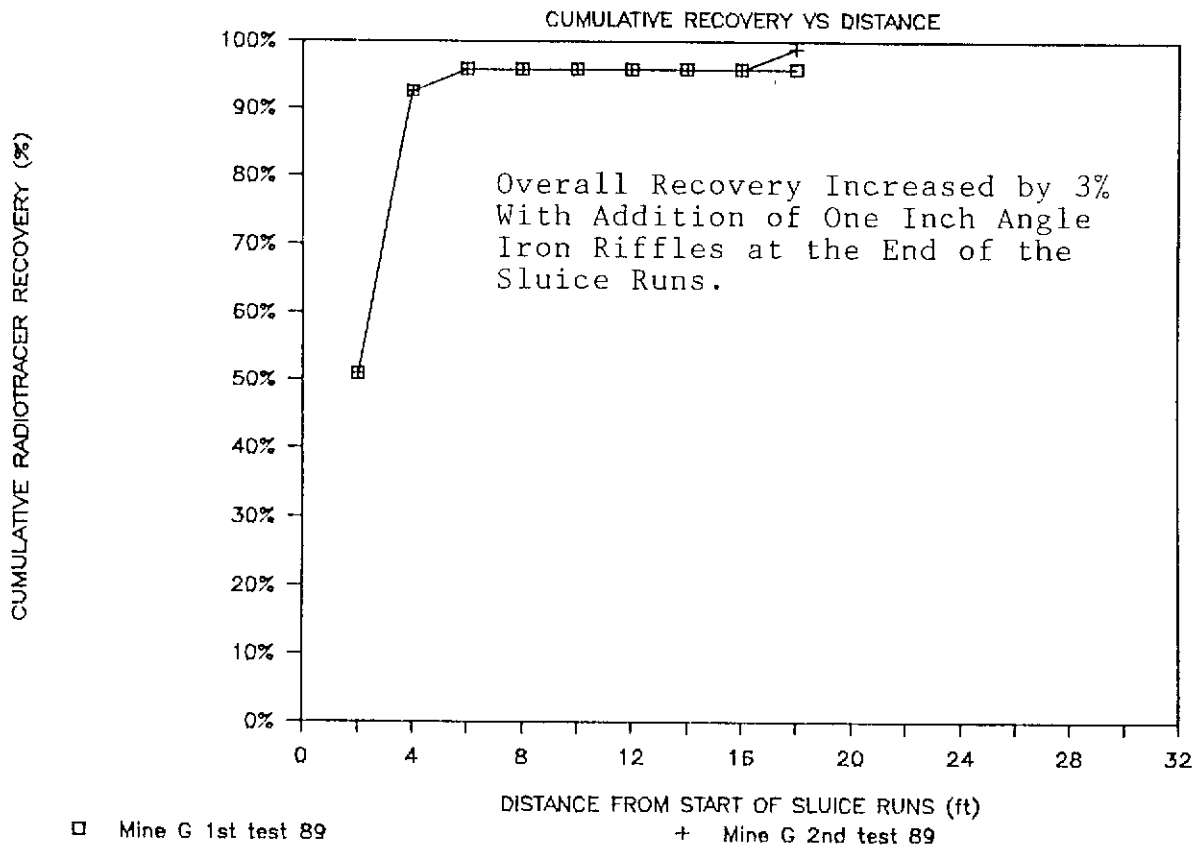
TABLE 8.10 CUMULATIVE RADIOTRACER RECOVERY FOR CONSECUTIVE TESTS

(Graphs 6, 7 and 8)

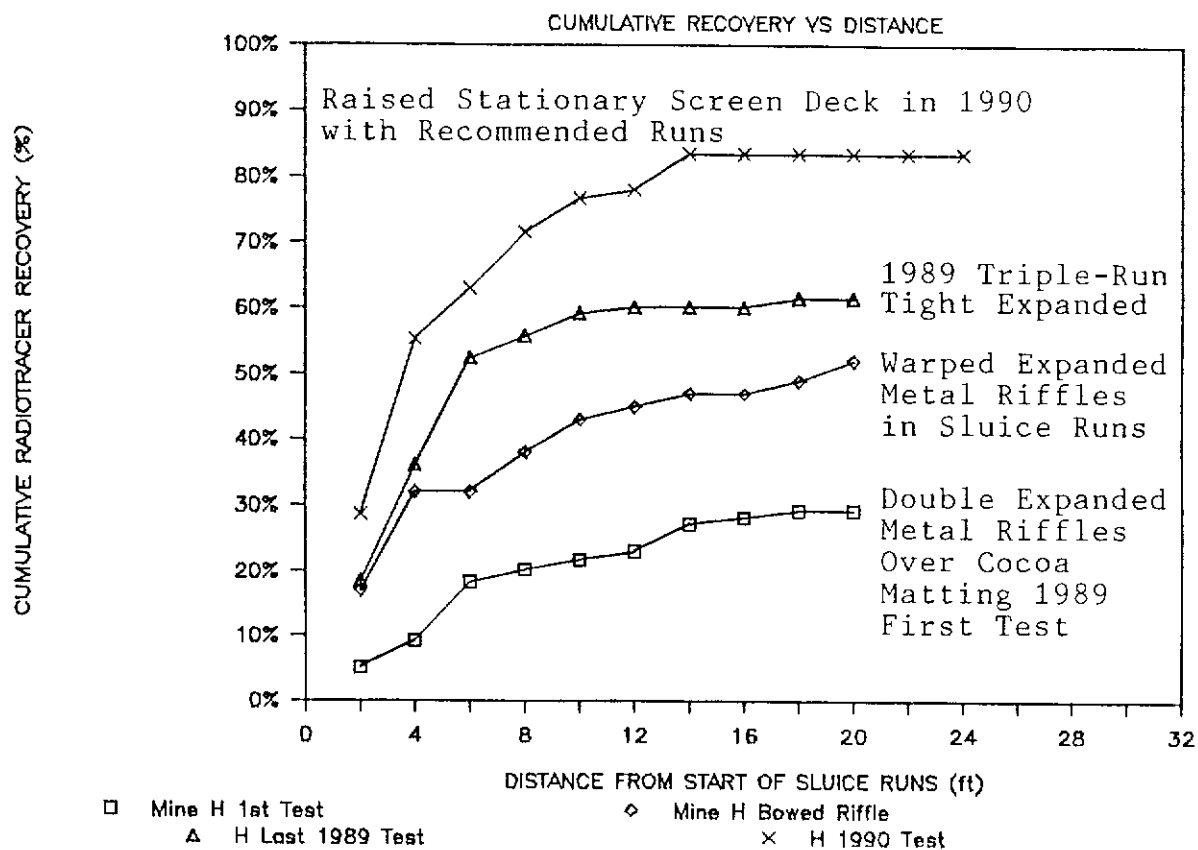
(Graphs 6, 7 and 8)											
Recovery Distance	G1	G2	H1	H3	H4	H90	K	K90	Q	Q90	
2	51%	51%	5%	17%	18%	29%	36%	24%	2%	37%	
4	93%	93%	9%	32%	36%	55%	76%	40%	11%	62%	
6	96%	96%	18%	32%	52%	63%	87%	52%	18%	74%	
8	96%	96%	20%	38%	56%	72%	95%	61%	30%	76%	
10	96%	96%	22%	43%	59%	77%	95%	69%	37%	81%	
12	96%	96%	23%	45%	60%	78%	95%	74%	45%	84%	
14	96%	96%	27%	47%	60%	84%	95%	76%	54%	89%	
16	96%	96%	28%	47%	60%	84%	95%	83%	62%	89%	
18	96%	99%	29%	49%	62%	84%	96%	87%	64%	91%	
20	End	End	29%	52%	62%	84%	End	89%	67%	92%	
22			End	End	End	84%		91%	72%	94%	
24						84%		97%	75%	96%	
26						End		97%	75%	End	
28								99%	75%		
30								100%	76%		
Overall Recovery		96%	99%	29%	52%	62%	83%	96%	100%	76%	96%

Notes: Minor modifications to the sluice runs at mines G, H and K resulted in increased gold recovery. The addition of screening at mines H90 and Q90 improved gold recoveries by 21 and 14 %.

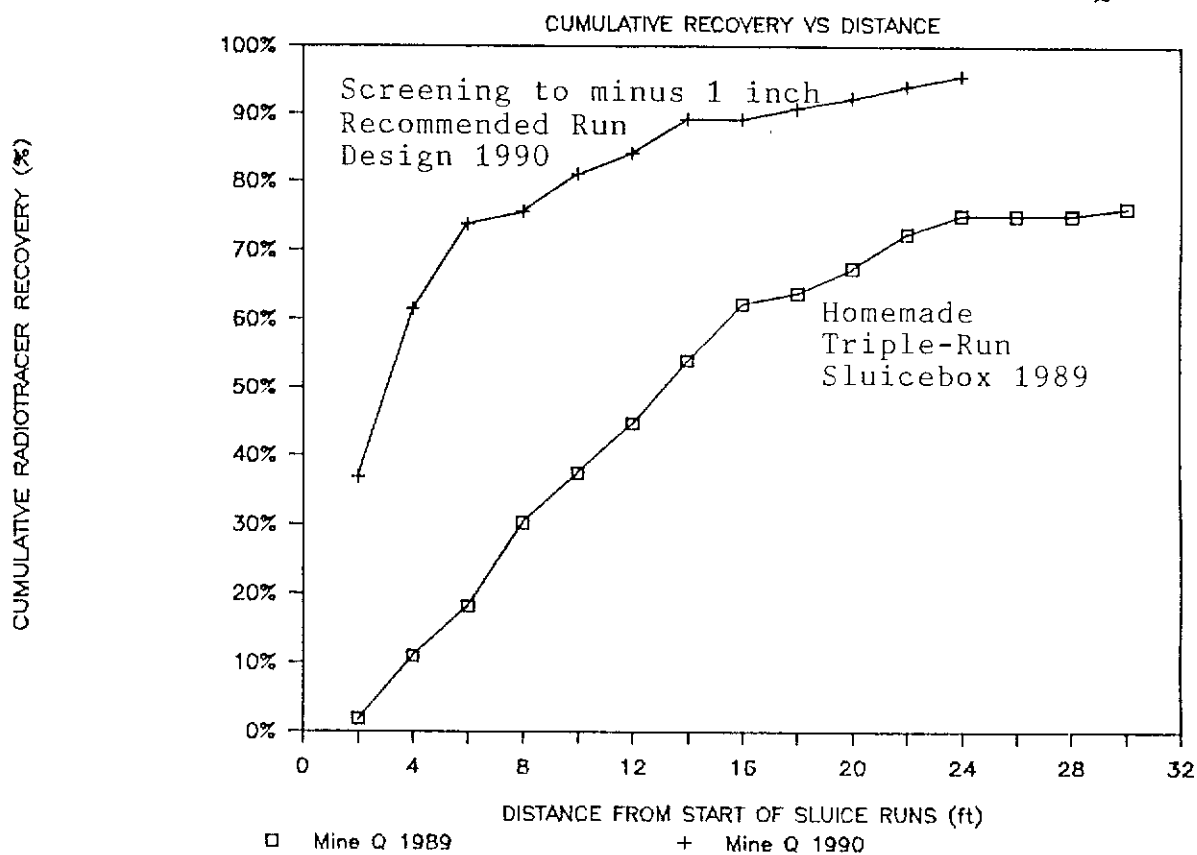
GRAPH 6 CUMULATIVE RADIOTRACER RECOVERY AT MINE G



GRAPH 7 CUMULATIVE RADIOTRACER RECOVERY AT MINE H



GRAPH 8 CUMULATIVE RADIOTRACER RECOVERY AT MINE Q





## 8.11 RECOVERY OF SLUICING SYSTEMS

The recovery of the various sluiceboxes is displayed in the following chart.

TABLE 8.11 RECOVERY OF SLUICING SYSTEMS  
(Graph 9)

Tyler Mesh	Dia mm	Single Run	Homemade Triple		Homemade "LD" -----Triple Run-----				Pearson Triple
		Z	M	Q	H1	I	L	T	U
+4	4.76								
+8	2.38								
+14	1.19	52%	84%	84%	56%	72%	100%	84%	44%
+28	0.60	68%	88%	68%	48%	92%	88%	96%	68%
+48	0.30	48%	84%	100%	12%	84%	88%	88%	84%
+100	0.15	36%	60%	88%	36%	86%	92%	80%	64%
-100									

Tyler Mesh	Dia mm	Ross Box -Triple Run--			Stationary --Decks--		---Derocker---		Finger Grizzly	
		O	O90	P	H90	W	D	N	X	Q90
+4	4.76									
+8	2.38									
+14	1.19	92%	96%	92%	96%	92%	100%	88%	100%	96%
+28	0.60	100%	84%	80%	84%	100%	98%	76%	100%	100%
+48	0.30	80%	88%	76%	84%	80%	93%	92%	92%	96%
+100	0.15	49%	80%	56%	64%	88%	66%	100%	90%	76%
-100										

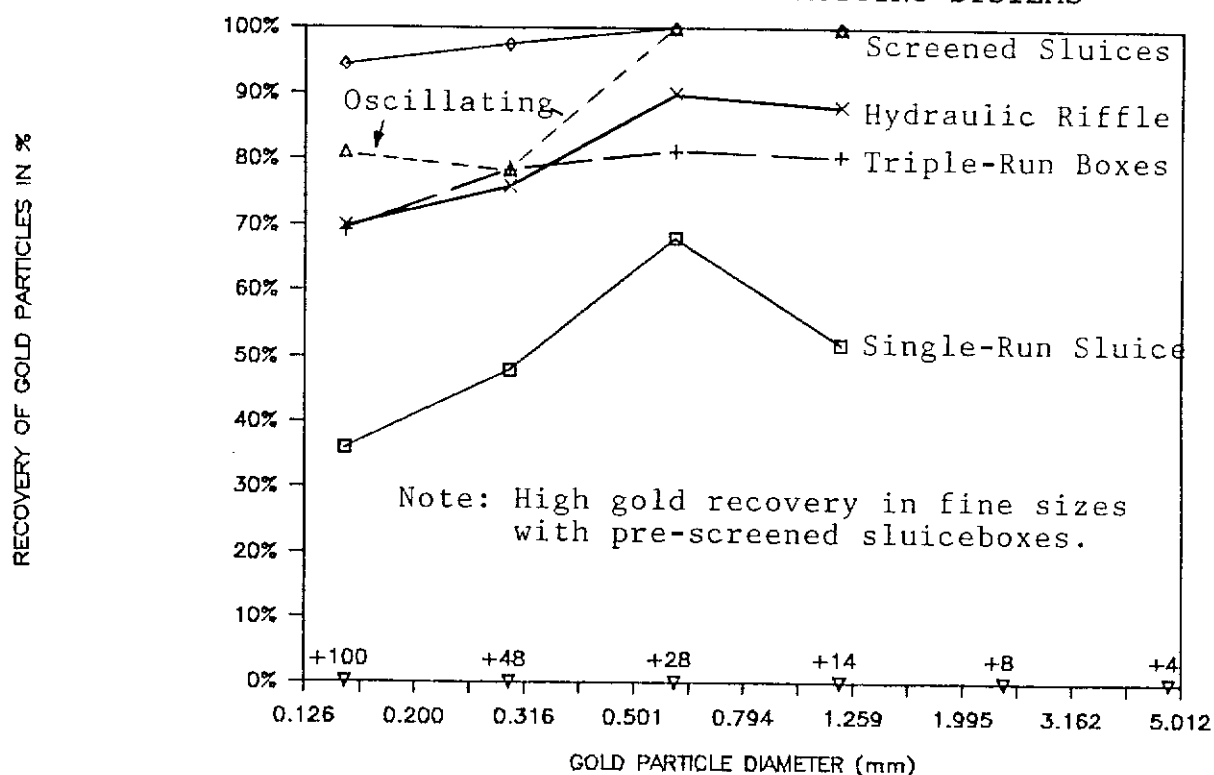
Tyler Mesh	Dia mm	--Rotating Trommel--				---Vibrating Screen Decks---					
		B	S	V	Y	A	G1	J	K	K90	R
+4	4.76										
+8	2.38										
+14	1.19	100%	100%	76%	100%	100%	92%	68%	96%	100%	100%
+28	0.60	100%	100%	84%	96%	100%	100%	100%	84%	100%	100%
+48	0.30	61%	100%	56%	96%	96%	96%	100%	100%	100%	92%
+100	0.15	78%	88%	52%	88%	96%	84%	96%	100%	100%	92%
-100											

Notes: The sluiceboxes with screened feed (B, S, Y, G, J, K and R) had the highest recovery except for mine V which used hydraulic riffles.

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

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

GRAPH 9 AVERAGED RECOVERY OF SLUICING SYSTEMS



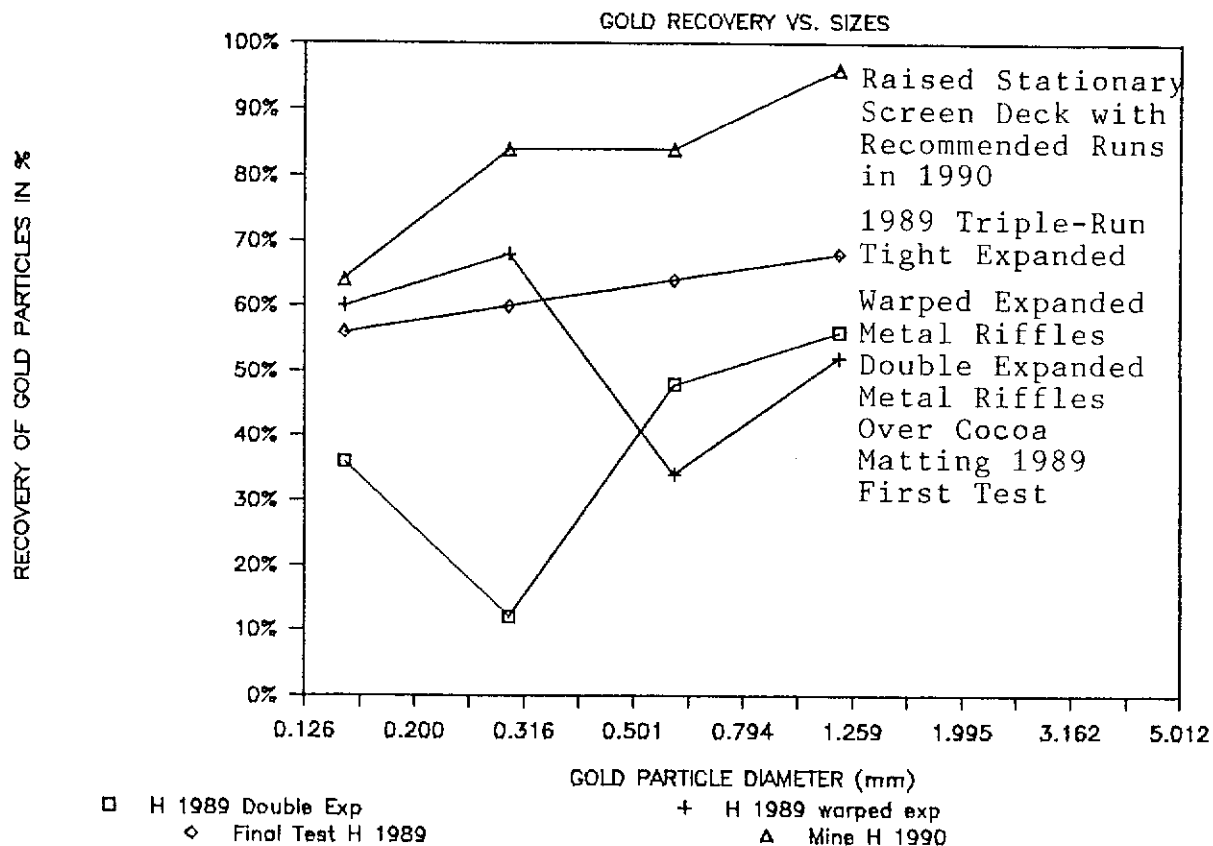
## 8.12 RECOVERY OF SLUICING SYSTEMS AFTER MODIFICATIONS

An additional test was performed at mine 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 mine H the doubled expanded metal riffles and cocoa matting were replaced with single expanded metal riffles and Nomad matting (H3). These test results were less than optimum because the expanded metal riffles were not tight against the matting. This was corrected and retested (H4). Both mines H90 and Q90 installed screening equipment in 1990 and mine K90 replaced its triple run sluicebox with a recommended sluicebox design.

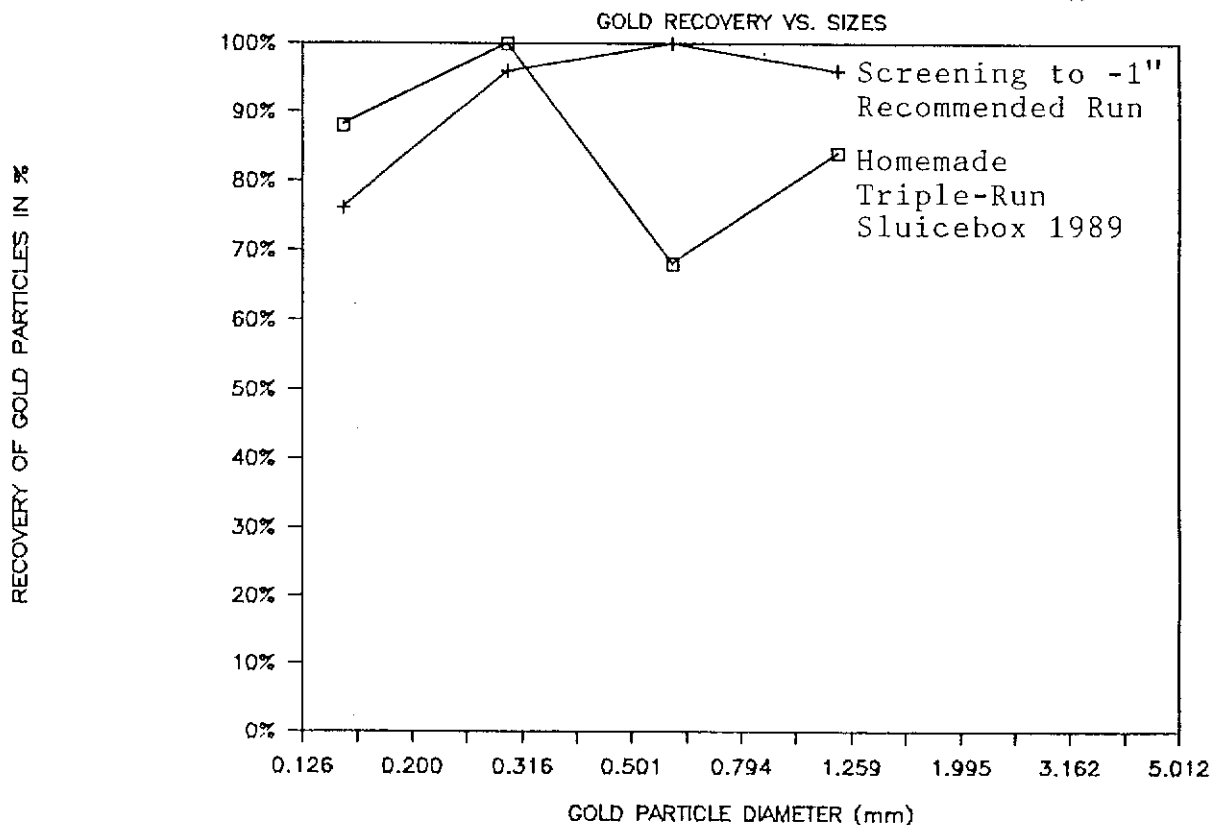
TABLE 8.12 RECOVERY OF SLUICING SYSTEMS AFTER MODIFICATIONS (graphs 10 and 11)

Tyler Mesh	Dia mm	G1	G2	H1	H3	H4	H90	K	K90	Q	Q90
+4	4.76										
+8	2.38										
+14	1.19	92%	100%	56%	52%	68%	96%	96%	100%	84%	96%
+28	0.60	100%	100%	48%	34%	64%	84%	84%	100%	68%	100%
+48	0.30	96%	96%	12%	68%	60%	84%	100%	100%	100%	96%
+100	0.15	84%	84%	36%	60%	56%	64%	100%	100%	88%	76%
-100											
Overall Recovery		96%	99%	48%	52%	62%	83%	96%	100%	76%	96%

GRAPH 10 RECOVERY AFTER MODIFICATIONS AT MINE H



GRAPH 11 RECOVERY AFTER MODIFICATIONS AT MINE Q



Notes: Overall recovery efficiency improved from 96 to 99 percent with the addition of one inch angle iron riffles to the end of mine 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 mine 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. Mine H and Q's gold recovery increased to 83% and 96% respectively with the installation of screening equipment. Mine K's recovery increased to 100 % when its triple run sluicebox was replaced with a recommended sluicebox design.

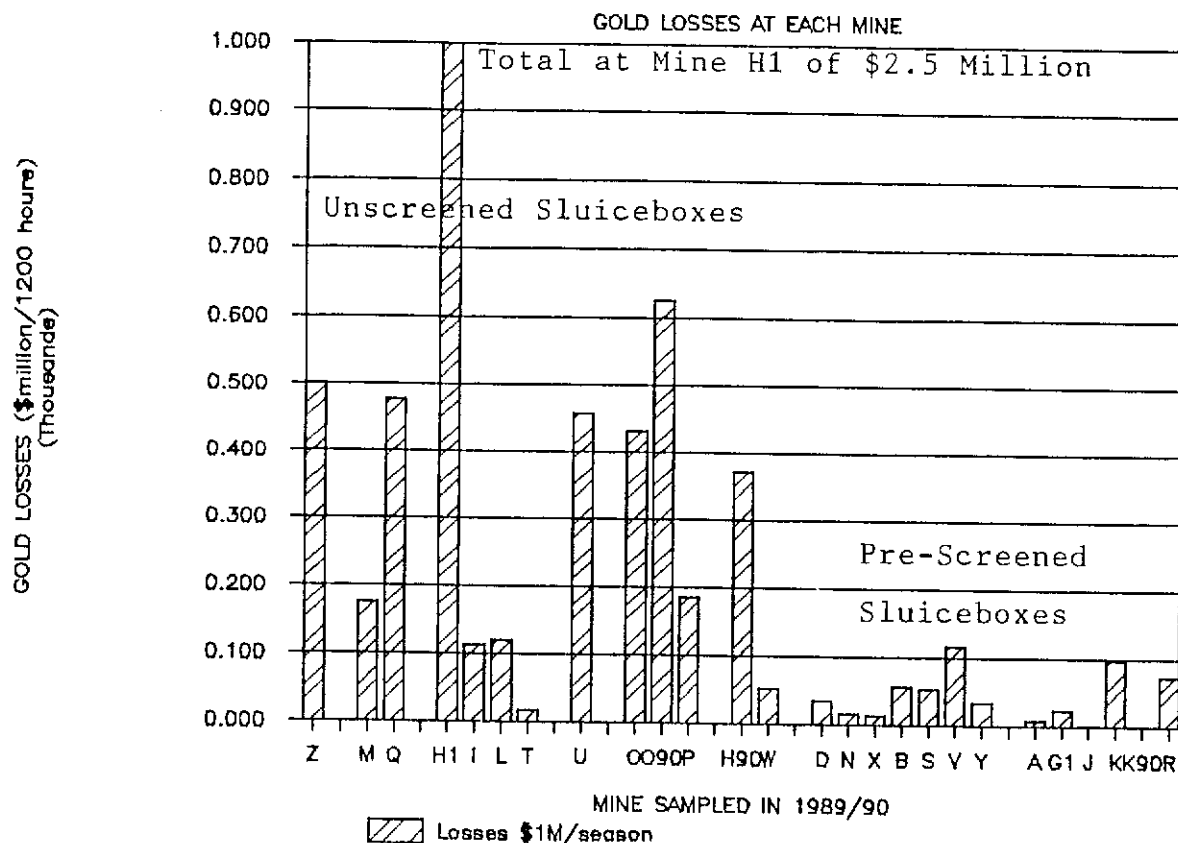
### 8.13 MONETARY VALUE OF GOLD LOSSES

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 8.13 MONETARY VALUE OF GOLD LOSSES  
(Graph 12)

Values in \$Can											
Single Run		Homemade Triple		Homemade "LD" Triple Run				Pearson Triple			
Mine	Z	M	Q	H1	I	L	T	U			
Raw Gold g/hr	41	14	39	209	9	10	1	37			
\$/hr @ \$400/ou	\$418	\$145	\$397	2152	\$94	\$99	\$14	\$381			
\$1000/1200 hr	\$502	\$174	\$477	2582	\$112	\$119	\$17	\$457			
Overall Recovery	48%	84%	76%	29%	86%	89%	87%	72%			
Ross Box Triple Run				Stationary Decks			Derocker			Finger Grizzly	
	O	O90	P	H90	W	D	N	X	Q90		
Raw Gold g/hr	35	51	15	30	4	3	1	1	6		
\$/hr @ \$400/ou	\$359	\$522	\$154	\$310	\$44	\$29	\$14	\$11	\$63		
\$1000/1200 hr	\$431	\$626	\$185	\$372	\$52	\$35	\$16	\$14	\$75		
Overall Recovery	89%	87%	73%	83%	92%	87%	85%	98%	96%		
Rotating Trommel					Vibrating Screen Decks						
	B	S	V	Y	A	G1	J	K	K90	R	Avg
Raw Gold g/hr	5	4	9	3	0.6	2	0.1	8	0	6	21
\$/hr @ \$400/ou	\$47	\$44	\$96	\$28	\$6	\$20	\$1	\$81	\$0	\$61	\$215
\$1000/1200 hr	\$57	\$53	\$116	\$34	\$8	\$24	\$1	\$97	\$0	\$73	\$258
Overall Recovery	79%	97%	77%	98%	98%	96%	98%	96%	100%	92%	84%

GRAPH 12 MONETARY VALUE OF GOLD LOSSES



## 8.14 RECOVERABLE LOSSES

The following estimates of recoverable gold are based on comparison with sluiceboxes operating with screened feed and under recommended 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 mine G and some modifications resulting in a doubling of recovery at mine H were completed in 1989. Mines H and Q installed screening systems in 1990. Mine K's perfect recovery is the result of screening and replacement of a triple run sluicebox with a recommended sluicebox design.

TABLE 8.14 RECOVERABLE GOLD LOSSES  
(Graphs 13 and 14)

Values in \$Can

	Single Run	Homemade Triple	Homemade "LD" -----Triple Run-----				Pearson Triple
Mine	Z	M Q	H1	I	L	T	U
Raw Gold g/hr	38	11 28	177	7	6	1	36
\$/hr @ \$400/ou	\$390	\$113 \$288	1817	\$76	\$59	\$11	\$367
\$1000/1200 hr	\$468	\$135 \$345	2180	\$91	\$70	\$13	\$440
Capital Cost	\$50	\$100 \$100	\$100	\$100	\$100	\$100	\$100
Operating Cost	\$5	\$10 \$10	(\$30)	(\$30)	(\$80)	(\$30)	\$10

Overall Recovery 96% 96% 93% 89% 95% 96% 98% 99%

	Ross Box -Triple Run--			Stationary --Decks--		---Derocker---			Finger Grizzly
	O	O90	P	H90	W	D	N	X	Q90
Raw Gold g/hr	24	49	14	13	4	2	1	1	6
\$/hr @ \$400/ou	\$245	\$501	\$141	\$130	\$42	\$18	\$13	\$10	\$57
\$1000/1200 hr	\$293	\$602	\$169	\$156	\$51	\$21	\$16	\$12	\$68
Capital Cost	\$100	\$100	\$100	\$100	\$50	\$60	\$60	\$60	\$30
Operating Cost	\$10	\$10	\$10	(\$30)	\$10	\$10	\$10	\$10	\$0

Overall Recovery 96% 99% 98% 90% 99% 99% 95% 99% 99%

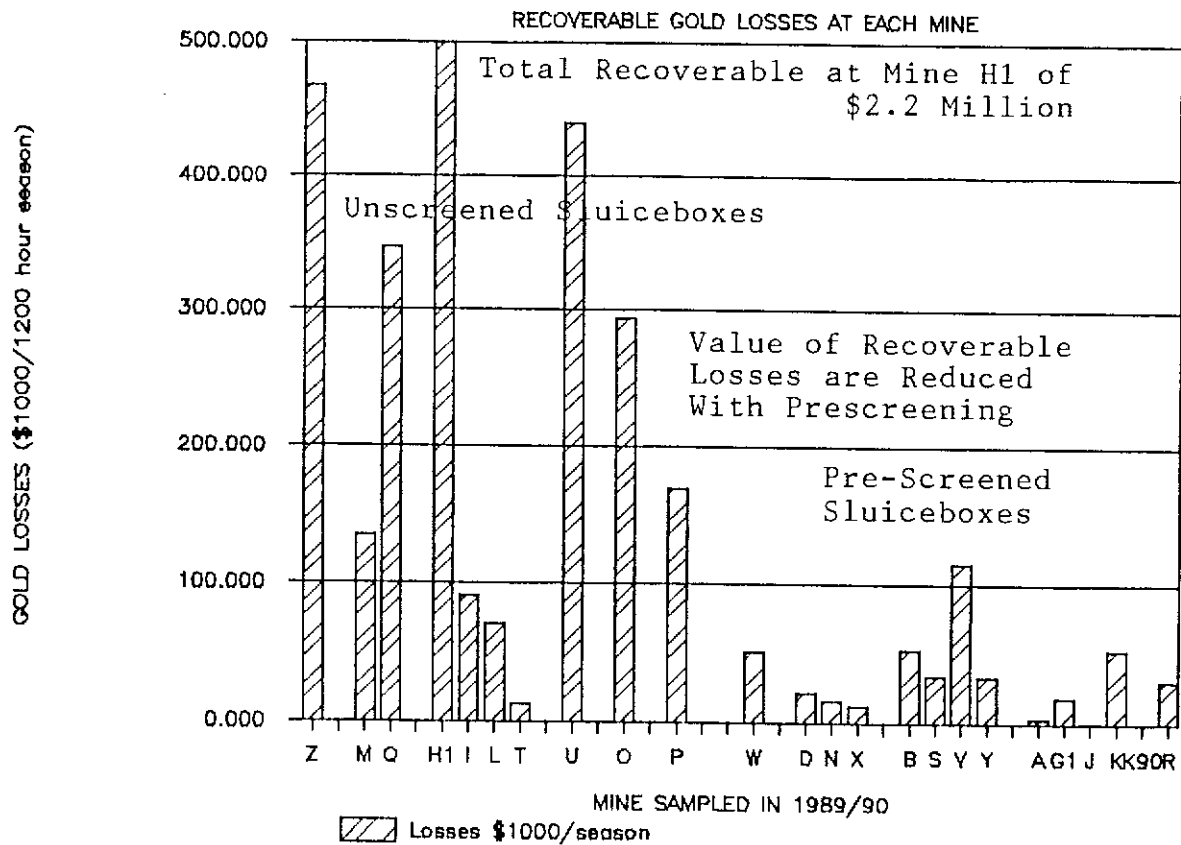
	--Rotating Trommel--				---Vibrating Screen Decks---						
	B	S	V	Y	A	G1	J	K	K90	R	Avg
Raw Gold g/hr	4	3	9	3	0.3	1.5	0.03	4	0	3	17
\$/hr @ \$400/ou	\$44	\$29	\$96	\$28	\$3	\$15	\$0.3	\$44	\$0	\$26	\$175
\$1000/1200 hr	\$53	\$34	\$115	\$33	\$3	\$19	\$0.3	\$53	\$0	\$31	\$210
Capital Cost	\$1	\$3	\$10	\$2	\$1	\$1	\$1	\$50	\$0	5	\$57
Operating Cost	\$0	\$0	\$0	\$0	\$0	\$0	\$0	(\$5)	\$0	0	(\$4)
Overall Recovery	99%	99%	99%	99%	99%	99%	99%	98%	100%	95%	

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

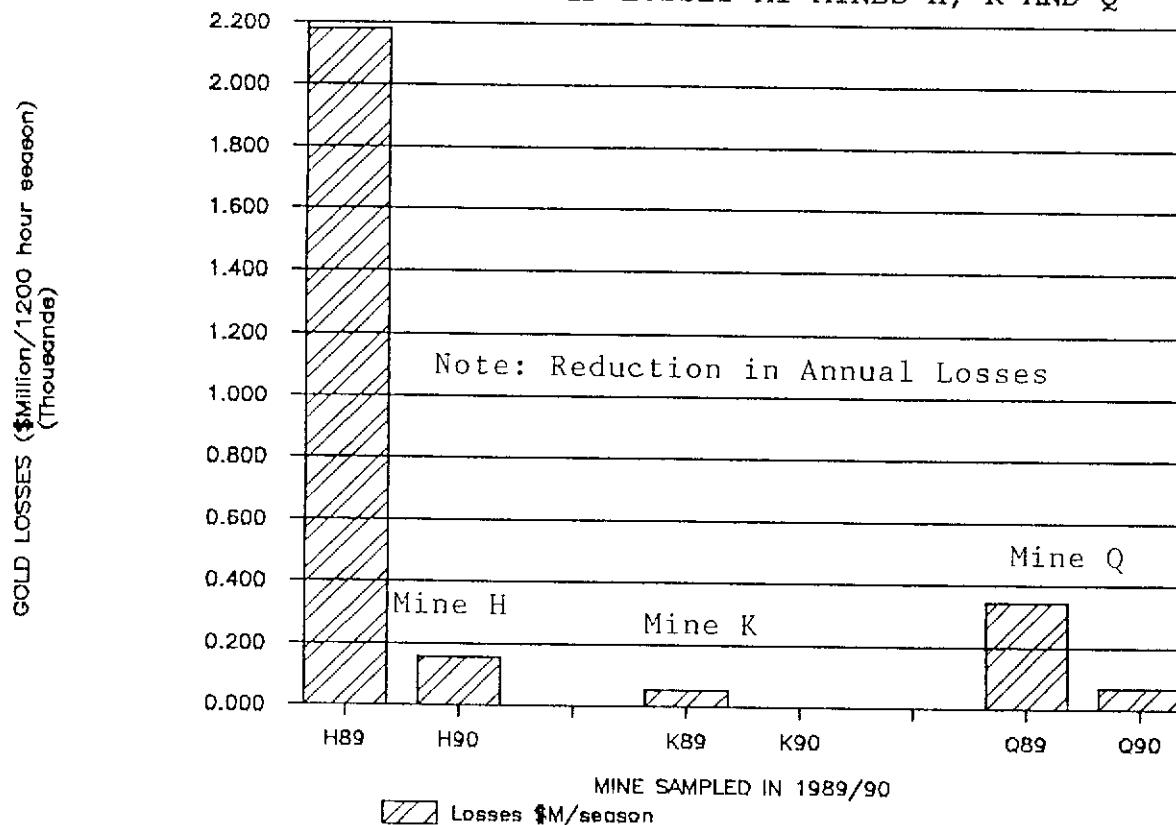
Mines G and H reduced their gold losses following modifications after the first tests in 1989.

In 1990, mines H and Q constructed screening systems and mine K constructed sluice runs in accordance with the standard recommendations. These costs were recovered in less than one season.

GRAPH 13 RECOVERABLE GOLD LOSSES



GRAPH 14 RECOVERED GOLD LOSSES AT MINES H, K AND Q



## 8.15 ACCURACY OF THESE RESULTS

The standard errors from these radiotracer tests were estimated from binomial probability theory with the equation:  $SE = \{(n \cdot p \cdot q)^{0.5}\} / n$ . Where n is the total number of radiotracers added, p is the proportion recovered and q is the proportion lost. Each overall recovery estimate would 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 8.15 STANDARD ERRORS OF 88/89/90 TESTING PROGRAM

	Single Run		Homemade Triple		Homemade "LD" Triple Run				Pearson Triple		
	Z		M	Q	H	I	L	T	U		
Standard Error	5%		4%	4%	5%	4%	3%	3%	5%		
	Ross Box Triple Run			Stationary Decks			Derocker		Finger Grizzly		
	O	O90	P	H90	W	D	N	X	Q90		
Standard Error	4%	3%	4%	4%	3%	N/A	3%	2%	3%		
	Rotating Trommel				Vibrating Screen Decks					Avg	
	B	S	V	Y	A	G	J	K	K90	R	
Standard Error	17%	2%	5%	2%	8%	2%	3%	2%	1%	2%	3%

The standard errors encountered in the 1988 conventional sampling program were much higher and ranged from 8% for mine A which had relatively low gold losses to as high as 50% for mines 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 48 hours allowing the sluiceboxes to be modified and retested immediately.



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## 10 APPENDICES

## 10.1 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

## 10.2 PLACER MINING MEASUREMENT CONVERSIONS

## WEIGHT EQUIVALENTS

Milligram	Gram	Kilogram	Pound	Metric Tonne	Short Ton
mg	g	kg	lb	t	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	Millimeter	Meter	Inch	Foot	Yard
u	mm	m	"	'	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	Liter	Cubic Meter	U.S. Gallon USg	Imperial Gallon g	Cubic Yard yd3
ml	l	m3			
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	Cubic Meter/ second	U.S. Gallon/ minute	Imperial Gallon/ minute	Cubic Feet/ second
l/s	m3/s	USgpm	gpm	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