How To Build and Operate Sluice Boxes

Part III
Riffle Testing

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Sluice Building – Part III – Testing

General Introduction

In the testing phase of this little sluice-building project I am not trying to repeat the work done by Clarkson, Poling, McCarter and others who analyzed commercial sluice systems but rather attempt to investigate the relative efficiency of various riffle designs that are common in the types of sluice boxes used by most of us amateur and part-time prospectors here in Northern California.

There have been some tests and data collection of small sluice boxes and power sluices prepared by others but the ones I have seen were primarily performed to investigate fine gold recovery systems. Many of these tests can be found in the DIY section of 49er Mike's gold forum (http://www.49ermike.com/index.shtml).

However gold recovery in my region is complicated by the fact that the vast majority of mineral is extremely fine in nature but intermixed with what we've been calling 'micro-nuggets' or pieces of material the size of a pin-head and larger. For this reason most sluices need to be designed to collect both types of gold. To do this the sluice is generally set up in dual-purpose mode consisting of an underlayment or matt of Nomad fabric or ribbed carpet covered with fine expanded metal mesh underneath a conventional set of riffles. Alternatively the box is divided into two sections, one with and one without riffles.

Unfortunately this type of dual-mode sluice is a compromise that sacrifices recovery efficiency somewhat but it saves most of us from having to carry two different boxes, or multi-level boxes into the field.

For fine gold recovery the use of riffles can actually be a negative design element and most boxes specifically built for this type of gold don't use any type of riffle system. Good examples of this box type are the 'DFS' (Damn Fine Sluice) and Steve Gaber's 'Pop-and-Son Sluice'.

On the other hand boxes designed to concentrate gold particles of 16-mesh and up in size must have riffles but don't really have a need for the fine expanded metal mesh or even the Nomad matting though both are recommended.

The objective of the testing then is to evaluate various systems in an attempt to create a sluice box that maximizes the good features of both types of sluices while minimizing the negative aspects found in most dual-mode sluice designs. Specifically we want to look at the impacts that riffle style, size and spacing has on small sluice performance.

Test Sluice

Since there isn't much of a budget for this particular project the test sluice was built from scrap materials so it isn't the prettiest thing you'll ever see but it should suffice for the purposes it is intended for.

The design consists of a 24-inch long 'test' section that will contain the various riffle sets and a removable 12-inch long 'feed' section that can be changed out if required. At the extreme rear is a small removable 'crash-box' style water inlet fitted with a 2-inch diameter pipe nipple that can be bushed down to fit a variety of pump sources. This inlet box is detached for stream tests and replaced with a small flare.

Figure 1

One side of the 24-inch test section is made from Plexiglas so we can hopefully get actual photographs and videos of the slurry flow over different riffles. This design is very similar to that used by others in many of the papers referenced herein.

The entire 36-inch length of the box is fitted with a removable 'false' bottom plate, not shown in the snapshot, so we can more easily try different combinations of slick-plate lengths and heights as well as different combinations of matting and mesh without having to actually glue anything onto the bottom of the primary structure.

If I had it to do over again I would build the box from wood that was fiber-glassed and use window glass in lieu of plastic since the Plexiglas panels were prone to scratching by the gravels. Had I used a wood box it would have been very easy to secure individual riffles in place with screws, which would eliminate the sidebars and make it easier to change spacing without having to build an entirely new riffle set for each test.

Even though this test sluice was built from scrap it is extremely precise with respect to shape and we went to great lengths to insure that the bottom was absolutely flat and that the sides were at accurate 90-degree angles. The bottom ended up being so flat that most of the riffle sets we used would actually form a watertight seal against the bare aluminum bottom. If there are any faults in our testing it is not because the test sluice was deficient in any way as this was the one variable that we wanted to eliminate from the ongoing testing cycles.

Test Products

Over the summer we had an opportunity to use, observe and sometimes measure the performance of several pieces of gear that we owned, borrowed or saw being used by other miners and people in the local club. Among those items were Keene 51's and 52's, Angus MacKirk sluices, our own home made boxes, a DFS and two versions of the popular 'Gold-Buddy', a 'Grizzly' brand mini high-banker, A G-1 power sluice, A Proline 2-1/2" power sluice, a D&K 1-1/2" power sluice and a new Keene 2-1/2" power sluice. All of this equipment was used in two different locations having very different dispositions and types of gold between March 12th and August 5th of 2009.

We also had a chance to see a lot of home-built gear being used on the rivers and thank those users for letting us observe their processes and photograph their equipment.

The data derived from using this equipment is not really pertinent to this particular article about riffle designs but the observations and experiences will be referred to since some of our findings when applied to the gear we actually used greatly improved its effectiveness.

Tests By Others

Most of the various discussions at the prospecting forums concerning tests and sluice performance data reference the report prepared by Randy Clarkson in 1990 but ignore a huge body of material prepared by other researchers and also old historical data in mining engineering books and publications that we've listed in the bibliography. All of this material should be studied by anybody interested in building sluices of any type. Most of the papers cited are available at no cost from the various mining industry groups and only a few are distributed through paid subscription services. We only had to buy five of the papers listed in the bibliography.

The Clarkson study of 1990, often cited in dozens of threads at many discussion boards has, in my opinion, been misunderstood and often misrepresented. Very few people refer to his earlier study from 1989 or even look at the source material contained in his own final study. The Clarkson studies however are without a doubt the most up to date we can use in our sluice design projects but they have to be understood for what they were, which is a study of a small scale commercial placer pilot project. The source material for the 6-inch wide by 8-foot long sluice they operated was only classified down to 1/2-inch gravel which few of us running stream sluices or even modern high-bankers would ever consider using today as 1/4-inch material is considered to be about the largest most prospectors will run through their boxes. The smallest riffles tested were 1-inch high. In addition the Clarkson pilot project relied on a steady controlled feed rate from a gravel hopper that most of us won't have the luxury of using. The pilot project also had access to an almost unlimited supply of high velocity water with 200 gallons per minute being the minimum used, far in excess of what even large capacity high-bankers can provide to the average small-time miner.

Hopefully some of the data we collect in this small non-scientific test of our own will add to what others have found in the past and be more applicable to small sluices that most of us own and us on a regular basis.

Mats and Underlay

When I started out on this little test project I had no intention of even using any type of matting or underlayment beneath the riffles we were going to test but it soon became obvious after a few days that different riffle systems perform better when matched with certain types of matting so by default we had to test these various types of secondary concentration and recovery fabrics to some extent but this is entirely secondary to the objective of testing the riffle designs.

Figure 2 depicts just a few of the various mats we tested over the summer. Starting at the upper left-hand side of the snapshot is the usual 1/8" V-groove mat (rubber, not vinyl) that seems to be almost universally popular. Next to that piece is a section of what I call 'waffle-mat' which is sold as a drawer or shelf lining material at most home improvement stores. It is very spongy and about 1/8" thick with a 1/8" grid. It comes in several colors. Next to that in the lighter shade of gray is a plastic diamond mesh material and next to that in blue is a plastic screen material of about 16-mesh. To the right of that is a section of typical 1/2" aluminum expanded metal mesh used to cover the mats.

There seems to be some confusion on the discussion boards based on pictures I've seen posted between real expanded metal mesh and the diamond-patterned punched plate material, which is very flat and one-dimensional. Actual expanded metal mesh is what I call two-dimensional and if you see the two products side by side they are easy to differentiate between.

Flat diamond punched plate serves no purpose in a sluice box unless it's being used as some form of grizzly for gravel classification and if you're using it over miner's moss in a sluice it isn't contributing to the collection of heavy materials in any way but many so-called 'economy' boxes are sold in this configuration and the material needs to replaced with real mesh in order for the sluice to perform properly.

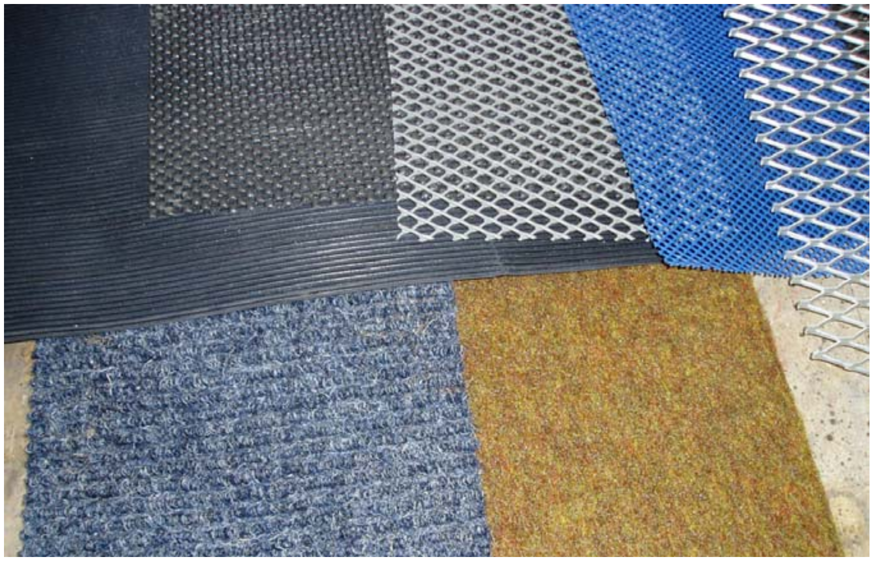

Figure 2

In the lower portion of the picture is a section of 1/4" grooved indoor-outdoor carpeting which also comes in a variety of colors and to the right is a segment of regular un-grooved indoor-outdoor carpet.

We also used the regular old standby of 'Miner's Moss', which is 3M brand 'Nomad' traffic matting in both the un-backed (#8100) and backed (#8150) versions.

We have friends who have made composite mats by layering several types of fabrics and then sewing or stapling them together at periodic intervals. One of the things we've seen used successfully consisted of layered 'crochet mesh' over course-weave Scotch-Brite abrasive pads which appeared to be especially effective on fines.

We also want to look into using the small modular range hood filters made from very fine layered expanded aluminum mesh since these units come in sizes that are perfect for sluice boxes.

With respect to mats in a sluice I seriously doubt if anybody has exhausted the possible combinations of various materials, used either alone or in combinations of multiple layers, so what we ended up using in these tests is in no way exhaustive and really should be another separate test that somebody decides to undertake.

There have been some excellent tests of various matting performance posted at the more popular discussion boards so readers need to do their own homework in digging out these reports based upon people's first hand experiences.

In depth independent research accounts for at least 75% of the work a successful prospector performs in his or her endeavors.

The one thing we observed when using any type of matting is that you absolutely must have some way of stopping the flow of captured materials once they enter the mat due to the continual water flow that runs inside or beneath the matting. The more ‘open’ the weave of the material the more important it is to control the flow. Using a mat with an impervious backing will not stop this slow migration of at least portions of the heavy materials that will eventually exit the sluice. I call this flow in the very bottom of the sluice or actually inside the matrix air space of material like miners moss the ‘under-flow’ and in miner’s moss it can be significant depending on what weave and thickness of material you are using. There are many materials out there similar to Nomad fabric that are not nearly as dense so you have to be careful about what you select.

We found that the simplest way of minimizing the effects of this under-flow is to install small (1/16 to 3/32-inch diameter) rods running transversely about every 6-inches on center in the bottom of the sluice. These rods can be welded in place or just secured with J-B Weld or some similar epoxy. The rods basically act like small ‘water-stops’ or ‘gasket-bars’ between the matting when it is compressed by pressure on the riffle assembly sidebars. In effect you’re creating small pockets beneath and within the matting that act almost like tertiary collection troughs. The rods are extremely effective in slowing both the quantity and the velocity of water running through the mat material. Ideally the rods should be placed in a position that is directly under a riffle. Even a small piece of wire, like a section of coat hanger, under the riffle has been proven to reduce the underflow of fine heavy materials.

Alternatively the 1/8 or 1/4” V-groove matting can be used on the bottom of the sluice under other types of mats and the ridges in the material behave much like the rods in creating mini water-stops as the upper mat is compressed by the riffles and sidebars.

If you get really paranoid about losing ultra-fine material that’s washed down inside or under the matting you can copy the concept of the Wolf Trap sluice and actually create a low lip on the exit end of the flume and use the gasket rods and v-groove matt under the Nomad. Beware however that doing this will cause the box to load up much faster so you have to do cleanups more often. Also keep in mind that the thicker layers of matting, especially relatively ‘open’ materials like Miner’s Moss will contain a significant amount of both water and concentrated materials and as a result will require more water volume and velocity to operate properly compared to denser matting such as Ozite carpet.

We found that Nomad and similar ‘spaghetti’ type mats required at least 15% more water volume than carpeting. In the range of flow rates we tested this equates to 5-15gpm more flow at any given sluice slope.

Ninety percent of the tests we conducted were done in a bare aluminum sluice with no matting of any kind being used and as long as there was sufficient water flow to keep the concentration vortexes operating we lost very little material due to running a bare box. I found this to be quite interesting and it points out the fact that matting actually doesn't aid in concentrating and consolidating material but acts instead more like an entrapment element that helps to prevent particles from be scoured or saltated during periods when the water flow changes or is interrupted, disrupted by a fresh load of gravel, or is stopped completely at shut-down.

This observation just helped to remind us that it's the water flow combined with the settling rate of heavy materials, aided by centrifugal vortexes, if using riffles or expanded metal mesh, that collects and concentrates the heavy materials. There seems to be a popular, and ongoing, misconception that matting acts like a filter or sponge that collects the heavy materials as they are washed down the sluice run and this effect is indeed present but to an extremely minor degree in a sluice box. It is the expanded metal mesh or riffles that actually provide the turbulence that concentrates the heavy particles and forces them down into the mat as mentioned earlier.

Keep this in mind as you're designing your own sluice, as even the best underlay will not make up for a poor box design or improper water velocity.

Test Data Collection

Water Flow Notes

Prior to actually performing any testing on the riffle designs I wanted to take a much closer look at overall water velocity and volume in typical sluice designs including conventional stream sluices, power sluices (high-bankers) and suction dredges.

To measure water flows we used a small digital water meter taken from my swimming pool pump and as a back check additionally used a digital stopwatch to measure the flow rate into a calibrated 5-gallon bucket. Flow velocity was calculated mathematically. The statistical data of the clean-flow recordings are included for reference in the appendix.

I used Manning's Equation to calculate the 'idealized' (no riffles) flume flow rates shown in the attached tables (Tables 3.3 thru 3.6) and checked the actual field measurements against these results. I was pleased to find that flow data taken from field measurements were extremely close to the calculated flow data so I feel that the water volume/velocity data provided herein is sufficiently accurate for typical gravity/centrifugal concentration device comparisons. In total we recorded the readings of over 100 test runs, which I think is probably the largest sample ever done for small sluices so I hope others can use this information when they are designing their own boxes.

Flow data for streams and rivers was derived by actual field measurements at specific sites using a salvaged sailboat Knot-meter and also obtained from the Departments of Fish and Game and Bureau of Land Management for specific rivers. The variation from place to place on any specific water course can vary radically but on average the flow velocity in most places (in California) a prospector will be likely to set up a sluice is about 2.9 feet per second. This is about human walking speed for reference, about 2 miles per hour. The lowest recorded was 1.2 fps on the flats at Bear River Campgrounds and the highest was 9.33 fps on the American River at Mineral Bar just downstream of the rapids.

I found that there is a definite relationship between *flow velocity* and the ideal riffle height/style with respect to vortex creation and the size of the downstream vortex regardless of water volume but unfortunately I don't have the sophisticated level of flow velocity testing devices needed to accurately document these findings so this is an area that needs much more investigation. We could accurately measure volume but had to calculate velocity so I would very much like to see some direct velocity measurements in future testing.

What I found to be especially interesting with respect to general flow through a typical sluice box is that most gravity feed stream sluices are set up with far to little flow and velocity to work properly and that most store-bought power-sluices (high-bankers) are set up with far to much flow and excessive water velocities.

Tables 3.3 through 3.6 tabulate the various clean flow depths/velocity/volume with respect to sluice box slopes. The old traditional rule of thumb for establishing the *minimum* laminar flow in a box is to have 2-knuckles (around 1.5 to 2") of water depth from the bottom of the box. This generally equates to about .75 to 1.25-inches of laminar flowing water moving over the top of the riffles.

In the 72 instances of sluice box operations that I had a chance to observe over the summer virtually no operator had this much depth of cover over their riffles. I think this is due to the fact that the importance of having non-turbulent laminar flow in the box has not been stressed enough in most general purpose sluice set-up articles. For this reason many people think that just having enough water to move the larger pebbles is adequate even if there is no deeper laminar cover in the box (except at the deep end which is almost unavoidable).

Keep in mind that the depth of the laminar flow should be measured in the area of the slick-plate as the riffles act as miniature dams and will hold back and pile up the water due to back-pressure in the small ponds between the riffles so you'll get a false idea of the true water depth if you measure in between the riffles.

In some respects dredges or hybrid types of power sluices which use suction hoses or jet logs have a distinct advantage over other types of sluices in that they can take advantage of significantly increased water flows even when using relatively small pumps and this is because they obtain water from not only the pump discharge hose but also from the water being sucked up the sluice suction hose. The distribution is about an even split in most instances. For example a small suction type power sluice may be getting 50gpm from the pump discharge but it's also taking in around another 50gpm from the stream through the suction side so the combined water volume at the crash-box or jet flare is around 100gpm that reaches the sluice.

Source Material Processing Capacity

There is wide discussion about feed rates and the maximum capacity of various devices by equipment manufacturers but I found that most of these rates are greatly exaggerated.

To create some test data that I knew was going to be factual I started by measuring the work done by an average prospector using a No. 2 shovel to simply fill buckets with loose gravel and that works out to only 10 gallons per minute by volume. If the material is gravel intermixed with larger pebbles, stones and cobbles the digging rate goes down rapidly. If the material needs to be classified the bucket rate goes down even further and faster.

Since 1 cubic yard of material is roughly 200 gallons by dry volume it would take an average prospector about 15 minutes to process a cubic yard if the digging conditions were ideal. Interestingly enough I found that this is almost the exact same figure used by excavation contractors when estimating hand dug trenches. (One cubic yard of gravel is approximately 150 shovel loads of material using a standard number 2 shovel).

In the field we found that in reality this takes about an hour under average conditions and digging in material that contains some larger rocks that have to be dislodged and discarded by hand increases this time significantly. At one especially rocky spot it took us almost 3 hours just to dig and classify about a yard of material.

In general it would be appropriate to estimate that one man can dig about one cubic yard (200 gal.) of material in any given hour of time and classifying this material takes almost the same amount of time so for any given 8-hour shift the typical miner can only prepare about 4 cubic yards of material by himself. Many ‘mining’ writers like to pretend that an average guy can process 8 cubic yards per day but this is highly unlikely in reality unless one doesn’t do any classification of the raw materials or the digging itself is extremely easy, which it usually isn’t. In rough conditions this might actually work out to only 2 cubic yards a day.

Having a sluice or high-banker that can handle an input of 2 cubic yards per hour doesn’t seem to make much sense if you’re only able to dig 1 cubic yard an hour unless you have a multi-person crew.

Next I measured the time it takes for an *average* prospector to *properly* feed a typical stream sluice like the Keene A51 which seems to be very popular. Interestingly this works out to about 15 gallons (2.01cf) by volume of dry gravel per hour. This is about .25 gallons per minute. Using this figure it ends up that a guy working by himself can really only properly process, from start to finish, about 120 gallons of gravel (16.08cf) per 8 hour day. This is just slightly more than one half of a cubic yard per day. This doesn’t sound like much until you realize that this quantity of material is roughly equivalent to working about 120 pans by hand.

Note that I have italicized the words *average* and *properly* in the foregoing paragraph as feed rates vary wildly from one person to the next. The figure of .25 gallons per minute (15 gallons per hour) is the average of what we observed from scores of samplings recorded over the summer for stream sluices that ranged from a high of 5 gallons per minute to a low of 5 gallons per hour.

Small power sluices like the ‘Gold-Buddy’ and similar electrical pump operated devices only have slightly increased feed rate capacity compared to the stream sluice since they to are usually hindered by available water flow rates from the pumps.

Even if you have a two-man crew the bottleneck in the system is the feed rate at the sluice itself if you’re trying to run a small-time production operation. The solution to the problem is to run multiple small sluices or one much larger box, perhaps one made in segments so it’s easier to pack into a site. Multiple sluice boxes are actually a more effective solution. No matter how fast you can shovel material the box will only process it as fast as the water volume/velocity allows. If you out-shovel the sluice flow rate you’re just flushing gold down the river for somebody else to find.

Since a stream sluice is primarily hindered by the volume and velocity of water it can use many people have started to use what is called a ‘power-sluice’ (high-banker) that creates it’s own independent water supply by pumping from a stream or river at higher velocities and with significantly increased flow volumes and hence larger feed rate capacities. A properly set up power sluice can accept classified material almost as fast as it can be shoveled by the average person so typical feed rates are in the neighborhood of 10 gallons of gravel, by volume, per minute. The actual range is between 5 and 10 gpm depending upon the particular equipment arrangement. This capacity, even at the low end, is about 20 times greater than the capacity of even the best stream sluice or battery powered sluice operation.

In the end it is the proper material feed rate to the entrance of the sluice, regardless of what type it is, that determines how much material a person can process in any given period of time and 8 cubic yards per day is pure fantasy unless you have access to classifying type material feed hoppers, a small crew and small power loaders.

The best we could do this June at Bear River with three men working pretty hard and steadily was 4 cubic yards per day in digging and classifying but we ended up with dozens of buckets of material that piled up waiting on the two sluices and one electrical-pump high-banker we had set up. After a few days we finally worked out a system where one guy digging and classifying could keep two small 8” high-bankers or four Keene stream-sluices in operation without much trouble.

Keep in mind that these figures only apply to manual stream sluices or small electrical pump type high-bankers, which is what we were trying to study. Running the larger capacity gasoline powered high-bankers is another story altogether and the riffle designs we cover in this test may not even be applicable to high water volume equipment.

Classification

We talked about the importance of classification in Part II of this article but I cannot over emphasize how important this simple step is towards improving the gold recovery of all sizes but especially for the finer flakes and flecks.

Many people don't realize that classification by itself is nothing special but it is absolutely critical with respect to allowing materials to become properly stratified in whatever water flow is available to the stream sluice. The less water volume and velocity one has available the more important classification/stratification becomes. This single fact is probably more important to gold recovery than any other single factor. Ironically however it is the one thing most amateur prospectors almost completely ignore as they shovel unclassified bench run material directly into their sluice boxes.

It is absolutely imperative that the slurry become stratified before it hits the recovery area whether that area is mats, meshes, riffles or any other combination of catchments. In order for the stratification to be realistically successful in the short distances found in most modern sluices classification is critically important. You will get tired of hearing me say this over and over again but as I mentioned already in several places classification is the 'secret' to effective recovery as without it stratification is almost impossible to achieve unless you have a really long slick-plate area, in the neighborhood of 16-inches long as a good starting point. The 12-inch plate we used for the tests generally was to short for ideal stratification.

Running a high-banker, even one of the small battery-pump models saves a little time over a stream sluice as you can feed raw material directly into the grizzly basically bypassing one step since the grizzly classifies as it's being fed. MacKirk makes a stream sluice based on this same principal but I haven't used one so I can't say whether it is effective or not.

Flairs and Stream Sluices

I measured the flow differences between standard non-flared sluices and those equipped with flares on the upstream ends and found that in general the use of a conventional flare will increase water flow velocity between 20 and 40% depending upon the size of the particular flair. The use a short 'scoop' type flare as seen on my prototype sluice can increase flow velocity by up to 60%, which is more than I anticipated when I built it.

In streams or river having relatively slow flow velocities the use of a flared intake is almost mandatory to achieve flow velocities necessary for the creation of the concentration vortexes behind the riffles and a ‘scoop’ type flare is far more effective in this endeavor.

Our tests indicate that most sluices equipped with riffles of any size only just barely begin to perform effectively at flow rates above 3.25 feet per second and that rate requires that the source material be screened down to at least number 4-mesh and 8-mesh at this speed is to be much preferred. A velocity of 4 feet per second, which equates to a flow of around 76gpm in an 8-inch sluice, is the minimum we found needed to operate riffles satisfactorily. This is approximately equal to 100gpm in a 10-inch box like the Keene A52 for instance. These are minimum figures and much higher flow rates really need to be created to optimize riffle performance.

Optimum Sluice Feed Rates

The general consensus, based upon a review of twelve studies concerning sluice and riffle design is that the optimum feed rate or feed ratio is very near 8:1 (water to gravel by volume) in a non-riffled sluice that only uses expanded metal mesh as a trapping element and 16:1 in a system that utilizes conventional solid riffles of any particular style. It seems relatively obvious that a sluice designed for both fine and course gold recovery must run somewhere between these two ratios or around 12 gallons of water per 1 gallon of classified gravel per minute or an 8% slurry.

If you search the Internet you will find various ‘experts’ who claim that a ratio as low as 4:1 is perfectly acceptable for sluices but I find such claims to be highly dubious since it was discovered long ago by mining engineers way back in the days of the 49’ers that the slurry should never contain more than around 20% solids (5:1 ratio) and as time progressed this ratio has been altered a little every decade as more and more becomes understood about fine gold recovery.

The 12:1 (water to gravel by volume) ratio is what we have tried to use for most of the riffle tests that follow.

You can estimate how much gravel you can feed the sluice or high-banker by using the data in Tables 3.3 through 3.6 which tabulates water flow for various slopes and depths of laminar flow. For instance lets assume that we have a 10” wide sluice set up to slope 1” per foot and we have 1” of water depth from the bottom of the box measured on the slick-plate. Looking at Table 3.5 for 10” sluice we see that the total minimum water flow under these conditions is 192 gallons per minute at 6.45 feet per second. If we want to maintain a 16:1 feed ratio we can supply gravels to the sluice at the rate of 12 gallons per minute (192gpm/16=12) or almost as fast as we can shovel. To run a ratio of 12:1 we can feed gravel at the rate of 16 gallons per minute. This would be a two-man operation. At an 8:1 ratio the gravel feed rate is 24 gallons per minute, which is pushing it even for three men feeding the box. The key here is the overall water volume flow rate of 192 gallons per minute which very few stream sluices can achieve without flairs and in some cases even velocity dams made from local rocks.

In reality the actual feed rates in the field will be approximately 25 to 30% less than these hypothetical figures because the gravel as it is added will slow the true flow rate significantly as the materials work their way past the riffles.

For a sluice to be effective it has to have both high water volume and velocity otherwise you cannot feed it fast enough to sustain an economically viable operation. Running a slow moving stream of water down the chute in an effort to catch ultra fine gold won't pay for your trucks fuel expenses. This is the single biggest failing of small sluices designed exclusively for fine gold recovery, as they cannot be operated in a high throughput or high volume manner.

Of course these are just theoretical numbers that represent a mathematically 'perfect' situation that seldom actually happens in real life.

Keep in mind however that flow rate and feed rate can have extremely wide variations and still be acceptable. These two variables are influenced by material size, gravel shapes, slit and clay composition, sluice slope, riffle size and water velocity.

Another factor that usually doesn't come into play with stream sluices but might be experienced with High-Bankers is Slurry Density Factor which is primarily dependent on the composition of the material you're feeding the box.

In some locations and under some circumstances you might find yourself feeding material that has a very high specific gravity in comparison to what is considered 'typical; which is quartz particles having an SG or around 2.3 to 2.7 but if you happen to hit on a run of raw material that is made up of heavier minerals with an SG of 3 or greater, like massive amounts of black or red sand for instance, then you need to cut down on the feed rate or increase the water volume significantly.

Sluice Sizes

I have mentioned that as I was building my original sluice as described in Part-I of this article I began to have second thoughts about it's size but after using it I was glad I stuck with the 8-inch width and didn't make it wider. After running these tests I am even more satisfied with using an 8-inch wide sluice as compared to a wider box.

Friends told me that I was hindering myself since I can't run a lot of material in a narrow box but based on what we experienced this summer we came to the conclusion that sluice width is not one of the critical factors in performance or processing capacity, up to a point, and that is where one switches from a stream sluice to a power-sluice.

As long as a person is shoveling material into a sluice of any type an 8-inch wide box readily accepts a shovel load of material just as efficiently as a 12-inch wide box but actually washes and stratifies that material much more effectively. In fact I'd go so far as to say that for a manually operated sluice the narrow box outperforms a wider box in almost all respects.

An 8-inch box not only easily accepts a full shovel load of material but it uses almost 25% less water volume to process that same material load compared to a wider box if we look at water velocity between various box widths. For a stream sluice this is an important consideration since we're usually very limited from a velocity standpoint and velocity is what actually gets a set of riffles operating properly. It is water velocity that actually does the work in a sluice far more so than water volume and narrower boxes naturally have higher velocity than a wider box given identical water volumes.

Narrower boxes also have the advantage in that they can be made much shorter than wider boxes due to the effects of material distribution as described in the following section.

Material Distribution in the Sluice

It's long been known that for optimum sluice operation the materials need to be feed at a uniform rate and at a uniform distribution across the width of the sluice. In a stream sluice or small power-sluice this isn't possible since we're feeding the raw materials manually but there are a lot of things that we as operators can do to improve the situation.

One thing is to use a small spade or even a trowel to feed the material and the other is to attempt to distribute the material as evenly and slowly as possible into the water flow.

Unfortunately few people actually do this and typically prefer instead to just dump shovel loads of material directly into the sluice or high-banker hoping to maximize recovery by maximizing material throughput. For fine gold recovery in short sluices this is almost an automatic formula for failure.

Ironically this procedure is actually perfectly fine however as long as the particular sluice has a long slick-plate length and is long enough in overall length as you'd find in a commercial operation. Unfortunately most modern carry-in type sluices are extremely short.

To illustrate what I'm talking about I took some photographs of typical shovel-loads of material that a person might feed into a sluice. Using a standard number-2 shovel a full load of material dropped onto a flat surface looks like the pile shown in the following snapshot.

Figure 3

This pile of minus 1/2-inch material is about 2.5-inches high, 6.5-inches wide and 10-inches long. By volume it is .14 cubic foot of material and is typical of a load we'll get with a number 2 shovel that most of us use at our sites. The material seeks a natural slope of 2 to 1, which is typical of almost all gravels and organic materials like regular old dirt.

When we toss this load into a sluice it is almost impossible to get it arranged in a perfectly symmetrical pile so more often than not the box gets loaded in a somewhat asymmetrical fashion as shown in Figure 4 below which is just one example of perhaps millions of possible piles that a person can end up with.

Personally I find it pretty funny that so many people at the discussion boards claim that a person can't shovel into a small 8-inch box and that a big hopper is needed when none of people we worked with in the field this summer had any problem at all hitting the mark with their loads on our small sluices.

It's also interesting to note that an average person shovels at the rate of one scoop every 5-seconds and that an average sluice processes that load about every 5-seconds so why make the equipment larger, bigger and heavier than what is actually needed to process the material if it's being fed manually?

In the Industrial Design trade this type of product concept is called 'human-scale engineering' and it is sadly lacking with respect to mass-produced small-scale mining equipment where overkill and overweight seems to be the answer.

Figure 4

Flowing water of any kind and at any velocity will eventually erode this pile and naturally attempt to stratify the material so that it conforms to the contours of the water stream as the load moves forward down the confines of the channel, which in this case is our sluice box.

Figure 5

In Figure 5 you can see where an introduced water flow is eating away at the pile starting at the edges but if you look towards the end of the sluice you can see that the flow is trying to naturally distribute the piled material uniformly across the entire width of the box even though it is grabbing materials predominantly from the right-hand side of the pile where the water had a clearer flow path.

Water flow will naturally try to organize any solids into a uniformly distributed horizontal load within the confines of a flow channel and it will also attempt to stratify that material into several layers as well.

Figure 6

In figure 6 you can see where the pile eventually collapses due to wetting and undercutting and starts to move down the sluice in a fairly uniform fashion, side to side, except for a small ‘tail’ on the leading end of the pile where the largest and heaviest pebbles have accumulated.

Notice that it has taken the entire 24-inch length of our test sluice to break down the initial pile of minus 1/2-inch materials before it has become a single stratified layer of material running down the sluice. This is why a long slick-plate area is so vital to sluice operation and the longer the better. From our tests the length of that plate area is 16-inches minimum for material screened down to a number 2-mesh and 24-inches minimum for larger materials.

The exact length of the slick-plate is largely dependent on how fine you screen the materials and on how high the water velocity is that you’re running through the sluice. Our figures are in my opinion minimum values.

Figure 7 is a snapshot that was the sixth frame in this time-lapse series taken at one-second intervals. It only took six seconds for a 10gpm flow running at 4fps to erode the initial pile of materials. The distinctive 'V' shape of the remaining materials illustrates how water will always attempt to follow a uniform course down the sluice even if the material load is significantly asymmetrical.

Figure 7

The remainder of this residual gravel was eventually washed down the box, a few pebbles at a time, in another three seconds. From start to finish it only took 9 seconds for this very slow flow to completely wash away a relatively big pile of materials containing many large pebbles that in real life we'd never even consider loading into a stream sluice.

The distinctive pattern of this residual gravel perfectly illustrates what is called the 'parting-angle' or 'separation-angle' found in flowing water. The phenomena was first observed and recorded by Naval Architects back in the early 1800's. The parting-angle is always between 12 and 15 degrees depending on water velocity. This phenomenon has been utilized in the design of some of the newer generation of 'plastic' sluices to improve flow performance where 'velocity' ledges, lips, ramps and shelves have been molded into the sluice sides in an attempt to make the flow more uniform across the entire width of the box so that boxes can be made shorter and still provide adequate stratification across the entire box width.

In a similar fashion some builders have been experimenting with boxes that have convex or concave bottoms and/or convex or concave riffles and I agree that this is the direction that we need to be going to improve box performance but right now most of us home-based builders are kind of stuck with just making simple stuff work as best as we can.

From what we observed the parting-angle is one of the elements that determines how long a sluice needs to be. For an 8-inch wide sluice, as mentioned earlier, you need at least 16-inches of slick plate area to permit complete stratification of materials. For a 10-inch sluice this area needs to be at least 21-inches long and for a 12-inch wide box the slick plate needs to be a minimum of 26-inches in length otherwise stratification will be incomplete by the time the gravel load hits the capture area. Of course longer lengths are preferred especially if you're feeding raw bench-run materials but our tests indicate that these lengths work very well with 2-mesh and finer source gravels.

Power sluices and dredges can get by with shorter slick-plates since some stratification occurs in the boil box and/or flare sections

The 'capture' area of a riffled sluice can actually be fairly short in comparison to a sluice that only uses mesh over moss or carpeting. From evaluating other studies the riffled capture area of boxes that work best seems to be around one square foot per every 100 gallons of total water flow per minute. In other words for a box designed to handle 100gpm of flow a riffle section containing 1 square foot of total area is near optimum. Using this rule of thumb usually results in a length long enough for a run of 6 to 7 riffles after the slick-plate and will give you around 96-square inches of net clear deposition bed in an 8-inch wide stream sluice. For a power sluice this length and the number of riffles can be increased by 25% for better results at higher flow velocities.

It is tempting to build sluices wider in an attempt to increase the area of the riffled collection area without making the sluice longer but keep in mind that adding only 2-inches to the width of a box increases the collection area by only 20% but will require the use of 50% more water flow to maintain the same velocity and it is the velocity that provides the energy to drive the riffle vortexes. For this reason it is always better to make the box longer if more collection area is needed and not wider.

Another minor thing that we observed is that a separate 'mesh and moss' fine gold collection area as seen on many combination type sluices works much better when it's placed on the downstream end of the sluice after the riffle run and not ahead of it as seen on some commercial boxes but you need to provide another slick-plate between the two sections.

Material Distribution at the Source

Many people have the mistaken idea that their source gravels contain a relatively uniform distribution of gold but savvy miners know that this isn't so and that every bucket run will contain a significantly different amount of gold and other heavy materials.

Gold tends to be found in placers distributed in layers, streaks or pockets that all include a certain amount of float or fines that are more evenly dispersed in the beds. For this reason it is not at all unusual to be running 5-gallons of material that contains almost no gold while the next bucket might contain a lot of gold only to be followed by another bucket load that contains no gold and the cycle can go on continuously.

Under these conditions, which are very real to all of us who are moving a lot of materials at a site, the sluice gets loaded and packed with a lot of non-productive silts, sands, ultra fine gravels and black sand in between getting a load of gold bearing materials. How effective the sluice is in handling these various productive and non-productive bucket runs depends on fate more than anything else as this is simply something beyond a scientific solution at this point in our sluice building technological curve.

I can do test runs here at home that show remarkable recovery results because I'm in total control of the source materials and almost always run a nice clean box with fresh unpacked mats. This is one reason I'm especially suspicious of equipment tests published by equipment manufacturers who perform tests in similar controlled conditions.

Under real life conditions in the field you don't have much control over anything, especially what type of materials you're digging and feeding into your sluice box and for this reason you really need to learn how to 'read' your box and determine when it's time to do a recovery cleanup or just flush it out completely.

It is this unequal distribution of gold in source gravels at any particular site that accounts for about 99% of the confusion and performance claims about various types of sluices. Two guys can buy identical boxes and be working 20-feet apart on a typical stream and one guy will end up loving his box while his partner ends up stomping his box into the ground at the end of the day. Both sluices perform identically but have processed very different areas in the stream bank.

For this reason what we want to build is a sluice that can handle the silts, sands and other nuisance types of materials yet stay unpacked and relatively clear so that it can process and concentrate good heavy materials when they get periodically introduced. This requires creating a relatively high water velocity through the box at all times.

This philosophy has put me into the 'fringe' category of sluice operators where the current school of thought is to run slow and low in an attempt to collect fine gold. I completely disagree with this concept based upon my own experience but each individual will have to make their own determinations based upon the characteristics of the equipment they happen to be using.

Sluice Myths

Before we go much further we really need to look at the all to popular myths surrounding sluice box operations and these same myths are also applicable to the operation of power sluices and dredges. Many of these myths have been discussed at the various prospecting forums for many years and have been presented in various professional papers but still largely go ignored by the vast majority of people who actually use sluices on a daily basis. For this reason we really need to revisit these myths and bring them back to the forefront once again as they are critical elements in the process of how we use and evaluate sluice operations.

The best and most complete list of these myths that I have run across was originally presented in an 1989 report entitled ‘Gold Losses at Klondike Placer Mines’ prepared for the Klondike Placer Miners Association and we’ll reprint them here.

The first myth is all too common and we’ve all experienced this with our own boxes and that is: “I’ve recovered a lot of extremely fine gold, therefore I’m recovering all of the gold particles which are coarser”.

The truth is that almost any sluice box no matter how primitive will recover a certain amount of fine gold even as larger particles get washed away.

The second myth is also all too familiar and that is: “I’m recovering a lot of small nuggets and flakes so therefore I’m recovering all of the nuggets that are larger”.

Actual test samples at numerous sites have shown that this myth is almost universally false as sluices set up for fine/small gold recovery are very poor at trapping larger particles above 16-mesh in size.

The third myth is so tired that we’ve all seen or heard it mentioned about a thousand times on the discussion boards and that is: “ I’ve panned my tailings and found no gold so my box is getting it all”. We’ve talked about this before and other researchers have proven that tailing piles are highly segregated and in their own right very effective concentration devices so to be accurate a person has to pan the bottom of that pile in order to actually sample what the sluice is missing. In other words you really need to re-sluice all of your tailings to actually see how effective your sluice is working and nobody really does this. This is where a small backpack dredge really becomes effective as a re-sampler.

This myth is one of my particular sweet-spots as I very often rework tailing piles left by other prospectors as they are fast and easy to do since the materials are already cleaned and classified just sitting there at the edge of the river. Some of our most productive days have been in working these piles on the Bear River. At one spot we could actually see small flakes in the tailings somebody had left behind so we just hand-panned the pile and it was pretty productive.

The fourth myth is also one of those classics that has been proven wrong by other researchers even though it still persists and that is: “I recover all of my gold in the first few feet or first few riffles of the sluice so I’m sure that I’m recovering all of the gold in my materials”.

This myth is just plain wrong in almost all respects and has been scientifically proven wrong by several researchers but it still lingers on. Basically if this is what you’re experiencing it means that the lower half of your sluice isn’t working at all and that a lot of gold is just being washed away as it’s pushed back up into the laminar flow strata.

The fifth myth is perhaps the most dangerous and that is when a person falls in love with a particular piece of equipment and won’t give it up even if it doesn’t work. They justify hanging on by some weird twist of logic that goes something like: “This is the most effective gear available and even if I’m loosing some gold it is less than if I used some other gear”. Also heard is: “Loosing gold is inevitable but this rig collects as much as is scientifically possible so it is state of the art equipment”.

A good miner never falls in love with his equipment, as there is no such thing as a ‘perfect’ piece of gear.

The sixth myth is that using riffles of any style in a sluice box will automatically guarantee that you’ll be washing away about 50% of all fine gold that is contained in the source gravels.

Like many other myths this is just not factual in reality and has been proven wrong by many researchers. The success or failure to capture fine gold has nothing whatsoever to do with riffles or meshes or capture fabrics but is almost exclusively dependent on proper classification and stratification of source gravels that are run down any type of sluice at a proper velocity.

Riffle Designs

We covered some of the basics of various riffle styles in Part II of this series but this isn’t an exhaustive test of the multitude of various riffle designs but rather a review of the more common types that the average sluice owner might be using or might consider building for their own box. For instance we haven’t tested round bar type riffles that many people are having great success with since this particular type is almost always a custom design and the variables are just to extensive to evaluate as the selection of the optimum rod diameter and spacing can become complicated to say the least. We did not look at the different ‘trap’ type riffle systems that utilize various ‘pocket-slots’ or ‘water-columns’ since again this type of system is always a custom application.

We also did not look at what I can ‘mix and match’ type systems that utilize two or more different types of riffles in a single box even though there are some commercial sluices that offer this provision.

There are literally dozens if not scores of different design schemes that need to be looked at but for this article we wanted to concentrate on the most common riffle types that an average person can build in their own garage over a weekend without spending a lot of money. As I mentioned before this sluice-building project will be ongoing so someday we might have the time to look at some of the more exotic systems and when we do they will get posted for sure.

Method of Riffle Measurements

So that we can compare apples to apples I want to clarify how I measure a typical riffle, which is partially illustrated in the following sketch.

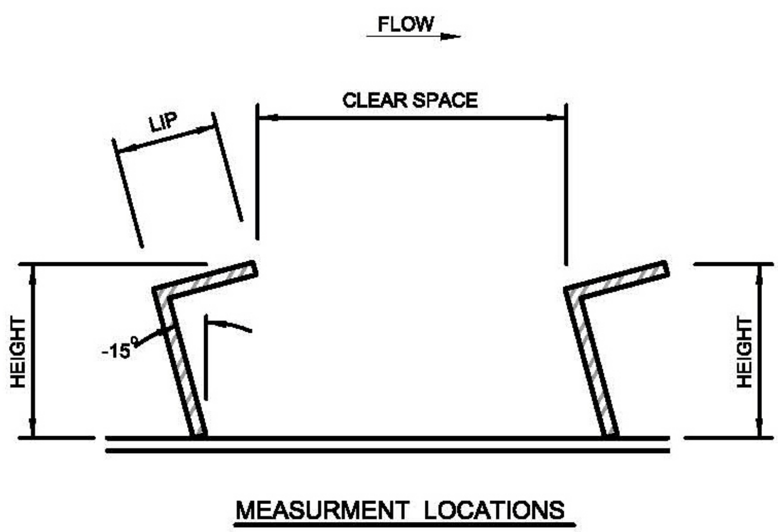

Figure 8

Since most modern riffles have some type of ‘lip’ on the upper end the old method of specifying spacing measured center to center can become problematic so we when we refer to riffle spacing we will always be referencing the distance between the furthermost projections of the riffle. I call this dimension the ‘clear-space’.

Back in the old days this distance was usually between 4.5 to 6-inches but over the years as we’ve learned more about sluices this dimension has been steadily shrinking and today a space of 2-inches is not uncommon. The ‘clear-space’ is usually proportional to the overall height of the specific riffle and tests by others have indicated that a clear space distance that is equal to two times the riffle height performs best. For instance a sluice with 3/4” high riffles will have a clear space of only 1.5-inches, which is much closer spacing that typically found on mass-produced sluices.

When I refer to the ‘height’ of a riffle I will always be referencing the extreme overall height measured from the base of the riffle to the highest point on its projection. As you can see in the illustration the angle or slope of the riffle can cause this dimension to be greater than the nominal dimension of the material being used. For instance riffles made from regular old 3/4-inch flat bar stock sloped at a front slanting 45-degree angle are only about 1/2-inch in height.

We will always refer to the slope of the riffles with reference to the direction of water flow and with respect to the true vertical position. For instance in the illustration the riffles are sloped –15-degrees with respect to flow direction from true vertical. If the riffles were sloped 15 degrees in the direction of the flow the rotation angle would be a positive number. When we refer to a ‘lip’ angle the number will always be in the positive direction up from true horizontal. In the picture above the lip angle is 15-degrees up from horizontal.

Flat Bar Riffles

Back in the sixties when I was first learning about working small placer operations almost all of us were using flat bar riffles made from 1/8-inch steel strap stock set at various angles that ranged from a slope of 15 to 60-degrees off the vertical. At the time we thought this was the ‘hot’ setup and it probably was way back then. This is still the same basic style of riffle provided by most manufacturers today with only minor variations with respect to materials and methods of construction.

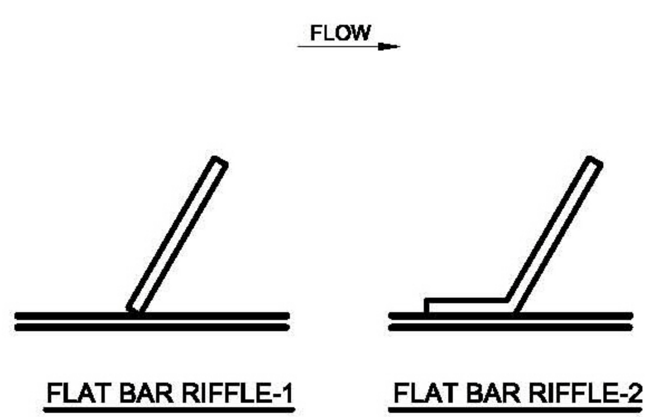

Figure 9

Ironically this particular riffle style has been found by most researchers who have studied riffle design to be about the least effective that one can be using in a sluice box. If this is so then I can't imagine why so many manufacturers are still building this type of riffle assembly unless it is because they are so economical to produce.

I had the opportunity to move to Alaska in 1980 and was introduced to the 'other' way of building riffles, which was utilizing regular angle iron welded in between the side rails. I told the guys they were way behind the times and asked why they weren't using angled flat stock and they took me to an area where they tossed their 'excess' machinery.

I saw dozens of flat bar riffles that looked like they had been beaten with sledge hammers and the foreman told me they switched to angle iron riffles since they handled the source materials better. I found out that their idea of source material was 2 to 3-inch rocks going down the chutes at 18-feet per second. This was an entirely different world from what I had experienced in California and Nevada. Even the reinforced flat bars in wide sluices tended to get deformed over time.

I was also told that they felt their gold recovery was actually much better using the angle iron riffles than it had been when they were trying to use the flat bar riffles.

Even though the experts say that sloped flat bars are relatively ineffective I still have a problem fully trusting in some of the data contained in studies I have read. My personal experiences say almost the opposite of the findings so this is an area we will investigate further. I feel that the flat-bar riffles I use in my own sluice perform just as well as anything fancy but I might be missing something. Hopefully these tests will tell the truth.

Angle Iron Riffles

As mentioned above angle iron riffles and their derivatives may have evolved not from a recovery design standpoint but from the standpoint of economical practicality more than anything else. They are extremely stiff and strong, easy to fabricate, the materials are readily available everywhere and they perform extremely well, even when rather crudely built. Unequal length angles are preferred, meaning angles where the vertical leg is longer than the horizontal flange.

I don't know who first decided to look into slanting angle iron riffles. The first mention of this technique that I've found in print so far came from one of the Yukon Placer Mining Industry reports dated 1978 and then I read about them again in the Clarkson 1989 study.

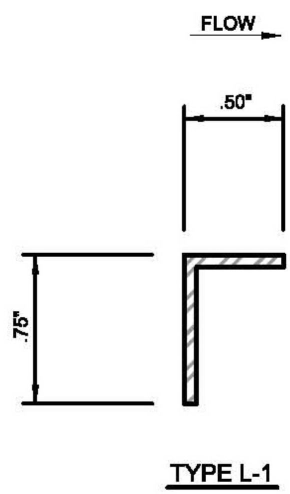

Figure 10

Angle section type riffles can be installed in the side rails in almost any orientation. The most common of course is to be situated in a perfectly vertical position as seen above. From here on out we'll refer to this type of riffle arrangement as the 'L1' style.

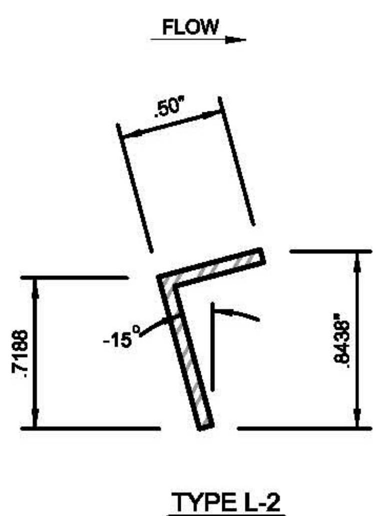

Figure 11

They can also be oriented so that they slope either upstream as shown above or even downstream but the downstream orientation does not seem to provide satisfactory results.

The Clarkson 1990 test report found that a riffle basically oriented as shown above was optimum for his pilot project so it is one of the styles we decided to test. This will be referred to as the 'L2' style as move ahead.

Compound Riffles

In Part II of this article I coined the term ‘Compound Riffle’ that I intended to be applied to almost any riffle that wasn’t either a flat bar or a piece of angle section. One of these compound type riffles is what’s called the ‘Lazy-L’ that is extremely popular today on the higher end sluices, high-bankers and dredges. Basically this design, shown in the sketch below, is a combination of the old traditional sloped flat bar riffle with the addition of the upper lip as found on conventional angle iron type riffles.

Most writers call this type of compound riffle the ‘Hungarian’ style so when you run into that term it typically will be describing a riffle very similar to one shown in Figure 12. Sometimes the riffle may have a flat section of steel on the bottom running horizontally so that the riffle resembles a distorted ‘Z’ shape.

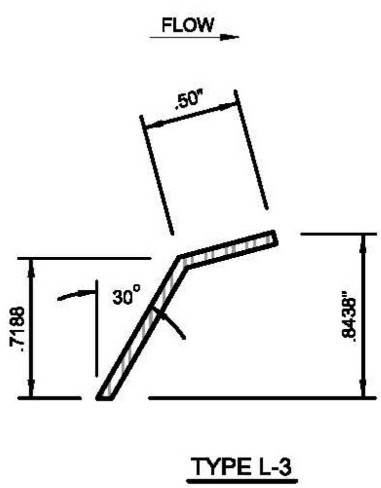

Figure 12

Some manufactures bend the upper lip to where it is parallel with the bottom of the sluice and some keep the lip canted upwards by around 5-degrees. Users say that the version with the slightly canted lip performs better.

We have seen compound riffles with several different bends and lip configurations and users all report excellent results with the various designs so somebody may want to do a study directed specifically at only compound riffle shapes. Our test riffles for this particular style are based on the dimensions and angles shown above including a 5-degree slant on the horizontal lip and will be called the ‘L3’ style riffle.

The theory behind these riffles is that the slanted vertical section will help in clearing larger pebbles with less water energy (like a conventional sloped flat bar riffle performs) while the horizontal lip aids in creating a downstream concentration vortex.

Riffle Construction

Almost all of the riffles used in our tests were constructed by using 3/4x1/8” aluminum in various sectional shapes. The compound riffles were bent from 1-1/4”x1/16” flat stock and we had several sets of regular steel riffles from old sluices made from 1/8” and 1/16” stock. The aluminum riffles were held together using J-B Weld epoxy since it allowed us to re-use the riffles at different spacing just by breaking the bond at the side rails. In total we built and tested 23 different sets and then simply ran out of time and patience far before I was actually satisfied with testing the various combinations of designs.

To anybody else who might like to do a similar study I strongly recommend having access to a fabricator who can build the riffle sets in quantity using some types of jigs as doing one-off custom riffles is very time consuming and also fairly expensive. We were on a very limited budget and exceeded our expenditure limit by about 500% but the riffles are not wasted as we’re going to weld up the final selections and use them in a production operation next year.

Figure 13

Figure 13 shows our little riffle building operation in practice where we’re using a simple wooden jig and using epoxy to set various riffles into some aluminum strap stock side rails. This goes pretty fast but in practice the epoxy on aluminum has severe limitations so we spent a lot of time ‘repairing’ riffles that were un-bonded when we were running high velocity water flow tests. Even a 20% slurry at just 5fps exerts a significant force against a riffle.

The next time I do this type of stuff I'll weld the riffles in place but reduce the number of riffles in any particular bank from the five we tested to a single run of three. I selected to look at 5 riffles during these test primarily to see what effect adjoining riffles had on their adjacent counterparts and doing a run of 3 or perhaps 4 seems to be adequate in hindsight with some exceptions that we'll talk about later.

General Observations

I want to talk about the general things we observed in this section of the article and then the specifics of the various tests in a later section so that that we don't mix up the more technical information with this nonspecific type of findings.

Up until around 1985 most sluice design engineering experts believed that riffles of any style or type functioned basically as velocity interruption devices and caused a slowing in the slurry flow that allowed heavy materials to drop out of suspension due almost exclusively to gravity induced settling rates. In 1986 however George Poling installed a Plexiglas panel in sluice and observed that something else was occurring as well and that under certain conditions a water eddy was created at the riffles that acted as a sort of mini-centrifugal concentrator that forced heavy materials to the bottom of the box between the riffle bars. He coined the term 'shearing particle bed' created by the turbulent eddies he observed to describe what was occurring.

In 1988 Randy Clarkson and Owen Peer took Poling's findings to the next level and actually observed and documented what they called 'concentration vortexes' in between the riffle bars. Their original report published in 1989 revolutionized sluice box and riffle designs.

My own test experience indicates that Poling's explanation of what was occurring is perhaps more descriptively accurate in reality than Clarkson's vortex terminology and we'll talk about that later in this article.

Now that we understand what 'shearing particle beds' and concentration 'vortexes' are and how they operate we can begin to evaluate riffle designs for not only their gravity collection characteristics, which is one functional aspect, but also on their vortex concentration characteristics as well, which are centrifugal in nature.

As we go forward please keep in mind that even the crudest riffles, like those made from sticks and twigs, will collect heavy materials fairly effectively, given enough length of run, but that some designs do it better than others.

Energy Depletion

One of the first things that we noticed in doing the riffle tests, regardless of riffle style, was that there is a tremendous amount of water flow energy lost as the flow passes over a series of riffles. The longer the riffle assembly is the greater the loss of energy and even with a relatively small number of riffles, five as we were using; the lower riffles were almost completely ineffective at lower flows. If the energy was raised to improve the performance of the lower riffles it became high enough that the upper riffles were overpowered.

As water passes over obstructions and/or irregularities in the channel bottom, such as the riffles in a sluice box, energy is lost due to increased friction and turbulence so velocity is reduced in the layers of water closest to the obstructions.

This phenomenon is shown in figure 14 and the flow characteristics can be seen in the areas highlighted by the red arrows where you can see a robust turbulence at the first and even second riffle and almost still water by the fifth riffle. If you look closely at the photo you can see the degradation of water activity at each riffle is relatively uniform and progressively reduced with respect to the overall length of the riffle assembly. We observed this general flow characteristic in all of the riffle styles we tested and at all flow velocities.

When you increase the viscosity of the fluid by adding gravel to create slurry the loss of energy is even more pronounced if you do not significantly increase the velocity of the flow by increasing slope or running a larger volume of fluid.

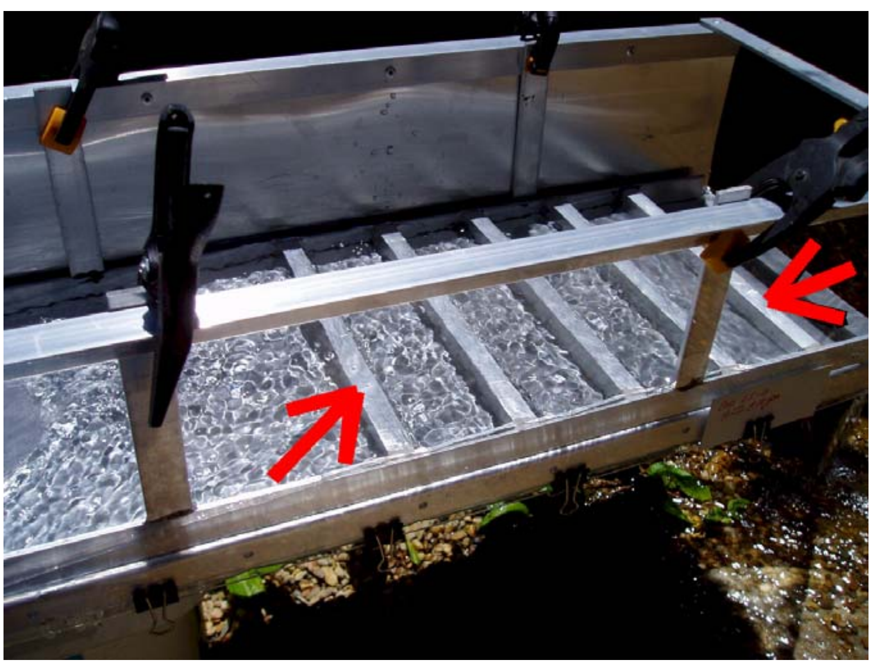

Figure 14

We routinely measured a velocity differential of up to 1.5fps over typical riffle runs of various types from head to tail when running clear and even greater differentials when running slurry so the energy loss can be substantial.

This immediately says two things to me and one is that riffles need to be progressively reduced in height from the rearmost part of the run towards the front and secondly that the spacing must also be progressively reduced in proportion to the height.

A better set of riffles would then look like a mathematically proportional set of stair steps with each bar being slightly shorter and closer spaced as you move towards the outlet of the sluice. This arrangement would take advantage of the reduced energy in the water flow as it moves towards the end of the sluice without creating a situation where the first few riffles became overloaded.

What seems funny to me is that I've seen modern hi-tech commercial sluices that are set up exactly opposite of this finding with the larger/wider spaced riffles on the downstream end of the sluice. I sometimes wonder if manufacturers actually do any research on their products.

This situation is perhaps the major reason that most people see gold captured in the first few sets of riffles in their sluices. It isn't because their riffles sets are all that great but because the lower riffles aren't doing any work at all. Imagine what would happen if each and every riffle in the run was working properly. Our tests indicated that only the first two riffles in any run were actually creating effective concentration vortexes due to this energy depletion and even at relative high velocities the third riffle was still somewhat ineffective.

Some people say this situation is good because it allows the larger pieces of gold to be caught by the first few riffles while the slower flow in the lower riffles allows the fine gold to settle here. That is true if you are relying exclusively on gravity separation but not if you want to collect materials by vortex concentration and this concentration effect is about twice as effective as gravity settlement.

Our test runs indicate that the flow velocity in the riffled area of a sluice can be a full 3 feet per second slower than the velocity measured in the slick-plate area of the box when the sluice is running with a total volume of 100 gallons per minute. To put this into perspective for a hypothetical sluice the first riffle might be receiving slurry at the rate of 8fps, the second riffle is seeing a flow of 7fps; the third riffle is getting 6fps while the fourth riffle is only seeing 5fps and the last riffle might only be receiving a flow of 4fps.
At the higher layers of the overall laminar flow small heavy materials and larger but lighter materials are still moving down the sluice at the original 8fps. By staggering the height of the riffles this 'apparent' flow velocity at the low levels at each riffle face can be increased significantly.

Force and Weight

Most of us, including myself, greatly underestimate how much water and material can accumulate in a typical sluice at any given point in time. Even on our little test box there was about 10 pounds of water in it even at low flow volumes and another 5 pounds in gravel. At high volume runs it was significantly heavier. I think most dredge operators are well aware of this fact but it isn't mentioned to often in discussions about sluices so I just wanted to restate this observation.

What isn't so obvious is the weight caused by the velocity of the water flow against the resistance of the riffles once the box gets sloped much beyond 1 in 12 and this can be substantial. I guess in engineering terms this is the effect of the acceleration of the slurry flow against an obstacle along a particular vector. We often tried to change out different riffle sets while the pump was running and it was very hard to unseat a set against the velocity of the water and at one point we put a fish scale on the forward-most riffle and measured 23 pounds of pressure needed to lift the bar out of the water flow. I think this phenomenon is why it sometimes seems so hard to get a small lightweight sluice lifted up out of the stream. At steep sluice slopes there is a very significant amount of force vectored downward that depends on the slope of the riffles. The force exerted on an object in a water flow is proportional to the face area of the riffle times the square of the water velocity. A portion of this force is vectored downward in relation to the riffle angle relative to true horizontal. Another portion of this force is vectored horizontally and this is what pushes the material through the sluice. As a result there are two components acting on the particles in the slurry, one horizontal and the other skewed off the vertical.

This may be the reason that riffles we tested which had rather steep static slopes (30-degrees from vertical) appeared to retain heavy materials of all sizes better than riffles with the more traditional 45-degree slopes. Sometimes people forget that the static riffle slope measured relative to the bottom of the sluice box, like 45-degrees for example, actually becomes a much more shallow dynamic angle when the box itself is sloped downward in the stream flow.

Our tests indicated that a riffle slope of anything less than 30-degrees up from true horizontal (60-degrees from true vertical) when the sluice itself was set at any particular slope was virtually completely ineffectual.

Ebbs, Surges and Irregularities

During the tests I had the sluice box set up on high legs and wood cribbing so that it would be easier for me to take pictures as I sat on a small stool so I had my face right in the action so to speak and could really appreciate the way water creates hills and valleys in the materials being run down the chute.

Even the poorest of riffles actually performed remarkably well in concentrating the heavy fine materials and sloughing off the lighter stuff and it was amazing to watch the agitating and concentrating action in real time through the Plexiglas panel. It's like jumping jack city when a sluice gets going and you can see the particles bouncing up and down in the turbulence created behind the riffles. We could see the white particles being ejected back up into the laminar flow after only one or two bounces. The red particles would bounce around back and forth far longer before they finally got ejected. The black particles just kept accumulating and getting buried deeper and deeper. It was absolutely amazing to observe the process as it occurred step by step just like all the experts say it happens.

Unfortunately the whole process came crashing down like a house of cards every time we added new gravel to the sluice or there was ebb or surge in the velocity of the water flow.

We also noticed that even the slightest movement of the sluice caused a major disruption in the concentration process between the riffles so we eventually moved the water supply control ball valve from the header box location back on a 6-foot long section of hose that lay on the ground so we didn't move the box when messing around with the water valve.

It was unavoidable not moving the box when a new load of gravel is dumped in and I personally think this slam to the sluice might account for a lot of the inefficiency seen in running sluices of all types. Our recovery rates when up rather substantially when we were feeding the boxes with a small hand trowel so it didn't get banged around with the shovel or jostled around having big loads of materials dropped in all at once.

These periods when the continual flow of water is interrupted or the viscosity of the slurry is increased are like huge slams to the concentration process and it literally has to start all over from the beginning. For this reason it is no wonder that the most efficient recovery systems use a feed hopper that supplies a constant and steady supply of materials. Of course this isn't possible on most small-scale sluices or high-bankers so the next best thing is to create some kind of feed trowel that delivers a uniformly consistent amount of material in each scoop that is evenly spread across the entire width of the box.
I think something like a small flat coal shovel with the handle welded sideways would be pretty good. A small hand-cranked fertilizer type hopper would be ideal but it would slow down the process and just add weight to the equipment.

I also noticed that even slight irregularities in the sluice bottom and lower sidewalls really messed up the distribution of materials. Dents are real offenders. Screws, bolts and rivet heads can be a problem if you're looking for fine material recovery and even small nicks on the edges of the riffles can cause problems.

Figure 15

If you look closely at the snapshot above you'll notice what appear to be silver colored streaks coming out from the edge of the riffles and where these streaks occur the vortex is interrupted and the heavy materials embedded in the mat is ejected back up into the flow. These streaks are actually small jets of concentrated high velocity water created by very small nicks in the riffles that were made during the manufacturing cutting process. It may be a good idea to take a file and emery cloth to the edges of your riffles to make them as uniform and smooth as possible.

Stopping the water flow completely is a disastrous moment in any of the various configurations we tested as all of the concentrated materials are immediately dispersed into the run-out unless there is some provision to catch them. We found that even large disruptions or significant reductions in the flow through the box were not nearly as bad as a complete shutdown of flow. Even very low water flows kept embedded and concentrated materials relatively consolidated but once the flow was completely stopped the heavies just started washing down the chute with the runoff. For this reason we urge everybody to make some arrangement to capture the run-out or runoff as the sluice is shut down at the end of any particular run. The losses of heavy materials can be substantial if you don't collect the runoff at shutdown.

Most experienced sluice owners have developed an instinctive knack for picking the sluice up out of the stream tipped just slightly backwards when first lifted to minimize the loss of the materials but we can't use this type of technique when we're shutting down a power-sluice. For high-bankers and dredges some type of short-hinged lip on the end of the box might be a good idea. A water pressure sensitive spring might even be used so that the lip would be automatically self-closing.

We just put a bucket on the end of the sluice in a kind of simultaneously timed and coordinated shutdown procedure that was sometimes pretty funny to watch in action.

The Finger Test

If you read the gold mining books and participate in the various prospecting forums you'll have already heard about all the different ways of setting up a sluice for proper operation but there is another excellent and almost foolproof way to determine when the flow starts to become optimized. I call it the 'finger test'.

When you initially set up the sluice you can stick you finger down in between two of the riffles and if all you feel is a sensation of smooth water flow the sluice is not working properly. If you increase the slope or increase the velocity of the water down the chute you'll find that you begin to get a sensation on your fingertip that feels like a slight vibration. If you keep fine tuning the box you'll find that this sensation becomes quite pronounced and it'll almost feel like a hundred little fish are nibbling away at your fingertip. When you get to this point and you feel a very vigorous vibration the box should be running properly to begin concentrating materials.

Don't stop when you feel the fist sensation of vibration. Keep messing around with the box until you sense the maximum vibration possible even if it appears that the sluice is at an extreme slope. The vibration is created by flow velocity and if you're running riffles you need this velocity to provide the energy that the riffles will use to concentrate your materials.

In many ways a sluice box is kind of like a small machine or engine of some type and it operates best within a certain power range just like a well tuned car and what you're looking for is that 'magic' performance range when everything just seems to come together perfectly.

Non-Riffled Boxes

There has been a relatively recent fad of using sluice boxes that don't use riffles of any type and rely instead on capture mats covered with a screen of expanded metal mesh. The makers of these boxes intend them to be used in the recovery of 'fine' gold and they do work as promised, up to a point. Unfortunately even the best of these boxes, and we tested 4 of them, are extremely prone to losing materials due to scouring every time a new load of material is introduced into the sluice, especially if the material contains larger stones and pebbles.

We looked at this in detail and came to the conclusion that the materials they capture are collected in the upper-most layer of the capture fabrics and held there primarily by friction, so almost any disruption dislodges them back up into the laminar flow. These are good sluices but without riffles there is no centrifugal force that drives (or holds) the concentrated materials deeper into the capture fabric.

My personal opinion is that such sluices, in field conditions, lose about as much material as they collect but this isn’t necessarily a bad thing as they do a very good job of collecting extremely fine material. The drawback is that you have to work a huge amount of raw materials to make their use cost-effective as compared to more conventional sluices where you can run more material in less time.

I’m sure these boxes have a use a certain sites but even in the areas that we work containing very fine gold we haven’t found them to be very effective as they are extremely slow if operated properly to maximize the collection of fine material. We found that they are most effective, actually extremely effective, if you do a clean up after running only a few scoops of material. Unfortunately this slows down production to a snails pace.

This is just my personal opinion based upon my particular style of prospecting and I’m sure other people will use these devices at their sites with good results so the comments are not intended to be a put-down but rather a casual observation.

Overload

It is very easy to overload any type of riffled or non-riffled sluice and from what we observed it is a common practice even when you’re supposed to be doing controlled test. As stated earlier the box will only process so much material at any given point in time based up the flow velocity. It is extremely tempting to just keep feeding the box hoping for the best but overloading the riffles just guarantees that you’ll loose at least 50% of the gold you’re trying to recover.

Our recovery rate on the test samples went up dramatically almost in direct proportion to how much we slowed down the feed rate to the sluice. Our maximum recovery occurred when we were feeding the box at an agonizingly, almost unbearably slow rate regardless of the riffle type being tested. We could achieve almost 100% recovery of our test pellets and even the fine materials in any situation just by feeding the sluice at a very slow rate.

I mentioned this before but it bears repeating and that is tests done in controlled situations are very different than real world production situations. If you try to duplicate test conditions at the site you’ll be working at a snails pace.

Unfortunately when you slow down the operation to a certain extent you will eventually get to the point where you can actually pan faster and more efficiently than you’re sluicing.

Besides overloading a box by feeding it to fast it is also very easy to overload a box by trying to run to much water through it. As mentioned before this usually isn’t a problem with stream sluices of small electrical-pump high-bankers but it can become a serious problem when running a larger gas-pump power sluices since water is fed so fast that it creates a huge amount of turbulence and interjects a tremendous amount of air into the slurry. Since gold is hydrophobic any small, or even large flat particles, will simple ride down the chute attached to the air bubbles rising to the surface.

Most power-sluices use dredge pumps that in actuality are far larger than necessary and pump at flow velocities of between 26 and 32 feet per second at the header box while even relatively large sluices perform best with *maximum* velocities of 15 feet per second. As you can easily see when the water enters the box it is moving about twice as fast as it should be so in the entire length of the sluice we typically see massive amounts of turbulence, foaming, frothing and air entrapment which is deadly to fine particle recovery. In fact it is almost as detrimental to the recovery of even large particles.

Figure 16

This particular snapshot was taken at random from the net but it is typical of what you'll see at almost any high-banker operation using a store-bough machine and a sluice running in this mode is probably operating at 50% of optimum and wasting a lot of good material.

Riffle Assembly Configuration

It is generally customary to build riffle assemblies with a set of side-rails that are the same height as the riffles. Everybody does this and it's exactly what we did when we built the riffles for these tests but in hindsight I think it's much better to use side-rails that are considerably higher than the riffles. The reason I say this is because we noticed that there is a significant distortion of the water flow at the junction of a riffle where it is attached to the side rail. Using a taller side-rail smoothes the flow at this intersection and also keeps all of the gravel in the trough and not running down on top of the rails.

I realize that this an insignificant thing but it did stand out during the tests as a possible area for improvement in riffle assembly design.

Riffle Shapes – General Observations

Sloped Flat Bar Riffles

In general throughout all of the tests flat bar riffles at virtually any slope failed to generate efficient concentration vortexes and seemed to operate basically as dams to interrupt and slow the water flow just enough so that the normal gravity settling characteristics of the various particles came into play. As a result capture of heavy materials was primarily based upon gravity so retention of fine gold and our test lead shavings was very poor. This was somewhat of a disappointment as I had expected this type of riffle to actually perform much better than it did, especially seeing how popular the design is on many commercially available sluices today. I guess I've been losing a lot of gold over the years.

The one thing that we did notice is that this type of riffle can be very closely spaced to improve performance and the 3.5-inch spacing we found on most production riffle sets can be reduced to 2-inches or even less. The performance improvement on closer spaced bars is significant but still not enough to actually warrant anybody using these riffles in a modern sluice unless you're running a wham-bam operation wanting to run the maximum amount of material in the least amount of time.

We also noticed that flat bars at more upright slopes performed better with respect to vortex creation. In other words bars sloped 30-degrees from the vertical performed better than bars sloped at 45-degrees for example. Even though they are thought to create more turbulence we found that they actually created less and they also created more of a back pressure wave which we found out later is vitally important.

The big advantage of these riffles is that they don't get loaded up even at high feed rates

Clarkson and Peer (1990) found that sloped flat bar riffles create excessive turbulence and that particles rejected at the riffle were ejected high up into the laminar flow stream instead of being transferred downward towards the next adjacent riffle.

Even though this particular style of riffle did not do well in our tests I think it performed relatively well at the much slower velocities we used compared to what Clarkson was using in his test. Even then however at slow flows we saw the same characteristics with respect to turbulence as seen in the following snapshot taken at only 20gpm on a 1 in 12 slope.

Figure 17

If you look at the upper left-hand portion of the picture you can see how the flow typically runs over the sloped flat bar in a rather long and high arc and the riffle to the extreme right in the photo shows some of the turbulence. This particular set of commercial riffles are sloped at 45-degrees which has become almost an industry standard for some reason.

Our custom-made set is sloped at 30-degrees (60-degrees from horizontal) which is how I was taught to build them and even though the slope is more extreme the turbulence isn’t nearly so bad as seen in the image below.

Old habits are hard to break and since I’ve used this type of riffle on and off for about 40 years I’m not yet ready to discard them completely. I think there is sweet spot with respect to slope angle and spacing where these old dogs will still perform well with some experimentation.

You can see by the ‘spatters’ on the Plexiglas that even this set creates a good amount of surface turbulence but little deeper level turbulence compared to what you’ll see in other types of riffles.

Figure 18

Vertical Angle Iron Riffles

The vertical types of Angle Iron (or aluminum angle sections) did not perform much better than the sloped flat bar riffles even though the upper horizontal lip supposedly aids in vortex creation. Up to a point the horizontal lip helps but not nearly as much as I had expected it would. Basically the lip simply increases the length of the vortex in comparison to a sloped flat bar riffle but not the height or intensity of the concentration vortex. The lip on our riffles was .5-inches but I cut one back to just .375-inches and it appeared to actually work a little better.

Clarkson and Peer found this riffle type to be their second most effective in their 1990 report but at the low flows we were looking at I would put them at the very bottom of our selection set. In fact they performed so poorly that I simply stopped testing them very early on in our test series. Basically about all I can say about this type of configuration is that it is ‘unremarkable’ in almost all respects.

I’m sure that they perform at some point but it takes a relatively high water velocity and steep sluice slope to get them to the operational state and we never reached that threshold in our little testing sessions.

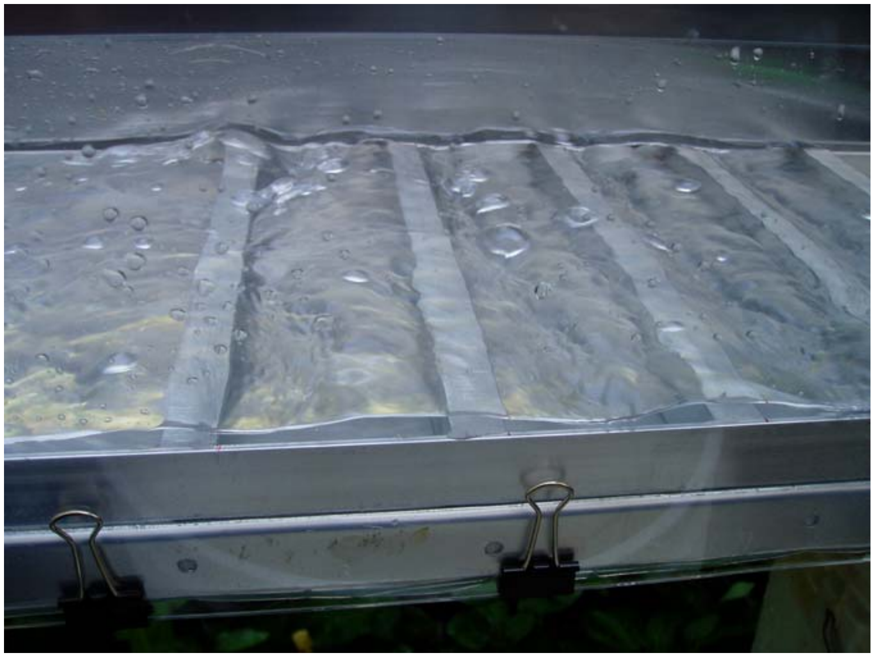

Figure 19

In this snapshot the rearmost riffle looks canted but that is just an optical illusion created by the water pressure wave at the first riffle in the run. In reality all five were identical in orientation. As you can see they don't do much of anything at 30gpm of flow with a velocity of 4 feet per second, which about minimum to get this set of riffles working.

Compound (Hungarian) Riffles

From a performance standpoint I was extremely disappointed in the behavior of the compound riffles since they supposedly combine the best features of all riffle types. I expected to see a visibly significant performance difference between this style and the more traditional designs but in reality the increased efficiency was very slight, almost impossible to measure in many instances. I had expected to see fairly aggressive vortex creation but in reality it was only a minor improvement over the vertical angle type riffle and at some flow/slope combinations these hi-tech riffles actually exhibited less vortex creation.

Despite the sloped ramp on the riffles, 30-degrees from vertical as we used on the conventional flat riffle bars, the compound riffles created far more turbulence than any other bars tested even at relatively slow flow velocities.

The snapshot below was taken running only 20gpm at about 3.75 feet per second on a 2 to 1 slope and as you can see the turbulence was significant, far in excess of anything we had seen in other riffle tests.

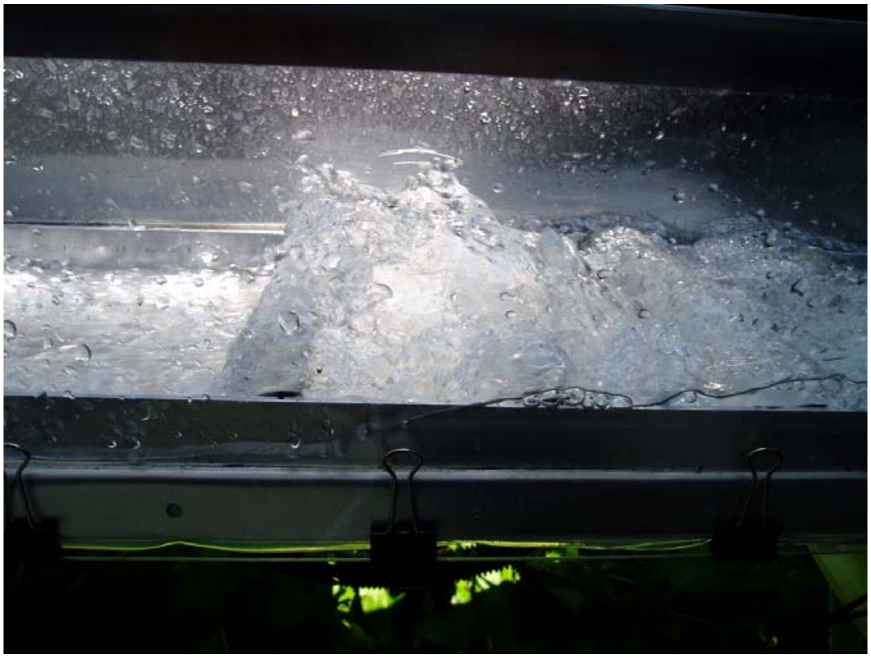

Figure 20

To get these riffles to work satisfactorily we had to reduce the slope to 1 in 12 at which point the creation of concentration vortexes was also reduced as a result.

Figure 21

This particular type of riffle needs to be spaced about 1-inch further apart to reduce turbulence at almost any flow rate but unfortunately when that is done they basically can't generate an effective vortex except at very high water flows and then exhibit all the bad traits found in conventional sloped flat bar riffles.

We built another set of these riffles but only 5/8-inch high, sloped at a more gentle 45-degrees and with the upper lip running perfectly parallel with the bottom of the sluice. I hoped that this would improve performance but it didn't seem to make much difference.

As you can see in Figure 22 the turbulence is just as pronounced as it was with the taller and steeper sloped design.

Figure 22

As mentioned earlier I had hoped that this riffle design would have ended up being the 'perfect' solution for small sluices but from a pure performance standpoint they performed very poorly in almost all respects compared to the old traditional sloped flat-bar riffle type. In fact I could not see that this style offered anything of value over other types we tested.

This particular type of riffle needs a lot of deep laminar flow over the top to aid in dampening the turbulence and if this can be achieved they perform well but basically about on par with other types from a recovery standpoint. We finally got this set to work pretty well running with almost any amount of water over 35-35gpm and sloped 1in 12 or less.

Reverse Sloped Angle Iron Riffles

As mentioned before the first time I heard about this particular riffle arrangement was in the Yukon Placer Mining reports and personally I thought they probably wouldn't work in the low flow velocity conditions of a small stream sluice or high-banker so I didn't bother testing them until last in the series.

This particular riffle style, illustrated in Figure 11, what I have labeled the 'L-2' type riffle, at first glance seems to be almost illogical based upon all that we've been taught about riffles over the years. It appears that the reverse slope into the upstream water flow will just create a huge gravel trap that will rapidly become impacted with material and even prevent smaller pebbles from traveling down the sluiceway but this isn't what happens in practice and I was amazed when I ran the first low flow test with this riffle assembly.

The very first thing that was immediately apparent even at very low flow velocities was that this style riffle builds up a very large concentration vortex that is not only long but also very high and extremely aggressive in action.

The big drawback is that this riffle will not function properly with larger gravels at very low flow velocity and packs up very fast with anything much larger than number 8-mesh materials if the water volume is on the low side. This riffle style needs a lot of fast moving water and a steep slope to perform well. If there is a fault it is that this riffle is to effective and captures virtually everything so it is very sensitive to how and what is being fed down the chute.

At low flows it appears that the space between the riffles gets filled with the larger gravel particles but if you watch what is happening this doesn't seem to effect the operation of the riffles and lighter materials will still keep getting ejected back up into the laminar flow and the heavier particles are driven towards the bottom of the sluice by the centrifugal force of the vortex.

I spent many hours just watching this particular riffle set working and was amazed at the size of the concentration vortex. In the end I came to the conclusion that this design behaves very differently than all other riffle styles and that there are two different components that come into play while other riffles typically have only a single component to their functioning.

During one test run I thought I saw pebbles being pushed 'backwards', actually moving upstream behind the riffles so I began throttling down the flow and reducing the slope until this observation was confirmed. At that point I realized that there is a very significant backwash or high-pressure area created very low on the upstream side of the riffles. No other types of riffles exhibit this trait.

The snapshot in Figure 23 illustrates this phenomenon very well.

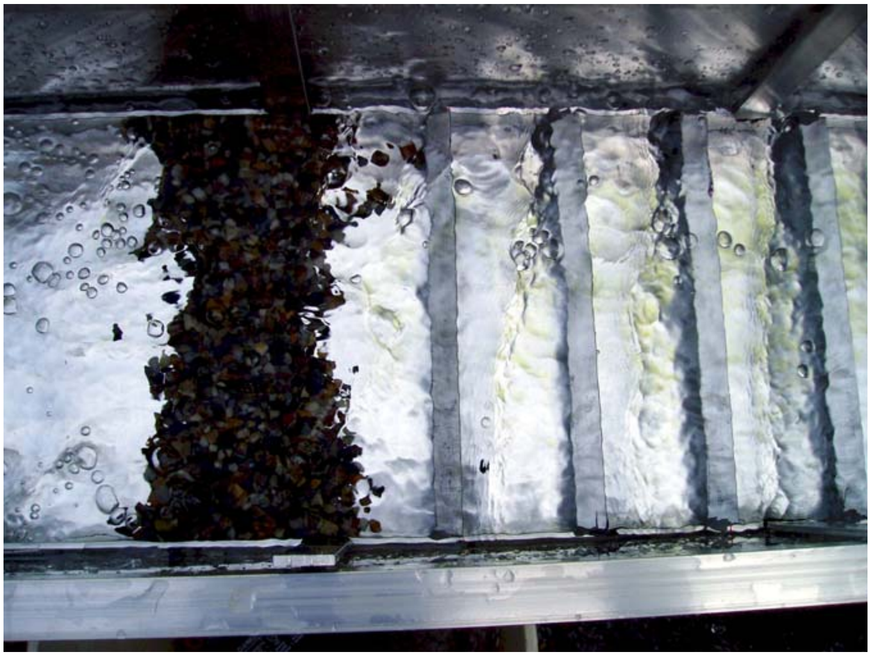

Figure 23

Here I was able to capture what type of action is occurring behind one of these reverse sloped angle iron riffles. We just kept adjusting the water flow and slope of the sluice until we caught this particular image. As you can see there is a very powerful backpressure area behind the riffle that is holding back the small load of ¼-inch gravel we dumped into the sluice. This particular snapshot was taken with just 10gpm running through the sluice at a slope of 1 in 12 inches.

This very low laying, backwards moving, high pressure wave is what contributes significantly to the creation of the rather large concentration vortex on the downstream side of these riffles. In fact it may be the 'secret' to effective vortex creation.

Once we increased the sluice slope just slightly this load of gravel just bounced down the chute but the fines were extremely concentrated between each riffle.

It is the combination of this high-pressure area behind the riffle and the horizontal lip at the top of the riffle bar that contributes to the creation of the concentration vortex. The horizontal lip by itself only contributes a very small amount to the creation of that vortex. I think that we've misunderstood or overestimated the role that horizontal lip plays on any particular riffle design.

The problem with this particular style of riffle is that it is extremely sensitive with respect to flow velocity and material composition so I can't say that it is actually a very good design for a 'general purpose' sluice box.

If the flow and slope are set up properly these riffles work like gangbusters but if anything is even slightly ‘off’ they only function about as well as conventional riffles.

Figure 24

Figure 24 is a snapshot of these riffles in action at 30gpm flow running at only 4 feet per second on a 1 in 12 slope. As you can see they are extremely aggressive in operation compared to the more conventional vertical angle iron bars seen below running at the same slope and flow.

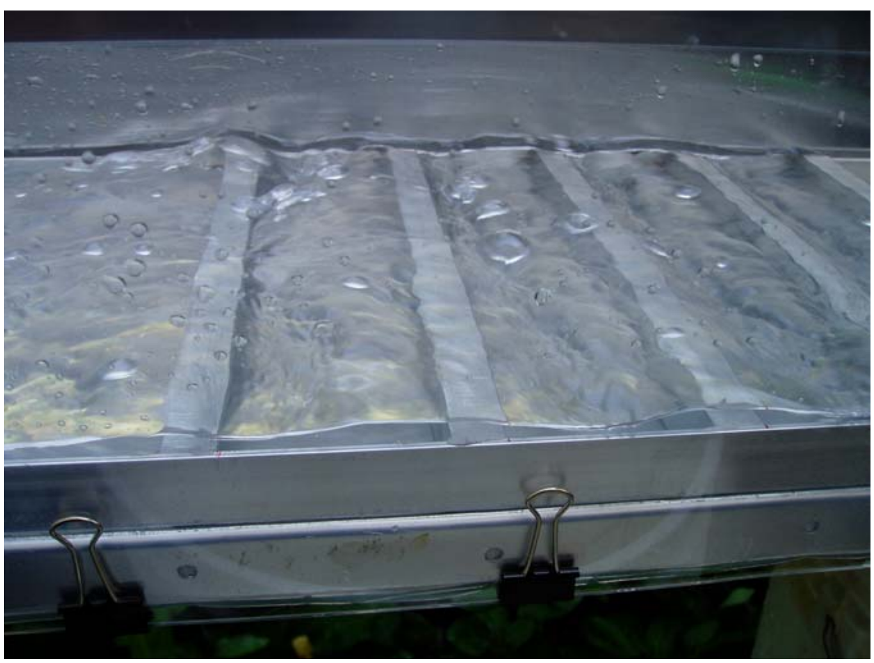

Figure 25

On our initial low-flow tests of this riffle style we felt that the 3/4” aluminum sections were just to tall so we built another set using 1/2” material and ran minus 1/2” gravels down the chute to see how these smaller riffles behaved and they did do better at flows lower than 30 to 40gpm but they were just as effective in concentrating fine materials.

This particular riffle style, at any size, far surpasses any of the other types we tested in their ability to collect and concentrate very small heavy materials but they are hard to get ‘used to’ as the operate very differently than conventional riffles.

I have tried to get a good picture of the so-called concentration vortex in action but it is very difficult and the shot in Figure 26 is about the closets I’ve come so far. I really need an ultra high-speed camera to properly document this.

Figure 26

If you look closely you can see that the water wave passing over an individual riffle appears to flow downwards sharply towards the bottom of the sluice and apparently just disappears instead of just flowing over the space between two adjacent riffles. It almost appears as if the water is being forcefully sucked down towards the bottom of the sluice. Then another wave just seems to be coming up from under the gravel materials and moves to the next riffle. The vortex is situated between those two individual waves deep down between the bars and no other riffles we tested exhibit this characteristic. Unless the box contains a very significant amount of water there actually is any of we’d call upper level laminar flow that runs continuously from one riffle to the next.

In use it will appear that the interstitial space between the bars is getting filled with larger pieces of gravel so the operator has a natural instinct to do a clean up but in reality this isn’t necessary and the apparent ‘loading-up’ is somewhat of an illusion. In operation these interstitial spaces are continually exchanging materials and ejecting both small and large lightweight particles while holding on to heavy particles and sending the smallest and heaviest to the bottom of the deposition space. In actual use the longer you wait between cleanups the better with this riffle style. We found that when you could see black sands in the upper surface the riffles had become packed but it took a long time to get to that point and even then they were still ‘working’ in consolidating heavy materials at the bottom of the bed even different densities of heavy black sands.

In the snapshot shown in Figure 27 I tried to pull the riffle assembly straight upwards from the sluice bed so I could get a picture of what was collected between the riffle bars after only running for a few seconds.

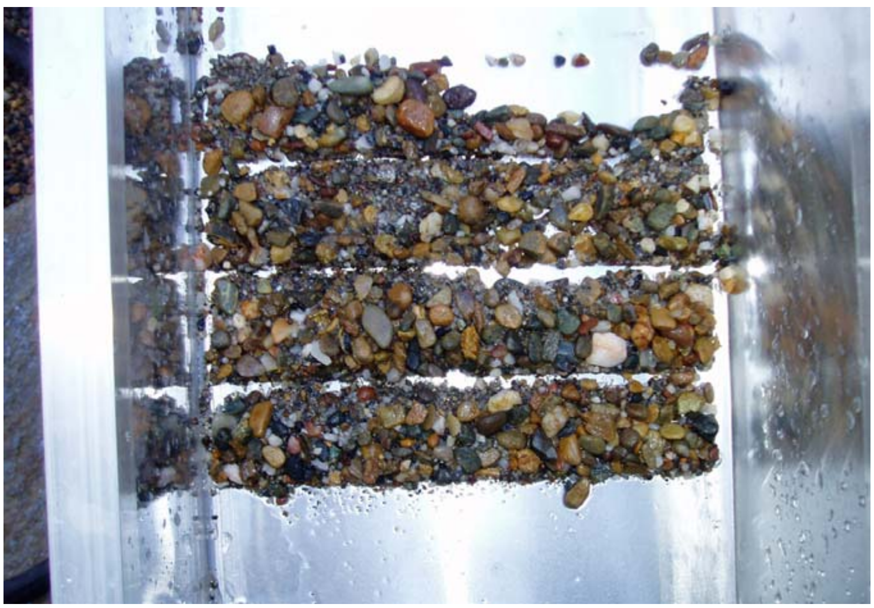

Figure 27

You can easily see the spaces left by the bars and the larger pieces of gravel that fill those spaces but what’s hard to see is the amount of very fine material that is on the bottom and consolidated in between the larger gravels. The amount of fine material in the spaces shown here is about three times greater than we found collected by any other type of riffle we tested. In fact the amount of fine material collected by this type of riffle running in a bare bottomed sluice was in some cases significantly greater than what we found collected in a typical commercial sluice fitted with Miner’s Moss as a collection agent so this riffle design is extremely efficient at concentrating fine heavy materials. After sifting these concentrates we found that about 50% of the finest black sands would pass a 100-mesh sieve while materials collected by other riffles weren’t nearly as fine.

Unfortunately as mention earlier this riffle style is also extremely sensitive to what it’s fed and at what rate and what water flow/velocity is available so it is not what we’d call a good general-purpose riffle design.

I've spent around three months observing these riffles in action and I've come to the conclusion that the so-called 'concentration vortex' is far more complex than originally described in prior studies and that the backpressure wave mentioned earlier has more to do with how these riffles work than the swirling vortex itself.

As mentioned earlier I think Poling's description of a 'shearing particle bed' that occurs at the intersection of two counter-rotating pressure waves is actually more descriptive of what is happening between these riffles than Clarkson's 'vortex' explanation. In fact from what we observed I'd say that the 'shearing particle bed' is more like a 'shearing zone' and that 'zone' is dynamic and changes size, shape and orientation in relation to water velocity and slurry viscosity.

Another interesting thing about this particular style of riffle is that each pair of bars acts almost totally independently from their secondary neighbors and very little water energy is lost as the riffle set increases in length and in the number of bars used in a run. Most other types of riffles work best when used with a limited number of bars that ranges from 4 to 7 but the reversed sloped angle types can have an almost unlimited number of bars in any given run and still function extremely well. For my next sluice I want to build a set that has 9 or 10 bars in the run.

For casual use this riffle type is probably to finicky but for a small placer operation where you can spend time fine-tuning your gear over a long period of time this riffle style is almost impossible to beat even though you have to almost re-learn everything you thought you knew about sluice riffles.

For comparison Figure 28 shows the results of running the same material through a set of 5/8" high 'Z' style compound Hungarian riffles set at a 2-inch spacing for the same length of time.

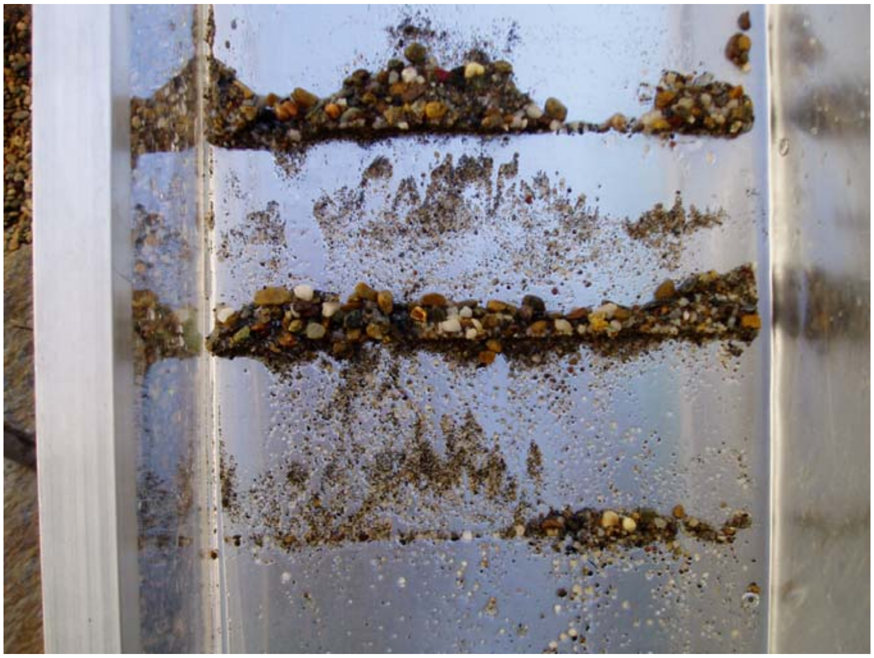

Figure 28

As you can see the compound riffles only concentrated a small fraction of the fine material in comparison to that accumulated by the reversed slope angle iron riffles.

I know that this is off topic but when I loaded this last picture it reminded me of when people would come by our little encampment on the Bear River to see what we were doing and they were always amazed to see us running bare-bottomed sluices and high-bankers. Most folks couldn't understand how a sluice could collect gold without using Miner's Moss or carpeting. Even some of the experienced people had no understanding at all of the intrinsic operational nature of sluices.

I guess this shows that we prospectors and miners as a whole haven't done a very good job of explaining to newcomers how easy it actually is to capture gold in a pan or a sluice and that the hard thing is finding the shiny stuff to begin with. No amount of gear, no matter how technologically sophisticated, will help somebody find a spot that is financially worth working.

After my personal experiences with these reversed sloped angle iron type riffles I am of the opinion that a set of 'miniature' riffles, perhaps only an eight of an inch high, set at about 1/2-inch spacing will outperform conventional expanded metal mesh in almost any sluice box with respect to concentrating and consolidating extremely fine heavy materials in miners moss yet still permit high throughput of raw gravels. I hope somebody has the time to look into this idea.

Preliminary Conclusions

One of primary conclusions that came out of the testing almost immediately was that water flow velocity was far more important than water volume with respect to proper riffle function and recovery of any heavy materials, including very fine gold. This finding, compared to traditional understanding of sluice design is contrary to what many of us have been taught which is to keep the flow relatively deep and slow to prevent washing or scouring away the fines. Even a low water volume driven at a relatively high velocity is more effective than a high volume driven at a slower velocity.

We are not the first to recognize this fact as many of our associates have been resorting to narrowing their sluices by clamping sections of 2x4's onto the interior sides to increase velocity in the flume. Some people we know have started building 6-inch wide stream sluices that perform several times more efficiently than the wider production models they used to use.

This finding is substantiated by several other studies where it was found that the flow velocity of the slurry has to be maintained at a relatively high level for the riffle vortexes to function properly.

Our tests indicate that the minimum flow velocity has to be greater than 4 feet per second regardless of the riffle type being used. This threshold velocity is relatively easy to achieve with narrow stream sluices but almost impossible to reach using the popular 10-inch wide sluices on typical streams and rivers without resorting to rock velocity dams and having to use flared sluices.

As you increase flow velocity you can also increase material feed rates and be far more productive but you have to be cautious as excess gravel feed introduced into the flow can significantly reduce overall flow velocity and overload the riffles.

We're trying to prepare a table to correlate feed rate to flow velocity but one of the variables is material size so this might take some time to sort through so it will not be a part of this test phase.

Secondly we found that the overall height of any riffle should ideally be 3-times the *maximum* dimension of any material feed to the sluice and slightly less is to be preferred if possible from a fabrication standpoint. A ratio of 2.5:1 is perhaps 'perfect'. In other words if you're feeding the sluice 1/4" gravels the *maximum* riffle height should be 3/4" or less as an example. The 'perfect' height for 1/4" gravels would be 5/8" but this riffle height would be a custom fabrication. Almost all of the 'mass-produced' riffles we tested were far to high for material screened down to a number 4 mesh but performed fairly well with 1/2" gravels but the high flows required to efficiently run 1/2" materials really wiped out the recovery of the smaller heavies.

We also found that specific riffle slopes did not have a significant effect on overall performance and that height seemed to be the primary limiting factor.

I was hoping that at the end of these tests we could prepared a graph charting height/slope/spacing for various material sizes but this looks like it is far off as the simple testing we've done here is not sufficient in the amount of data we generated. It's better than nothing but in my opinion it is just a start for other tests to be preformed in the future.

Testing – General Comments

When I first thought about doing these test I figured that I could do everything over the course of a few weeks since I'm retired and can spend as much time as needed every day messing around with this stuff. That assumption soon proved to be entirely false and the whole project became about 1000% more complicated and time consuming than first imagined. Now that's it past I can actually appreciate the amount of time others have taken to do similar tests so my hat is off to people who post on the discussion boards like 'Zooka', Vortxrex' 'Pop-and-Son' and others who have a love for this gold addiction and a wish to help other people by sharing things they have found through a lot of hard work. Many people have been doing similar test for several years so my small series of tests are only minor in comparison with respect to the time I have put into them but it's really given me an appreciation for what others have been doing for all us prospectors, miners and explorers.

What we've done in this paper so far, in my opinion, is just the tip of the iceberg with respect to in-depth testing on our end and this will be an ongoing project that we'll be updating over time as we get better in designing the tests to arrive at more cohesive conclusions to particular problems. None of this stuff is cut and dried and very static so there are hundreds of gray areas that need to be investigated including how we do testing to begin with.

Basically people need to look at this article as my 'two-cents' or my personal opinion about where we are with respect to small stream and power sluices. Other people will have different opinions and all of us need to gather information from as many people as possible in order to get better at finding and collecting gold. I've been prospecting for about 45 years but Lord knows I need all the help I can get.

Keep in mind as you read this article that we were only interested in testing riffles as used in small stream sluices and small high-bankers and for this reason we found that almost all of these riffles had a 'sweet-spot' with respect to performance that was far below that you might see when running equipment that process more material at higher flow rates. For the riffle assemblies we tested that 'sweet-spot' was between 4 and 6 feet per minute of flow in an 8-inch wide sluice depending on the size of the source materials.

Test Conditions

The tests were conducted in two stages. The first stage took place under controlled conditions in my backyard with the test sluice set up relatively high on a stand in ‘power-sluice mode. I call this the ‘Controlled Phase’ for obvious reasons.

Water for the Control Phase tests performed up to 50-gallons per minute of total flow were conducted by re-circulating water from a series of holding tanks. Water for test requiring flows above 50gpm was obtained by pumping directly from the river that runs through my backyard. Unfortunately there isn’t any gold in this river.

The second stage of testing took place in the field at the Bear River campgrounds and Mineral bar campgrounds, both sites near Colfax California.

Gravel materials for the Controlled Phase tests consisted of quartz and granite sands and gravels obtained from the Bear River site. We collected a total of 15 gallons of random source material and continuously reused it after running it in bulk repeatedly to remove virtually all of the visible native gold we could recover using conventional processes.

The various tests for each riffle design were conducted in stages beginning with a minimum water flow of 10 gallons per minutes and a slope of 1/2” per foot progressing up to a slope of 2-1/2” (3” in a few instances) per foot in 1/2” increments. The same test was repeated with ever increasing water flow in 5gpm increments up to 100 gallons per minute, which was the maximum capacity of the pump we used.

The initial tests were conducted using the sluice in a bare configuration with no mats installed and no gravels added to the water so that we could see only the characteristics of the water flow over the different riffle sets.

The second set of tests was identical to the first except that gravels passing a number 2 mesh sieve were added at the rate of one gallon (dry volume) per minute.

The third set of tests consisted of adding gravels that only passed a number 4 mesh sieve.

The fourth set of test consisted of adding gravels that only passed a number 8 mesh sieve.

Materials that passed a number 2 sieve were the largest that we tested in a controlled situation but we did make a few runs of unclassified materials at the river just to see how the various riffles handled larger stones with relatively slow water flows and these observations will be included later in the article.

In each test situation we introduced dry gravels to the sluice, by garden spade from a pivoted bucket we mounted in a home made stand. We caught all of the tailings in a 5-gallon bucket. We then switched buckets and did a clean up of the sluice and captured the concentrates separately.

Each test ‘session’ lasted for approximately 4 minutes and processed 2 gallons of raw materials. We let the sluice run ‘clean’ for approximately 1-minute at the end of each run.

For each run we compared the amount of captured concentrates and ‘keeper materials’ against the original source materials with respect to the ratio of captured material after the material had been well dried. We used the shallow type automotive ‘drip’ trays as drying troughs placed on my boat dock that gets sun all day long. We would periodically rake the concentrates to reduce drying time. The drying process took far more time than any other aspect of testing.

I am sure people will immediately criticize the duration and quantity of materials used in the tests since such short runs will not provide enough sampling to determine how much loss occurs due to scouring or overloading between various types of individual riffle styles but keep in mind that all we’re testing is the ‘relative’ collection and consolidation difference between the styles. It would probably take a person an entire year of working full time to do a series of runs using 50 gallons of gravel for each test.

Concentrating, collecting, and measuring the collected materials became a horribly time consuming nightmare and actually measuring our samples may take the rest of this year so early on we just started dumping all of the initially concentrated materials into labeled 1 quart cans and began processing this down as time permitted using a ‘poop-tube’ followed by a run on a homemade ‘Miller Table’ where necessary.

The results of the test are delineated towards the end of this article.

Test Materials

When we switched from clear water testing to actually running gravels and test samples I first tried to duplicate methods done by others in the past.

I only had about an ounce of real placer gold on hand and to be honest I wasn’t all that willing to use, and possibly loose, what I’d worked so hard to get in early March. The bulk of this ounce was fine to extremely fine and I was afraid that all of the small stuff would eventually get wasted away during cleanups, bucket transfers and working the concentrates so I looked for other alternatives.

I have seen where other researchers used radioactive tracer specimens but unfortunately I was fresh out of that stuff so my poor boy shade tree engineering methods will just have to suffice.

Brass

I had read of tests where brass dust left over from machine operations were used so we salvaged 55.2 grains of –50 mesh dust from a local machine shop. 22 grains of this material passed a 100-mesh sieve. The problem with this test material was that the finest particles just floated on the surface of the water. At first I figured that it was contaminated with oils so I ran it thru a bath of lacquer thinner followed by a wash in Acetone with no change in the results. I even added some 'Jet-Dry' to the recirc tub and it helped but we still had a tremendous problem with some of the fine powder just floating on the surface. Almost all of the riffle styles however easily collected 80-85% of everything that wouldn't pass a 50-mesh sieve. Over time, after the material had a chance to oxidize, the float problem was less severe. I would not recommend that anybody waste their time trying to use brass or bronze as a test agent unless they're using particles coarser than 50-mesh. I think the problem with brass is that it is just to light, having a specific gravity of around 8.5. It is heavy enough to be easily separated from black sands but the flour tends to get picked up easily by the water flow unless you use a rather large amount of wetting agent. The picture below illustrates a sampling of this dust.

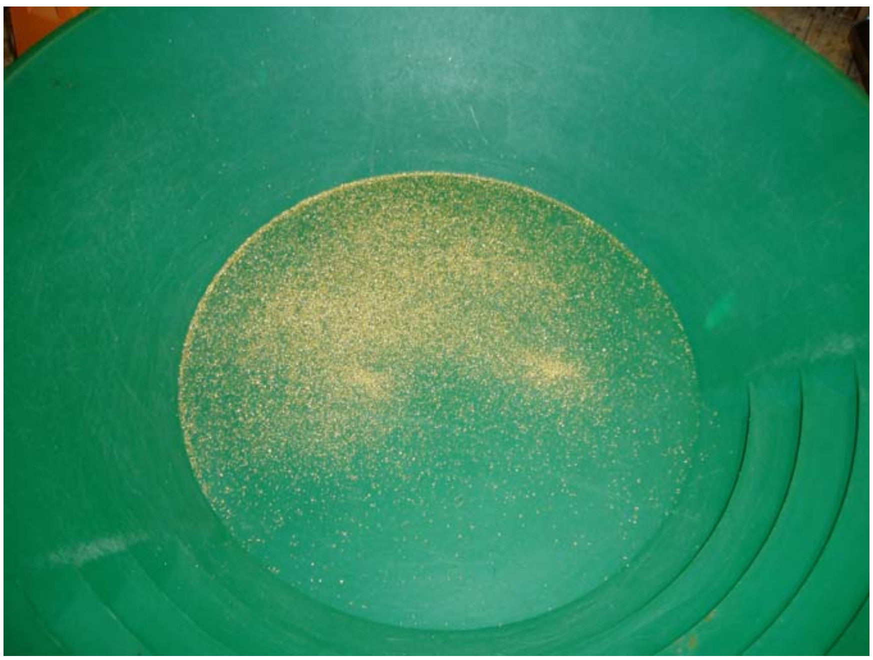

Figure 29

I didn't feel like the experiment with Brass was a wasted attempt however as it provided us with some very good information about at what point, in particle size, riffles begin to fail in effectiveness compared to mesh-only type sluices and that point initially appeared to be about at the 20 to 30-mesh level of particle size and not the 14-mesh range theorized by Clarkson, Peer and others. The much reduced water velocities we were using in these small stream sluices of course can explain this difference.

Tungsten

I had also read of tests where Tungsten was used as test particles so I took a couple of my Tig welding electrodes and ground them into dust with my disc grinder. The process took about an hour to create around 60 grains of material so I'll never do this again and separating the dislodged abrasive particles from the tungsten took about another hour. This time I washed the material in lacquer thinner before I tried to use it. Tungsten dust is vicious stuff and I found out the hard way that the finest dust-like particles would actually embed themselves in your skin so you need to wear gloves if you want to make your own batch of this stuff. The good thing about it is that Tungsten is almost as heavy as gold having a specific gravity of around19 but the particles are very sharp, angular and geometrically crystalline in nature. They do not 'behave' very much like flecks of gold in a typical sluice setup.

Unfortunately even with this heavy material the smaller particles insisted on floating on the surface unless we used a wetting agent but we did manage this time to collect in the 80 to 85% range, depending on which riffle set was used, of everything coarser than 100-mesh which is the finest sieve I own. It was easier to capture the finer Tungsten particles compared to the runs using Brass but even then the 'behavior' of the material was very unlike how real gold acts in a pan or a sluice. In practice its characteristics are more akin to very heavy black sand.

I did eventually find out that there are companies who sell various grades and types of Tungsten particles but I didn't follow up on the leads to see if we could obtain particles that were 'flake-like' in conformation. This is on my list of things to do in the future.

Like Brass, I would not recommend that anybody use Tungsten as a test agent.

Cobalt

This was another interesting experiment as I have a lot of the non-radioactive specimens of Cobalt on hand and it has a specific gravity of around 8.5 to 9.0 and while much lighter it is very much like Tungsten in that it is very 'crystalline' in nature and doesn't behave like the softer metals in a sluice. The pieces I have are used to make cutting tools for lathes. Cobalt offers no advantages as test agent.

Lead

I have a lot of experience using lead as a 'training' specimen as we used to use it in 'Panning Camps' up in Alaska when we'd give lessons to tourists so I knew that it worked well but I had hoped that the much heavier Tungsten would give us better results in the tests. Unfortunately the Tungsten was more akin to running abrasive 'grit' down the sluice and we found that it would actually embed itself into the aluminum and even some of the gravels so in effect it was far to aggressive in behavior to be a good substitute for real gold even though it was heavy.

Lead only has a specific gravity of around 11 but even at that it is about twice as heavy as even the heaviest black sands so it is very easy to pan and people have been using it for decades as a training material. We used to make up large batches of shotgun shot that we'd 'deform' using smooth-jawed pliers and then paint it 'gold' to appear close to the 'real thing'. I had about five pounds of this stuff stored in some jars so we decided to give it a try in our experiments.

The materials we used consisted of lead shot that was randomly 'deformed' and ranged in spherical size from number 4 (.13" dia.) to number 11 (.06" dia.) pellets. The flattened specimens ranged in size from .06 to .18" in diameter. The picture below shows a random sampling. Due to the deformation and flattening some specimens would pass a number 16-mesh sieve so I consider this to be –8 to +18 material in general nature. In other words the course pellets are a good substitute for nuggets, pickers and flakes.

In addition to these course materials we also created a variety of lead shavings and 'dust' that ranged from 20 to 100-mesh and finer in particle size.

Figure 30

The small gold colored lead pellet weighs 1.1-grain and is somewhat flattened but the largest dimension is just under a sixteenth of an inch. It represents a fairly typical example of the small pickers we find at most of the sites we work.

The small pile of lead shavings also weighs in at 1-grain while the larger pile of material to the right weighs 19-grains.

The reason I took this photo was to graphically illustrate how much material physically represents the amount of 'gold' retained and lost at the 95% retention level claimed to be possible when using some of the modern sluices.

Figure 31

These pieces of lead might appear to be pretty regular in shape from this head on snapshot but in fact they are fairly well deformed on at least three sides and some are downright gnarly in conformation and the shavings are very irregular in shapes and sizes. We painted them to look more like gold for the classes and for panning training they work remarkable well.

Like before we ended up with excellent results capturing even this deformed lead shot so we needed to look further.

This time I created a new brew of lead shavings and dust by hand filing a pile that weighed in at 62.3 grains. Ironically I wound up with some material that at least looked like stuff you might find in a streambed. Some of the particles were elongated but almost microscopic. Ninety percent of these lead particles passed a 50-mesh sieve and another 40% was caught on the100-mesh grid so I only ended up with a very small portion of material that was finer than 100-mesh in comparison to the amount of dust-like particles I had when using brass or the Tungsten.

On the first test run using the lead I was pleased to see that it behaved in the sluice almost exactly like I was used to seeing gold behave and there were no problems with surface float but I didn't have nearly enough fine particles so I began to explore ways to make lead 'dust' which is a lot harder than one would imagine.

So-called ‘plumbers’ lead or ‘sinker’ lead or even bullet lead is far to soft to make good dust so I wound up destroying an old lead ‘duck’ as they are called. These little things are used as weights in the drafting business to hold spline battens in place on the drafting board. I’m guessing that they are an alloy with harder zinc as they are actually pretty hard to file and if you use progressively finer files you can generate some very fine particles but it takes an agonizing amount of time.

Of all the materials we tried this stuff is about as close too real gold, in behavior, as you can come by and remarkably it’s the cheapest stuff you can buy and the easiest to find.

We found out through trial and error that ‘fresh’ made lead particles are to sharp to be used without first being ‘seasoned’ and allowed to oxidize. To take the microscopic sharp edges off the particles our ‘seasoning’ procedure consisted of tumbling the material in a matrix of fine aquarium gravel and then placing it wet, on a cookie sheet, to weather outdoors for about a week. I’m still experimenting with ways to colorize it so it’s easier to see intermixed with black sands.

The problem with using lead unfortunately is that it is very soft, even in an alloy form, so over a period of time being re-used it becomes highly deformed and in some cases re-amalgamated, or at least stuck, with neighboring segments so for the best testing you really need a ‘fresh’ batch of material for each three or four runs that you want to do. This is what we finally settled on doing.

We prepared a fresh batch of lead test agent particles for each particular series run we wanted to test. Since I’m not a scientist I don’t know how this decision affected the tests but from where I stand it would seem to represent a more ‘real-world’ scenario where every batch of gravels will be slightly different to begin with.

You can create lead ‘dust’ that will pass a 200-mesh sieve if you have a lot of patience and ‘sand’ the material using 320 to 400 grit abrasives. For our –100 material we had to use a small hand sander. It takes about 30-minutes to create around 30 grains (about 2 grams) of dust and you have to discard a lot of shards that tend to bond to each other from the heat created by the sanding process.

Based upon prior testing using brass and Tungsten I decided that we’d make cuts of the test particles at +50, -50 to +100 and -100 increments. If I had it to do over again I’d add another coarser range on the upper end. To be honest most of the people I know actually don’t even bother with anything finer than around 50-mesh material and just leave it and the sands stored in cans sitting on the garage shelves for years on end waiting for some spare time to process it. We also ran the larger deformed lead shot which is all caught in a number 20-mesh sieve and in the tables this is simply listed as +20 material. In several studies this was considered to be the finest particles that riffles could capture without using matting of some kind.

To speed up the testing process we did not necessarily re-use the same test sample materials over and over again as there was a considerable amount of lag time between when we were running test and drying materials so in the test charts you will notice the amount of test samples might vary from run to run. This does not change the outcome of the tests in any way as we always measured the collected samples from any particular run in comparison to the amount of original samples used for any particular run. When a batch of samples were completely dried and weighed they were thrown back into our ‘bulk sample bucket’ to be recycled. We tied to keep each test sample ‘load’ added to each bucket of gravel as identical as possible to within two or three grains.

Gold

In the end we finally broke down and decided to use some real gold for some of the tests once we had an idea of what riffles worked best at certain slope/flow combinations. We purchased 200 grains of gold ‘dust’, that is material that passes a 100-mesh screen, to use in the final stages of the tests. Some of this material is so fine that in the smallest granulations it behaves more like baby powder than any thing else. It is so fine that if you get it on your fingertip you can’t rub it off without loosing it completely. I don’t have a sieve fine enough for some of this material but would estimate that at least 50 grains of this particular batch will pass a 300-mesh sieve.

Measurement Accuracy

One of the problems with testing of any kind is trying to establish some minimum level of accuracy, or range of possible error, as many people call it, and we’ve tried at all levels to be as accurate as humanly possible when using the measurement tools at our disposal but when it comes to weighing recovered materials the situation becomes very problematic.

First of all I was taught to always measure gold in grains and to be honest I don’t know when or why people started to use grams. I suspect pawnbrokers who didn’t have very good scales at their disposal started the practice. Almost any real gold shop has a good scale that can measure in grains of weight and in my personal opinion this is the unit (grain) that most people need to be using if they’re serious prospectors, especially if they’re trying to measure very small quantities of material. Even a relatively small flake of gold, like a very small tweezer-sized piece, can weight 1-grain (0.064grams). That’s a piece about the size of a pinhead just for reference. On some of the popular economy digital scales being used by people today that are only accurate to .1 gram an object that small very often is not read very accurately despite the claims of the equipment makers. We have a very good but very old Volander and Sons commercial sized assay scale that I’ve been using for almost 30 years and it is hard to beat for accuracy compared to the digital scales since it can weigh down to .1 grain. We used this scale for all measurements that required the greatest amount of accuracy.

Anyway that's just my personal prejudice about scales and units of measure and everybody has their own opinions about the subject but for these tests we are using 'grains' as the basic unit of measure.

We found that when measuring collected samples that we could easily be 'off' by up to 1 grain between the initial collection and the final samples after we processed it all the way down to what we considered to be clean and thoroughly dried sample specimens so this is what we've decided to use as our possible margin or error, 1-grain. That's plus 1 or minus 1. I hope that this is sufficiently accurate for testing since we haven't done this before.

Measuring Test Run Results

When we first started doing the test runs and measuring the samples we used a recovery method that I thought was pretty standard and used by most of us part-time prospectors but I got educated pretty fast by some of my friends.

My normal 'recovery' process when actually prospecting a site consists of doing a cleanup of the sluice or high-banker and then hand panning the initial concentrates to collect the good stuff in a snuffer bottle. I normally dump the remaining contents of the pan back into the stream. During these test I went a little further and brought the initial concentrates back home and ran them down a 'poop-chute' and then ran the concentrates from that step down a Miller Table and then discarded the remainder.

A couple of friends told me that I was still throwing away a lot of recoverable material and showed me how to screen the concentrates at each phase of recovery in a multi-staged operation and the results were remarkable and brought home the importance of classification at each and every stage of the recovery process. Unfortunately this takes a huge amount of time but as the price of gold goes up this time can be very worthwhile.

The moral of this paragraph is that almost all sluices collect a tremendous amount of very fine gold that is only lost or deliberately discarded when we go move into secondary and tertiary phases of working the concentrates.

Test Results

The raw data from the test results are shown in the following tables. To use the tables one first finds the 'Test Series' they are interested in. Each series represents a different type of riffle or different sizes of particular riffles. The details are described in the header information. In addition we list whether or not matting was used, and if so, then what type. Any additional notes that apply to a particular series are also included in the header information.

Within the individual tables themselves we have shown what we call the 'Run Number' and this is the system we used to manage all of the data and photographs that pertained to each individual test.

Each 'run' will represent a single test for a particular riffle with the sluice at the listed slope receiving a listed (nominal) volume of water at a specific flow velocity. In addition you will see three rows of information tabulation the quantity of test material used and then recovered per run. You can calculate the percentage if need be. The materials rows are listed in two levels. The numbers on the upper side indicate the original amount of test material and the number beneath that value represents the recovered amount of materials. The recovered weight divided by the original weight will give you the percentage of recovery. All weights will be in grains.

Where you see an asterisk (*) in any cell it indicates that the riffle set did not perform well enough at a particular flow or slope to bother testing. Each riffle set had fairly unique and specific range or a threshold of slope-flow conditions to perform at peak effectiveness and it is these peaks that we were concerned with. Testing at less than optimum configurations would have been a waste of time.

If a table does not contain an entry for a particular slope it indicates that the sluice was not able to perform at all at that particular combination so the results of the test were recorded in our records but not tabulated in this report. We actually preformed many tests at a slope of only 1/4" and 3/16" per foot to see if running a 'flat' box really made a difference in fine gold recovery and came to the conclusion that there was no significant increase to be achieved by reducing flow by decreasing slope past certain points. Likewise we ran tests at steep slopes where the riffles were just overpowered so these results are not shown either.

<u>Test Series Number 1</u>

Riffle Style L1 (5/8" high) Sloped Flat Bars (commercially purchased)
Source Gravels pass a number 2-mesh screen
Bare bottom sluice. No matting used.

Run Number	Slope (In./Ft.)	Flow (gpm)	Flow Vel. (fps)	Particles +20	Particles +50	Particles -50 to +100	Particles -100
1	1/2 in 12	*					
2	1 in 12	*					
3	1.5 in 12	*					
4	2 in 12	10	2.97	70.2 70.1	25.1 24.9	25.2 24.7	25.4 24.2
5	2.5 in 12	10					
6	3 in 12	*					

Test Conclusions

1. Anywhere from 10 to 25% of all ‘pay’ materials collected in a typical sluice can be lost at shutdown if a shutdown procedure is not used. In addition almost the same amount of materials may be lost every time a new ‘load’ of source materials are introduced to the sluice if some form of controlled feeding is not used. This fact was probably the most significant thing we learned from doing these tests.

2. Classification is critical and the increase in fine gold recovery is almost directly proportional to the extent of classification used on the source materials in relation to the general distribution of pay materials at any particular site. One quarter-inch spacing on a high-banker grizzly may be too wide in some instances and I urge people to look at changing this to 3/16-inch if they’re work fine gold areas.

3. Flow velocity is far more important than flow volume and even sluices designed exclusively for fine gold recovery can benefit from high flow velocities. In sluices using riffles it is the velocity that provides the energy needed to get riffles of any type up to their ‘working’ level.

4. Narrower sluices are more ‘efficient’ than wider sluices for any given length so if in doubt go narrower and longer rather than wider and shorter. It is much easier to have better control of velocity in narrow boxes and recovery of both large and small pay materials depend on velocity and not volume.

5. Sluices have to be brought up (or down) in flow velocity to the point where the riffles (or meshes) begin to ‘work’ and actually start concentrating heavy materials. Proper sluice setup and tuning can account for huge differences in collection efficiency so in this respect there is no substitute for owner experience with a particular piece of equipment. A novice running a particular sluice will never collect as much ‘good stuff’ as somebody well experienced with the same gear digging in the same spots. This is just one of ‘facts of life’ that we all have to get used to. There is no ‘magic’ box that makes all of us equal and experience will always trump technology.

6. In a similar vein as the theme mentioned above there are no ‘good’ riffles or ‘bad’ riffles as they all work up to a point and an experienced user can get good results using a less than optimum riffle designs compared to a newcomer who happens to be using state of art riffle designs. For this reason ‘testing’ of any type is kind of a subjective thing to begin with as over time we all learn how to maximize what it is that we have on hand at any particular moment in time. Don’t take ‘tests’ to seriously as the end user has almost total control over their own gear no matter what some ‘tests’ may indicate. The objective is to find and capture gold and how you end up doing that is entirely up to each individual. Miners are about the most independent bunch of people on this planet.

7. Based upon what we experienced over the summer doing these tests I estimate that the so-called ‘recovery’ percentages we saw under the controlled conditions most likely equate to something at least 15% less in field conditions. In other words if we saw 95% recovery on the test stand the ‘real’ recovery would have more likely been around 80% in the field where runs go on for much longer than we tested. The region of 95% efficiency in any machine or apparatus is almost impossible to achieve except in controlled conditions and there is significant loss during shutdown on field equipment compared to our test boxes. Always keep in mind that the recovery rates we recorded are just ‘relative’ values used for comparing different configurations of riffles. Even if all of the various riffles had scored in the 50 to 60% range the results of the tests would have still shown that certain riffles performed better compared to others.

8. After literally hundreds of runs in various configurations I’ve come to the conclusion that in some instances a bare bottom aluminum sluice actually collects more of the extremely fine gold particles than a sluice quipped with almost any type of matting. I think that once the particles get to a certain level of ‘fineness’ they are held in place more by ‘friction’ or ‘adhesion’ than anything else. For this reason we found that ‘unlined’ mats performed better than mats that had some kind of bonded ‘bottom’ type sheeting or layer. Aluminum boxes in this respect probably are better with respect to collecting extremely fine materials than stainless steel boxes since over time the bottoms are more easily abraded and striated becoming almost like sandpaper in texture.

9. Closely akin to what we mentioned above we also experienced numerous occasions when we shut down the sluice and found a thin layer of ‘soup’, or what I call ‘gray-matter’ on the bottom. This solution consisted of water mixed with ultra-fine lead particles, perhaps in the same size range of ‘baby-powder’. If you ran a squeegee down the box you could collect at least an eight of an ounce of this stuff in a measuring cup. Most of this material is completely lost during the secondary recovery process of running the concentrates down a poop-chute or any one of the other popular separation processes as the material simply becomes to diluted in the process water. For this reason it is probably a good idea to use a tertiary separation and recovery process if you’re really keen on getting the entire quantity of ultra-fine gold that’s actually captured by a typical sluice box.

Small Time Operators

On of the side-results of this non-scientific experiment that may be of interest to others like myself who are small-time or part-time operators is that a two-man team can dig and prepare gravels and run and tend two to three small power-sluices that are fed from one high-pressure pump while still coming close to maintaining the 12:1 feed ratio. This type of operation can triple ones gold recovery rate very easily without much of an increase in labor so it appears to be a very feasible concept in theory but we'll have to wait to see if it can be substantiated in the field.

Battery Operated High-bankers

I'm amazed at the amount of bad press the various Battery operated High-bankers and re-circulator type sluices have gotten on the various discussion boards. We used three during this test period and ended up actually buying one since it worked so well compared to some of the far more popular small gasoline powered units. They do go below the 'radar' so to speak so in some situations they can really help you out in sensitive areas that you might be prospecting. Their capacity is about half of what you'd expect to get for a gas-pump unit but it's nothing to sneeze at as they can do some incredible work once you understand their limitations and work out a small production operation that suits their idiosyncrasies. We did not find that was were any limitations due to battery capacity as many people claim and in fact we actually operated far beyond the time limits that we were theoretically supposed to do. I think either that batteries are under rated or that the amperage draw of the pumps is overstated.
We use Attwood, Rule and Johnson pumps and much prefer the Johnson's in all respects.

We will be putting together a small article about electrical pump high-bankers this winter so if anybody has any personal experiences they would like to share they can email me at gee25@pacbell.net if interested.

I personally think that most people who put them down simply haven't used some of the good ones.

Dredging

I used to be diehard dredger back in the old days but as I've mentioned before I switched over to using high-bankers because they are easier to pack into remote locations and in my personal opinion much more efficient in operation.

If you take a good hard look at what dredges actually do you can begin to understand what I mean about being inefficient. You will also understand why bigger dredges are better, almost a necessity, if one wants to get serious about using these devices.

Basically a dredge is just a water-based version of a small backhoe fed sluice box. Instead of scooping up large random sections of dry materials in a bucket you suck it up a hose. Both of these processes are ‘bulk operations’ where you simply process large amounts of raw material. In such operations your rewards are almost exclusively based upon the quantity of raw material you can process since there is very little discretion you can utilize in following pay-streaks or pay-levels that lay in the native soils you’re working.

A guy working a dry bench with a small tractor fed sluice or high-banker can probably actually do much better from a gold recovery standpoint than a dredger can but dredging is very easy and very economical work compared to handling dry materials which is why it’s still so popular. It is a very cost/labor effective way to mine but not necessarily a very recovery effective method for processing the raw materials. Like everything else in life it’s all just a compromise.

Here in California we might not have much more say-so in how we prospect and mine in the future as the politician seem to think they have a better idea of what we should be doing so dredging in this state may be coming to an end. If it does then high-bankers will be the next target and then stream sluices and then finally they’ll get around to hand panning by limiting the size of pan a person uses in the ‘permitted zones’.

Appendix

Table 3.1
Minimum Water Flow Velocity To Move Various Materials

Size of Material	Minimum Flow Velocity Req'd.
Fine Sands	0.50 fps
Fine Gravels	0.75 fps
1-inch Pebbles	2.00 fps
2 to 3-inch Pebbles	3.30 fps
3 to 4-inch River Rocks	5.30 fps
6 to 8-inch River Rocks	6.70 fps

The date for Table 3.1 was derived from Young's 'Elements of Mining' and tabulates the minimum water flow velocity to move specific (spherical) materials in a flume along a smooth and flat plane by hydraulic force alone. If the flume is sloped even slightly the velocity figures can be significantly reduced but this is a good basic benchmark to be utilized in the design of gravity recovery apparatus. Please keep in mind that these figures are for movement through a perfectly smooth flume with no obstructions such as riffles and the materials are as close too spherical as possible.

Table 3.2
Ideal Water Flow in Pipe or Hose

Conduit Inside Diameter (Inches)	Gravity Flow Rate (Gpm)	High Pressure Flow Rate (Gpm)
0.75"	11.00	36.00
1.00"	16.00	58.00
1.25"	25.00	100.00
1.50"	35.00	126.00
2.00"	55.00	200.00
2.50"	80.00	300.00
3.00"	120.00	425.00
4.00"	200.00	600.00
6.00"	500.00	800.00

The data for Table 3.2 is based upon 'best' engineering principals for clear water flow thru smooth uninterrupted conduits having no significant losses due to fittings. These values are on the 'safe' side and can be used by us backyard builders as good benchmarks without having to worry excessively about various losses but they do have to be used with reason.

Table 3.3

Depth of Laminar Flow
In Relation to Water volumn and Velocity

8-inch Wide Sluice

Sluice Slope In./Ft.	Percent of slope	Water Depth From Bottom	Req'd. Flow (gpm)	Flow Velocity (ft./sec.
1/2"/ft.	4%	1/4"	11.79	1.96
1"/ft.	8%	1/4"	16.33	2.72
1-1/2"/ft.	13%	1/4"	20.42	3.39
2"/ft.	17%	1/4"	23.58	3.92
2-1/2"/ft.	21%	1/4"	26.36	4.38
1/2"/ft.	4%	3/8"	24.29	2.58
1"/ft.	8%	3/8"	33.66	3.58
1-1/2"/ft.	13%	3/8"	42.07	4.48
2"/ft.	17%	3/8"	48.58	5.17
2-1/2"/ft.	21%	3/8"	54.31	5.78
1/2"/ft.	4%	1/2"	38.51	3.07
1"/ft.	8%	1/2"	53.36	4.25
1-1/2"/ft.	13%	1/2"	66.70	5.32
2"/ft.	17%	1/2"	77.02	6.14
2-1/2"/ft.	21%	1/2"	54.31	5.78
1/2"/ft.	4%	5/8"	54.37	3.51
1"/ft.	8%	5/8"	76.03	4.85
1-1/2"/ft.	13%	5/8"	95.04	6.07
2"/ft.	17%	5/8"	109.76	7.06
2-1/2"/ft.	21%	5/8"	122.69	7.83
1/2"/ft.	4%	3/4"	73.02	3.89
1"/ft.	8%	3/4"	101.17	5.38
1-1/2"/ft.	13%	3/4"	126.47	6.73
2"/ft.	17%	3/4"	146.04	7.77
2-1/2"/ft.	21%	3/4"	163.27	8.68

Table 3.4

Depth of Laminar Flow
In Relation to Water volumn and Velocity

8-inch Wide Sluice

Sluice Slope In./Ft.	Percent of slope	Water Depth From Bottom	Req'd. Flow (gpm)	Flow Velocity (ft./sec.
1/2"/ft.	4%	1"	107.06	4.45
1"/ft.	8%	1"	148.35	6.17
1-1/2"/ft.	13%	1"	185.43	7.71
2"/ft.	17%	1"	214.15	8.90
2-1/2"/ft.	21%	1"	239.40	9.95
1/2"/ft.	4%	1-1/2"	210.32	5.60
1"/ft.	8%	1-1/2"	291.41	7.75
1-1/2"/ft.	13%	1-1/2"	364.27	9.69
2"/ft.	17%	1-1/2"	420.66	11.19
2-1/2"/ft.	21%	1-1/2"	470.26	12.51
1/2"/ft.	4%	2"	329.93	6.45
1"/ft.	8%	2"	457.14	8.94
1-1/2"/ft.	13%	2"	571.43	11.18
2"/ft.	17%	2"	659.89	12.91
2-1/2"/ft.	21%	2"	737.70	14.43
1/2"/ft.	4%	2-1/2"	440.97	7.04
1"/ft.	8%	2-1/2"	610.99	9.75
1-1/2"/ft.	13%	2-1/2"	763.75	12.19
2"/ft.	17%	2-1/2"	881.99	14.08
2-1/2"/ft.	21%	2-1/2"	985.99	15.74

Table 3.5

Depth of Laminar Flow
In Relation to Water Volumn and Velocity

10-inch Wide Sluice

Sluice Slope In./Ft.	Percent of slope	Water Depth From Bottom	Req'd. Flow (gpm)	Flow Velocity (ft./sec.
1/2"/ft.	4%	1"	136.07	4.57
1"/ft.	8%	1"	192.32	6.45
1-1/2"/ft.	13%	1"	235.60	7.91
2"/ft.	17%	1"	272.06	9.13
2-1/2"/ft.	21%	1"	304.12	10.21
1/2"/ft.	4%	1-1/2"	270.15	5.80
1"/ft.	8%	1-1/2"	381.83	8.20
1-1/2"/ft.	13%	1-1/2"	467.73	10.04
2"/ft.	17%	1-1/2"	540.15	11.60
2-1/2"/ft.	21%	1-1/2"	603.79	12.97
1/2"/ft.	4%	2"	415.39	6.69
1"/ft.	8%	2"	587.09	9.45
1-1/2"/ft.	13%	2"	719.18	11.58
2"/ft.	17%	2"	830.52	13.37
2-1/2"/ft.	21%	2"	928.45	14.95

Table 3.6

Depth of Laminar Flow
In Relation to Water Volumn and Velocity

12-inch Wide Sluice

Sluice Slope In./Ft.	Percent of slope	Water Depth From Bottom	Req'd. Flow (gpm)	Flow Velocity (ft./sec.
1/2"/ft.	4%	1"	167.02	4.65
1"/ft.	8%	1"	236.05	6.57
1-1/2"/ft.	13%	1"	289.17	8.06
2"/ft.	17%	1"	333.93	9.31
2-1/2"/ft.	21%	1"	373.28	10.40
1/2"/ft.	4%	1-1/2"	334.32	5.96
1"/ft.	8%	1-1/2"	472.51	8.43
1-1/2"/ft.	13%	1-1/2"	578.83	10.32
2"/ft.	17%	1-1/2"	668.43	11.92
2-1/2"/ft.	21%	1-1/2"	747.80	13.32
1/2"/ft.	4%	2"	517.41	6.92
1"/ft.	8%	2"	731.29	9.77
1-1/2"/ft.	13%	2"	895.51	11.97
2"/ft.	17%	2"	1034.51	13.83
2-1/2"/ft.	21%	2"	1156.49	15.46

Table 3.7
Typical Pump Specifications

Pump Model Designation	Horsepower	Capacity (gpm)	Suction Diameter (Inches)	Discharge Diameter (Inches)	Outlet Velocity (fps)
Honda WX10K1A	1.0	37 gpm at 51 psi 118’ Head Lift	1.00	1.00	15.11
Honda WX15AX2	1.5	72 gpm at 54 psi 125’ Head Lift	1.50	1.50	12.89
Honda WH15XK1C1	2.5	115 gpm at 55 psi 127’ Head Lift	2.00	2.00	11.74
Honda WH20XK1AC1	4.0	134 gpm at 61 psi 141’ Head Lift	2.00	2.00	13.68
Keene P90	2.5	100 gpm at 69.56 psi 161’ Head Lift	1.50	1.25	26.14
Keene P100	3.5	150 gpm at 64.8 psi 130’ Head Lift	2.00	1.25	39.22
Keene P103	4.0	150 gpm at 51.84 psi 120’ Head Lift	2.00	1.25	39.22
Keene P180	6.5	310 gpm at 77.76 psi 180’ Head Lift	2.50	2.00	31.05
Keene P280	9.0	350 gpm at 86.4 psi 200’ Head Lift	2.50	2.00	35.74
Keene P350	10.0	475 gpm at 58.32 psi 135’ Head Lift	4.00	3.00	21.56

Table 3.8
Water Flow and Velocity in Pipe or Hose

Conduit Inside Diameter (Inches)	Water Flow (Gpm)	Flow Velocity (Fps)
1”	10.00	4.09
1”	15.00	6.13
1”	20.00	8.17
1”	25.00	10.23
1”	30.00	12.26
1”	35.00	14.30
1”	40.00	16.34
1”	45.00	18.38
1”	50.00	20.43
1.25”	10.00	2.61
1.25”	15.00	3.92
1.25”	20.00	5.22
1.25”	25.00	6.54
1.25”	30.00	7.84
1.25”	35.00	9.15
1.25”	40.00	10.46
1.25”	45.00	11.77
1.25”	50.00	13.07
1.25”	55.00	14.40
1.25”	60.00	15.69
1.25”	65.00	17.00
1.25”	70.00	18.30
1.50”	30.00	5.45
1.50”	35.00	4.54
1.50”	40.00	7.26
1.50”	45.00	8.17
1.50”	50.00	9.08
1.50”	55.00	9.99
1.50”	60.00	10.89
1.50”	65.00	11.80
1.50”	70.00	12.71
1.50”	75.00	13.62
1.50”	80.00	14.52
1.50”	85.00	15.43
1.50”	90.00	16.34
1.50”	100.00	18.16

2.00”	50.00	5.11
2.00”	55.00	5.62
2.00”	60.00	6.13
2.00”	65.00	6.64
2.00”	70.00	7.15
2.00”	75.00	7.66
2.00”	80.00	8.17
2.00”	85.00	8.68
2.00”	90.00	9.19
2.00”	95.00	9.70
2.00”	100.00	10.21
2.00”	125.00	12.77
2.00”	150.00	15.32
2.00”	175.00	17.87
2.00”	200.00	20.43
2.00”	250.00	25.53
2.00”	275.00	28.00
2.00”	300.00	30.64
2.00”	350.00	35.74
3.00”	150.00	6.81
3.00”	200.00	9.08
3.00”	225.00	10.21
3.00”	250.00	11.34
3.00”	275.00	12.48
3.00”	300.00	13.62
3.00”	325.00	14.75
3.00”	350.00	15.89
3.00”	375.00	17.02
3.00”	400.00	18.16
3.00”	425.00	19.29
3.00”	450.00	20.43
3.00”	475.00	21.56
3.00”	500.00	22.69

Table 3.9
Pressure to Head Lift Conversion

Pressure (psi)	Head Lift (feet)	Pressure (psi)	Head Lift (feet)
1	2.31	19	43.9
2	4.62	20	46.20
3	6.93	25	57.70
4	9.24	30	69.30
5	11.60	35	80.80
6	13.90	40	92.40
7	16.20	45	103.90
8	18.50	50	115.50
9	20.80	55	127.00
10	23.10	60	138.60
11	25.40	65	150.10
12	27.70	70	161.70
13	30.00	75	173.20
14	32.30	80	184.80
15	34.60	85	196.30
16	37.00	90	207.90
17	39.30	95	219.40
18	41.60	100	230.90

Table 3.10
Measured Clean Flow Data at Slick-plate
(No Riffles Installed in Sluice)

10gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/4”/ft.	17/64”	9.73	1.47
1/2”/ft.	7/32”	9.93	1.83
3/4”/ft.	3/16”	10.03	2.08
1”/ft.	11/64”	10.42	2.31
1-1/2”/ft.	5/32”	10.09	2.58
2”/ft.	9/64”	10.22	2.83
2-1/2”/ft	1/8”	9.90	2.99
3”/ft.	7/64”	9.92	3.17

15gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/4"/ft.	11/32"	14.97	1.74
1/2"/ft.	9/32"	14.79	2.14
3/4"/ft.	1/4"	15.63	2.48
1"/ft.	15/64"	15.33	2.68
1-1/2"/ft.	13/64"	15.66	3.06
2"/ft.	11/64"	14.16	3.13
2-1/2"/ft	5/32"	14.70	3.50
3"/ft.	1/8"	15.18	3.74

20gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2"/ft.	21/64"	19.19	2.36
3/4"/ft.	19/64"	20.75	2.76
1"/ft.	9/32"	20.90	3.02
1-1/2"/ft.	15/64"	19.60	3.34
2"/ft.	7/32"	19.85	3.67
2-1/2"/ft	13/64"	20.21	3.95
3"/ft.	3/16"	20.05	4.17

25gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2"/ft.	3/8"	24.29	2.58
3/4"/ft.	11/32"	24.92	2.95
1"/ft.	5/16"	25.52	3.26
1-1/2"/ft.	9/32"	25.62	3.71
2"/ft.	1/4"'	25.52	4.04
2-1/2"/ft	15/64"	25.28	4.31
3"/ft.	7/32"	25.42	4.57

30gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2"/ft.	27/64"	29.14	2.77
3/4"/ft.	3/8"	29.74	3.17
1"/ft.	11/32"	29.94	3.47
1-1/2"/ft.	19/64"	29.34	3.90
2"/ft.	9/32"	29.59	4.28
2-1/2"/ft	17/64"	30.77	4.65
3"/ft.	1/4"	31.25	4.95

35gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2"/ft.	15/32"	34.65	2.95
3/4"/ft.	27/64"	35.09	3.39
1"/ft.	3/8"	34.34	3.65
1-1/2"/ft.	11/32"	35.67	4.25
2"/ft.	5/16"	36.10	4.62
2-1/2"/ft	9/32"	35.45	4.91
3"/ft.	17/64"	36.24	5.24

40gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2"/ft.	33/64"	40.53	3.13
3/4"/ft.	29/64"	40.19	3.55
1"/ft.	27/64"	40.07	3.37
1-1/2"/ft.	3/8"	40.46	4.41
2"/ft.	21/64"	39.99	4.80
2-1/2"/ft	5/16"	40.35	5.16
3"/ft.	19/64"	40.15	5.45

45gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2”/ft.	9/16”	45.06	3.25
3/4”/ft.	31/64”	44.18	3.67
1”/ft.	7/16”	44.06	4.02
1-1/2”/ft.	25/64”	44.81	4.58
2”/ft.	23/64”	45.24	5.03
2-1/2”/ft	11/32”	44.97	5.38
3”/ft.	5/16”	45.32	5.71

50gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2”/ft.			
3/4”/ft.			
1”/ft.			
1-1/2”/ft.			
2”/ft.			
2-1/2”/ft			
3”/ft.			

55gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2”/ft.			
3/4”/ft.			
1”/ft.			
1-1/2”/ft.			
2”/ft.			
2-1/2”/ft			
3”/ft.			

60gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2”/ft.			
3/4”/ft.			
1”/ft.			
1-1/2”/ft.			
2”/ft.			
2-1/2”/ft			
3”/ft.			

65gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2”/ft.			
3/4”/ft.			
1”/ft.			
1-1/2”/ft.			
2”/ft.			
2-1/2”/ft			
3”/ft.			

70gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2”/ft.			
3/4”/ft.			
1”/ft.			
1-1/2”/ft.			
2”/ft.			
2-1/2”/ft			
3”/ft.			

75gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2”/ft.			
3/4”/ft.			
1”/ft.			
1-1/2”/ft.			
2”/ft.			
2-1/2”/ft			
3”/ft.			

80gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2”/ft.			
3/4”/ft.			
1”/ft.			
1-1/2”/ft.			
2”/ft.			
2-1/2”/ft			
3”/ft.			

85gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2”/ft.			
3/4”/ft.			
1”/ft.			
1-1/2”/ft.			
2”/ft.			
2-1/2”/ft			
3”/ft.			

90gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2”/ft.	7/8”		
3/4”/ft.	3/4”		
1”/ft.	11/16”		
1-1/2”/ft.	39/64”		
2”/ft.	35/64”		
2-1/2”/ft	33/64”		
3”/ft.	31/64”		

95gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2”/ft.	57/64”	94.94	4.27
3/4”/ft.	25/32”	95.06	4.86
1”/ft.	23/32”	94.84	5.33
1-1/2”/ft.	5/8”	95.04	6.06
2”/ft.	37/64”	94.83	6.64
2-1/2”/ft	17/32’	95.59	7.14
3”/ft.	1/2”	95.88	7.57

100gpm Flow Range

Sluice Slope	Water Depth at Slick-plate	Flow (gpm)	Water Velocity (fps)
1/2”/ft.	59/64”	100.94	4.36
3/4”/ft.	13/16”	99.66	4.95
1”/ft.	47/64”	99.90	5.43
1-1/2”/ft.	21/32”	100.56	6.19
2”/ft.	37/64”	99.30	6.75
2-1/2”/ft	35/64”	100.40	7.27
3”/ft.	33/64”	99.90	7.69

The data shown in Table 3.10 is the field measured flow volume and velocity taken at the area of the slick-plate in our test sluice. The flow volume for each individual step or stage is not a nice round number because it was not always possible to achieve the exact precise flow volume by throttling the pump and twisting the ball valve in the supply line but we came as close as humanly possible to the nominal flow rate for any particular chart listing.

References:

1. Poling, G.W. and Hamilton, J.f., ‘Fine Gold Recovery of Selected Sluicebox Congifgurations’, University of British Columbia (1986).

2. Wang, Wenquian and Poling, G.W., ‘Methods for Recovering Fine Placer Gold’, (1983).

3. Clarkson, R.R., ‘Gold Losses at Klondike Placer Mines’, Klondike Placer Miners Association (1989).

4. Peterson, L.A., et al, ‘Evaluation of the Effects of Total Suspended Solids Levels on Gold Recovery in a Pilot Scale Sluice’, Kohlmann-Ruggiero Engineers (1984).

5. Peterson, L.A., et al, ‘Evaluation of the Effects of Total Suspended Solid on Riffle Packing and Fine Gold Recovery in a Pilot Scale Sluice’, Centec Applied Technologies (1986).

6. McCarter, W.A., ‘Placer Recovery’, Klondike Placer Mining Association, Canadian Inspections and Exploration and Geological Services Division Presentation paper, (1982)

7. Hague, J.M., ‘The Recovery of Lode Gold in Jigs’, Engineering. and Mining Journal., Vol. 141, No. 4, (1940).

8. Longridge, Cecil Clement, ‘Gold Dredging’, The Mining Journal, (1905).

9. Poling, G.W, ‘How Riffles Work, Results of Yukon Study’, University of British Columbia, (1982)

10. Clarkson, R.R. and Peer, Owen, ‘An Analysis of Sluice Box Riffle Performance’, New Era Engineering Corp., Klondike Placer Miners Association, (1990).

11. Williams, David, ‘Georgia Gold Rush; Twenty-Niners, Cherokees and Gold Fever’, University of South Carolina Press, (2003).

12. Phillips J. Arthur, Mining Engineer, ‘Mining and Metallurgy of Gold and Silver’, F. and F.N. Spon, London, (1867).

13. Zamyatin, O.V. et al., ‘The Concentration of Auriferous Sands and Conglomerates’, Moscow, Nedra press (1975).

14. Young, Otis E., ‘Western Mining: An Informal Account of Precious Metals Prospecting, Placering, Lode Mining and Milling on the American Frontier from Spanish Times’ University of Oklahoma Press, (1982).

15. Egleston, Thomas, ‘The Metalurgy of Silver, Gold and Mercury in the United States’, (1887).

16. Madonna, James A., ‘Precious Metal Recovery Using Sluice Boxes in Alaska and Canada’, School of Mineral Engineering, University of Alaska, Fairbanks, (1988).

17. Tourtelot, Harry A., ‘Hydraulic Equivalence of Grains of Quartz and Heavier Minerals, and Implications for the Study of Placers’, U.S. Geological Survey Professional paper, (1968).