British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

GOOD PRACTICE IN THE DESIGN AND USE OF LARGE SLUICE BOXES

Commissioned Report CR/02/029N

DFID KAR Project R7120

Foreword

This report is the published product of a study by the British Geological Survey (BGS) in partnership with ITDG and with the Guyana Geology and Mines Commission (GGMC) as the principal collaborator on the DFID KAR project R7120. Mr Edmund Bugnosen, an independent small-scale mining consultant also contributed to this part the project. The aim of project R7120 'Recovering the lost gold of the developing world' is to identify and introduce better working practices to small-scale gold miners to give improved gold recovery, lessen environmental damage and increase wealth and well being in mining communities. This handbook contains information for Mining Engineers, Mines Officers and Mines Technicians to enable them to give good advice to small-scale miners about the construction and operation of sluice boxes to maximise the recovery of gold and minimise environmental damage. Field observations, trials and demonstrations carried out in Guyana with GGMC form the basis of the advice given in this report. This handbook is a reformatted version of BGS Technical Report CR/02/029N.

Acknowledgements

We particularly want to thank the Commissioner and staff of GGMC who have collaborated and contributed throughout the duration of this project. Many individuals at GGMC have freely given their advice, and provided the local knowledge so important to the field aspects of this project and helped to review draft chapters of this report. Of the many individuals who have contributed to the project we would particularly like to thank Mrs Dianne MacDonald, Manager of the Mines Division for her active support and efforts on our behalf that enabled the fieldwork to be carried out.

This project also worked in collaboration with the Guyana Environmental Capacity Development project (GENCAPD) funded by the Canadian Aid Agency CIDA. There was a very fruitful interchange of information and one field demonstration was carried out in partnership. The Canadian mining consultant Mr Randy Clarkson is particularly thanked for sharing his considerable knowledge of the operating principles of sluice boxes.

Clive Mitchell and Edmund Bugnosen commented on various versions of this report and made minor contributions.

BRITISH GEOLOGICAL SURVEY

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Good practice in the design and use of large sluice boxes *British Geological Survey Commissioned Report, CR/02/029N.*

Summary

Small-scale gold mining is an important source of livelihood for many poor people in the developing world. The gold recoveries by small-scale miners are notoriously poor but a scoping study, (Styles et al 1999) showed that there was considerable potential to improve the situation. The main way of recovering gold from alluvial gold ores is sluicing, but the small-scale miners often have a poor understanding of the principles of the operation of a sluice box or how to make it work better. This report contains information to give Mining Engineers, Mines Officers and Mining Technicians in developing countries a good understanding of the design and operating principles of sluice boxes. This will enable them to give good advice to small-scale miners about ways to make their mining operations more efficient and improve their gold recoveries.

The report is aimed at alluvial miners in areas where water is readily available and relatively large sluice boxes are used. It is based on experience in Guyana and is particularly relevant to gold mining in south America and south-east Asia. The gold recovery process is described from the delivery of ore to the box through to extraction of gold from final concentrates. At all stages of the process the principles are explained and recommendations given on the best practice. This covers the design, construction and operation of the various components of a sluice box.

Particular attention is paid to the gold trapping system in the box; the riffle system and the mats. This is an aspect that often receives little attention but has profound effects on the gold recovery and can be relatively easily improved. A system of mats and riffles developed in Canada is readily applicable to small-scale mining has been demonstrated and is described in the report. It is important to have the correct water flow conditions in the box for the gold trapping system to work efficiently. Ways to test the conditions are given and the design features that need to be modified to achieve optimum flow are described.

In addition advice is given on ways of minimising the adverse environmental impact of alluvial gold mining, both on decreasing the use and release of mercury and spoiling of water resources.

The importance of testing both the alluvial ores and the products of the mining operations is stressed. This helps to ensure that appropriate gold recovery methods are being used for the type of ore being mined. It also keeps a check on the efficiency of the gold recovery and gives immediate warning of problems.

CONTENTS

Plates

Tables

Front cover Sluice box being used by small-scale gold miners in Guyana.

1 Introduction and Overview

Small-scale gold mining is an important source of livelihood for many poor people in the developing world. The gold recoveries by small-scale miners are notoriously poor but a scoping study, (Styles et al 1999) showed that there was considerable potential to improve the situation. The main way of recovering gold from alluvial gold ores is sluicing, but the small-scale miners often have a poor understanding of the principles of the operation of a sluice box or how to make it work better. A series of field trials and demonstrations were held to introduce better practices and new but appropriate technology to small scale miners. These demonstrations showed that the miners are keen to learn and willing to change their methods if they are convinced that there are benefits and it is economically viable.

Plate 2 Small 'Brazilian' sluice (Guyana).

The sluice box is widely used for the recovery of gold from ores. Simple construction and easy operation have led to the sluice box being used all over the world but, like many apparently simple things, there are many complex processes involved**. Understanding these processes is the key to improving gold recovery**. Lack of understanding of the mechanisms involved has led to inefficiency and the loss of much gold during sluicing operations. High losses in the past have meant that in some places miners continue to recover economic quantities of gold from tailings that may already have passed over a sluice box two or three times.

Plate 1 Large sluice (Guyana).

Sluice boxes come in a wide variety of sizes and methods of construction. This handbook pays particularly attention to the design and operation of

Plate 3 Large Sluice (Malaysia).

Plate 4 Small sluice (Zimbabwe). *(Photo E. Bugnosen)*

larger sluice boxes as are used in various parts of south America and south east Asia where there is a plentiful supply of water. A separate report (CR/02/030) has been produced aimed at small, simple sluices, such as those used in many parts of Africa. **This report is aimed at mining technicians and engineers in developing countries who give advice and assistance to small-scale miners.** It will explain some of the complexity of the sluice box and it will give guidance on how to improve performance. It will help them advise small-scale miners on the best means to improve their operations, with an emphasis on improving gold recovery and reducing the negative impacts on the local environment.

2 General principles of sluice box operation

The sluice box works on a very simple principle; heavy particles in a stream of flowing water will tend to settle to the bottom. The rate at which a particle settles depends upon its density, size and shape; large, dense, spherical particles will settle quickly, whereas smaller, less-dense and platy particles will take longer. The overall result is a stratified (layered) stream with dense material at the bottom and less dense material at the top. The dense material thus comes into contact with the bottom of the sluice box and, with an appropriate trapping mechanism, it can be collected there.

A gold mining operation using a sluice box to recover gold involves a number of stages or activities; from the way the ore is mined to the frequency of cleaning the box. The way all these things are done affects the overall efficiency of the mine.

The topics to be covered in the following sections are:

- Ore delivery
- Screening
- The general features of a sluice box
- Feeding the slurry to the box
- The sluice box
- The gold trapping mechanism
- Clean up
- Recovering gold from the sluice box concentrate

3 Ore delivery

There are many ways of delivering the mined ore to the sluice box. However, for optimum performance the sluice box requires a controlled, steady delivery of material at an appropriate feed rate. The feed to a sluice box has two components, ore and water, and these must be thoroughly mixed in the correct proportion for the sluice box to work at its best. The delivery method used depends on the source and characteristics of the ore, the source of the water and power, the availability of equipment and the capital resources.

SLURRY PUMPING

This is often the favoured option, amongst small-scale miners, where a relatively large volume of ore needs to be processed (several tons or cubic metres every hour). However, this method depends on an adequate water supply. In a typical operation two pumps are used: one high pressure pump or monitor is used to break up the sand and gravel ore and a second suction pump to move the ore slurry to the sluice box. The use of pumps may not be feasible in many situations, as they are a relatively high cost, high technology solution. Pumps used for the movement of slurry need to be more robust than those used for clean water. Pumping does, however, offer a number of advantages:

- it actively mixes ore and water to help form a slurry
- it helps to break up lumps of clay
- it can deliver a relatively constant feed to the sluice box, which helps to maintain an efficient operation

EFFICIENT OPERATION REQUIRES A STEADY SUCTION AT THE PUMP INTAKE AND AN EVEN DELIVERY OF SLURRY TO THE SLUICE BOX

If the speed of the pump is varied, this causes surges in the delivery of ore slurry and the efficiency of the sluice box will be compromised. Surges in the slurry flow will cause heavy concentrate to be lost over the end of the sluice, whereas slower slurry flow will lead to clogging of the sluice bed with mud and sand which stops gold being trapped.

Plate 5 Large 6 inch gravel pump (yellow) powered by a diesel engine (Guyana).

Plate 6 Small 4 inch gravel pump powered by portable diesel engine (Guyana).

The size of the pump controls the size of the box, a pump with 6 inch inlet and outlet can feed a box about 4ft 6 inches wide whereas a 4 inch pump is suitable to feed a box about 3 feet wide.

SEPARATE DELIVERY OF ORE AND WATER TO THE SLUICE BOX

Water is easier to pump than ore slurry and the pumps used are smaller and cheaper. This favours the practice of mixing the ore and water in a box at the head of the sluice box. **The ore slurry should be screened before passing over the sluice box**, to remove coarse unliberated ore, rock lumps and clay balls. An inclined grizzly screen usually works well for this purpose and punched plates can also be used, especially if the amount of clay present is small or easily dispersed. However, the presence of stiff cohesive clays may block the openings of the screen and lead to the need for frequent cleaning.

The ore can be fed directly into the mixing box by bucket, shovel, sack-load or by mechanical means. The water should be delivered at a constant rate. Water comprises between 85% and 95% of the feed volume. Therefore, small variations in the rate at which the ore is added will not have a significant impact on the rate at which the feed slurry is delivered to the sluice box. **Too much water is wasteful but rarely has a negative effect on the operation of the sluice box**, whereas too little water makes the slurry too thick and impedes the settling of gold grains.

There are, however, situations where both the water and ore are added batch-wise. In these cases it is recommended that the water and ore be mixed (ideally 5 to 15% ore by volume) before feeding onto the sluice box. This will enable the operators to retain control over the water:ore ratio and to maintain a relatively constant rate and consistency of the feed slurry that is delivered to the sluice box.

The rate at which water is delivered to the sluice box should be such that the flowing slurry stream should be deep enough to allow stratification of the mineral components. If the stream is too shallow it is likely that less-dense material will come into contact with the bottom of the sluice box and be retained and cover the gold trapping system. If the stream is too deep it is likely that stratification will not occur close to the bottom of the box and the trapping system and gold will be lost into the tailings. Ideally the stream depth should be between 20 and 30 mm ($\frac{3}{4}$ to $1\frac{1}{4}$ inches). The water depth can be adjusted by varying the feed rate to the sluice box and the width of the box.

In very simple sluices where water is in short supply and added from buckets it is very difficult to achieve good flow conditions and efficient operation.

Plate 7 Combined separate mixing and screening through a grizzly (Suriname). *(Photo P. Pawiroredjo)*

4 Screening

WHY SHOULD THE ORE BE SCREENED?

Gold particles can be recovered using a sluice box (Section 5.0) because they have a much higher density (19.25 g/cm^3) than other minerals, such as quartz (2.65 g/cm^3). However, **gold-bearing ore contains material with a wide particle-size range** from mud up to pebbles several centimetres in size. The gold in contrast has a much more restricted range from a maximum of perhaps 2–3 mm down to less than a tenth of a mm. This can cause problems when attempting to separate dense particles (such as gold) from less-dense particles (such as quartz). Separation of gold works best when all the particles are of a similar size, as coarse-grained, less-dense particles (coarse sand and pebbles) can behave in a similar way to fine-grained, dense particles (gold).

Gold-bearing ore is prepared for processing by a method known as **screening**. This is where the ore particles are sorted according to their size. At a small-scale mine, screening may simply be the removal of large particles, such as boulders and cobbles. At larger commercial mines the very fine material, such as clay and silt may be removed or the ore split into coarser- and finer-grained material for separate processing. Material that has been screened will consist of particles of a similar size or within a certain size range.

SCREENING INCREASES THE LIKELIHOOD THAT GOLD WILL BE RECOVERED FROM ORE

This is because the movement of gold particles (in a sluice box) will be controlled by those properties, such as its high density (and other physical properties), that will lead to its recovery rather than its particle-size, which may lead to its loss.

SCREENING OPTIONS

The simplest way to screen gold-bearing ore is to use a fixed ('static') screen which has a series of holes (also known as 'apertures') or slots for material to pass through. Particles that are smaller than the holes pass through the screen and are known as the undersize. Particles too large to pass through the screen are known as the oversize. The main purpose of screening the feed depends on the type of ore. For alluvial ore it is necessary to remove the very coarse material, such as pebbles and lumps of rock or clay, as these are much coarser than any gold particles and also disturb the operation of the sluice box. A size around 25 mm (1 inch) might be appropriate. For crushed bedrock ore the size of particles will be much smaller and the range of sizes much narrower. It is necessary to remove larger particles, which may contain 'unliberated' gold (ie that trapped inside the rock) and return them for further crushing. A size of 5 mm or even smaller might be appropriate.

Particle-size Geological usage	Technical/Industrial	*British Standard Mesh usage* BS410: 1986	**American Standard Mesh** ASTM E11-87
	25 mm (1 inch)	-	-
	2.36 mm	7	8
2 mm		8	10
	1.18 mm	14	16
1 mm		16	18
	600 µm	25	30
500 µm (0.5 mm)		30	35
	300 µm	52	50
250 µm		60	60
	150 µm	100	100
125 µm		120	120
	75 µm	200	200
63 µm		240	230
	38 µm	400	400
32 µm		440	450

Table 1 Mesh sizes for sieves according to UK and US systems.

Screens (also known as 'sieves') exist in a wide range of different hole sizes. They can be described by the size of the hole (its diameter in mm or inches) or by its **mesh size** (the number of holes in a linear inch of the screen). The British and American systems for describing mesh sizes for sieves are slightly different and the common sizes are shown in the following table.

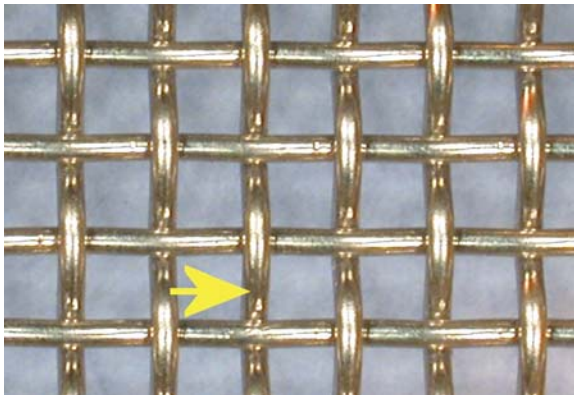


Plate 8 Mesh of a metal screen with mesh size shown by the arrow.

Screening equipment that is currently used in the mining

industry has a wide variety of hole sizes, slope angles and operating mechanisms (static, vibrating or rotating). This handbook will consider those screens best suited for use with simple sluice boxes; hand–held, grizzly and trommel screens.

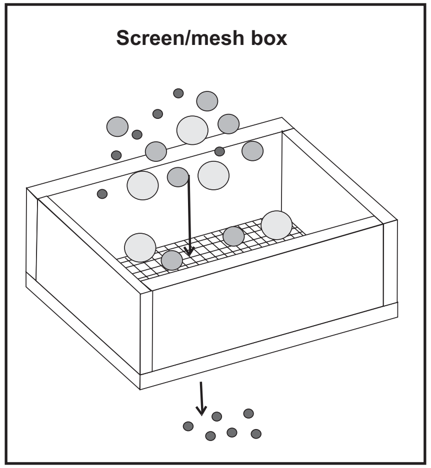


Figure 1 Diagram of a static screen.

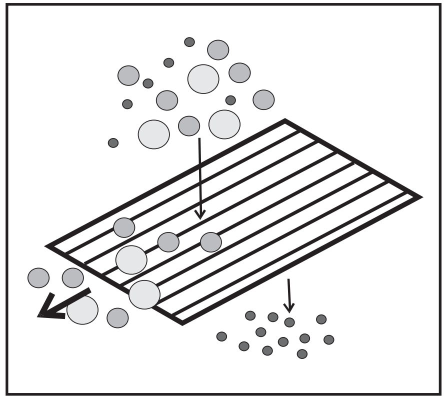


Figure 2 Diagram of a grizzly.

Hand-Held and Static Screens

Small sluice box operations may not have the resources to invest in screening equipment. In this case, when the throughput is low, the miner may be able to size the feed using a hand-held screen.

Simple screens can be made from wire mesh mounted in a wooden or steel frame for support and ease of use. Screens can also be made from metal sheets with holes punched through them.

Grizzly Screen

A grizzly is a static screen that consists of a series of parallel bars. These bars are separated by a gap that is set to reject coarse material. The undersize forms the feed to the sluice box. **It is recommended that the grizzly screen is set at a gap of 25 mm (1 inch).**

The grizzly should be inclined to allow oversize material to be removed easily and prevent blocking of the screen. If the screen becomes blocked ('choked') the feed to the sluice box is restricted and undersize material (containing gold) may be discarded with the oversize. Therefore, **grizzly screens must be cleaned regularly to prevent gold loss**.

The bars of a grizzly are usually made of steel, for example old rails or high tensile steel reinforcing rods. Wooden grizzlies require more attention but they are relatively cheap and appropriate in forested regions. A large steel grizzly was shown in Plate 7.

Trommel Screen

A trommel screen is like an ordinary screen that is wrapped around itself into a cylinder. It is open at both ends and slopes down away from the point at which material is fed into it. Trommel screens are rotated and this causes material fed into them to tumble. As the particles tumble they come into contact with the holes in the screen and, if they are smaller than the hole, they pass through. Particles that are larger than the holes stay inside the screen and are discharged out of the end of the trommel.

Unlike static screens, trommels rely on a dynamic screening method. A result of this is that the undersize material produced by a trommel is finer than that produced by the same hole size in a static screen. With a dynamic screen it is more difficult for particles close to the size of the hole to pass through the holes. Therefore in order to produce oversize material coarser than 25 mm it is recommended that a hole size of approximately 35 mm is used. The speed of rotation has a similar effect. The faster the drum rotates the smaller the effective size of the holes.

The rolling and tumbling of the feed in a trommel does help to break up clay lumps/ balls and weakly consolidated material. Ideally, trommels are operated with wash water and this helps wash finer material through the holes and ensures that any gold particles on the surface of larger lumps are washed into the sluice box feed.

Screens do present their own problems to the operator; with the perceived disadvantage of most screens being the cost (trommels) and the need for additional labour (hand screening and grizzlies).

IN GENERAL, THE GAINS FROM IMPROVED SLUICE BOX PERFORMANCE WILL MORE THAN OFFSET THE INCONVENIENCE AND THE COST OF THE SCREENING SYSTEM

Screening

- removes coarse-grained material that does not contain recoverable gold, and can be considered to be a pre-concentration stage.
- reduces the volume of material to be treated by the sluice box and increases the proportion of gold in the sluice box feed.
- eliminates clay balls, that would otherwise pick up gold particles and take them to the tailings,
- improves the overall performance of the sluice box process.

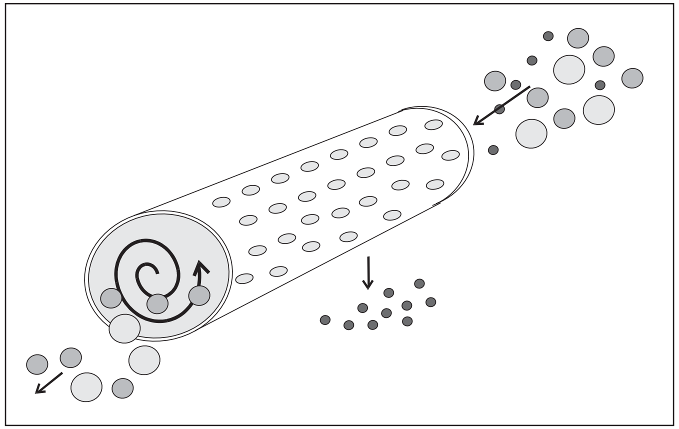
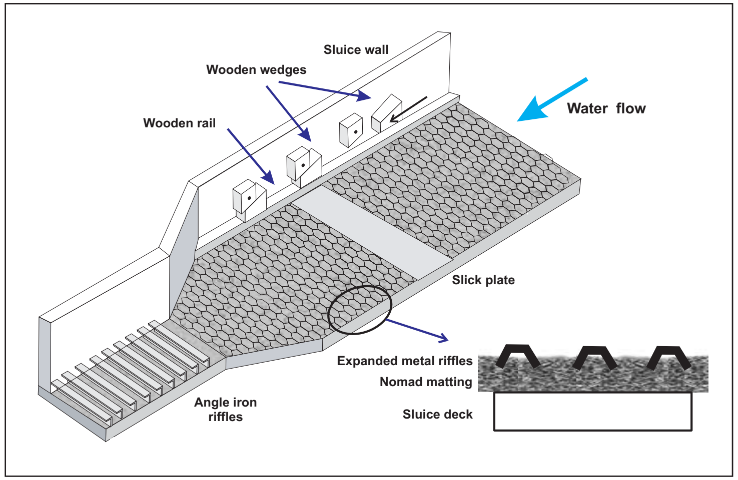


Figure 3 Diagram of a trommel.

Screening is a means of improving the amount of gold recovered but **choosing the screening size is a trade-off between the efficiency of the subsequent processing and the amount of ore that can be processed** (known as the 'volume throughput'). A screen with a small hole size will produce fine-grained feed material for the sluice box, which will then be able to operate efficiently and at high gold recoveries. However, there is a possibility that coarse-grained gold will be lost with the oversize from the screening. Also, the screen may require frequent cleaning (which may lead to temporary halts in production) and operation at a lower throughput rate as it is necessary to remove a relatively large volume of oversize material. A screen with a larger hole size will ensure that no coarse gold is lost and operate at a faster throughput rate. However, the feed to the sluice box will be coarser, which may lead to a less-efficient operation and lower gold recoveries**. The screening size chosen must be right for the ore at each mining site**.

5 The general features of a sluice box

Figure 4 Simple diagram of sluice box.



Although a sluice box is a relatively simple device it needs to be operated correctly for it to work and recover gold efficiently. The 'operating parameters' of a sluice box fall into three distinct categories; the feed, the design of the sluice box itself and the 'gold trapping mechanism' (ie how the gold is recovered).

The ore "feed" parameters (Section 6.0) are:

- Flow velocity (speed) down the box.
- Solids content of the feed.
- Particle size range of the feed and the gold

The "sluice box" design parameters (Section 7.0) are:

- Length and width of the sluice box.
- Gradient (slope) of the box.

The parameters relating to the "gold trapping system" (Section 8.0) are:

- The type of lining.
- Enhancements such as riffles.

It is good practice to measure and record the values of these parameters whenever the sluice box is set up.

MONITORING OF THESE PARAMETERS WILL ENABLE THE SLUICE BOX OPERATORS TO CONTROL THE PERFORMANCE OF THE SLUICE BOX AND QUICKLY PINPOINT THE CAUSE OF ANY PROBLEMS AS THEY ARISE

6 Parameters of the slurry feed to the box

The 'feed slurry' is the suspension of water and undersize material from the screening process. The consistency of this slurry, including the amount of ore it carries, the size of the particles and its feed rate onto the sluice box, affects the efficiency of gold recovery from the ore. The properties of this slurry are often ignored and are can be the cause of poor gold recoveries. **Feed slurry properties are critical to a well-operated sluice box**.

PARTICLE SIZE OF GOLD

The size (and shape) of gold particles influences the rate at which they settle and the proportion recovered from a slurry stream. This is a parameter that the miner cannot change. However, an understanding of the particle size and shape characteristics of the gold will enable the miner to tailor the design and operation of the sluice box to match the gold he is attempting to recover. For instance, some types of riffles (angle iron) are very good for recovering gold bigger than one millimetre in diameter and while others (expanded metal) are better for capturing finer gold.

Gold particle size is an important consideration when selecting your screen hole size. The screen hole size should be larger than the coarsest gold particles present to ensure that gold is not lost to the oversize. The particle size range of gold in the feed material can be determined in various ways. A simple field test involves carefully hand-panning gravel from the main ore sources to observe the size of gold grains present. For a more accurate and representative figure, large volumes of gravel would have to be processed. This can be carried out using a carefully operated test sluice (see section on testing ore deposits). Samples (several kilograms) can be collected for laboratory test work consisting of sieving into several size ranges and determining the gold content of each size range.

FLOW VELOCITY (SPEED) DOWN THE BOX

The flow velocity (speed of the ore slurry) is dependent upon the volumetric feed rate and the geometry of the sluice box. For a given box width and gradient, the flow velocity will increase as the feed rate increases. Narrowing the box or steepening the gradient will result in a higher flow velocity at a fixed feed rate. In general, it is not important to know the velocity of the flow accurately, it is only necessary to check the box to see that the flow is fast enough to wash away the less dense material. **If there is a good trapping mechanism it is unusual for gold to be lost due to unnecessarily high flow velocity of the feed, but if the trapping is poor gold will be washed away.**

WHERE WATER IS IN SHORT SUPPLY A NARROW SLUICE BOX SHOULD BE USED TO ENSURE THAT THE FLOW VELOCITY IS SUFFICIENT TO KEEP THE GOLD TRAPPING MECHANISM CLEAR OF LESS DENSE MATERIAL

Measurement of the flow velocity in a sluice box is relatively straightforward. The method outlined below will give a good indication but it is not absolutely accurate because flow velocity varies with depth, proximity to surfaces and internal currents.

Flow Velocity Measurement

Usually it is not necessary to accurately measure the speed of the feed slurry. The ultimate test will be the amount of gold recovered by the sluice box. If the speed is too low the sluice box will quickly become blocked with fine material but if it is too fast it will be scoured clean and little heavy material will be retained. The speed of the slurry flow is an important parameter to measure during tests of the performance at different set-up conditions. This is a useful and quick means of measuring the speed of the feed slurry:

1 Measure the length (metres) of a section of the sluice box.
2 Obtain some pieces of paper or wood that will be visible in the slurry stream.
3 Obtain a stopwatch. A watch with a second hand will suffice but the operation may require two people rather than one.
4 Drop the paper/wood into the stream at the top of the section and record the time (in seconds) it takes to reach the bottom. If a normal watch is being used, the person watching the stream will need to call out at the start and finish.
5 The velocity is the length divided by the time (metres/seconds, or m/s^{-1}).
6 Repeat steps 4 and 5 to obtain an average value.

Slurry velocity is especially important where riffle systems are being used to improve sluice box performance; this will be discussed in a later chapter.

SOLIDS TO WATER RATIO (SOLIDS CONTENT) IN THE FEED

The consistency of the feed slurry is a key factor in the 'stratification' and settling of the material during processing. Feed slurry of the correct consistency will allow gold particles to separate out of the slurry stream, come into contact with the bottom of the sluice box and be 'captured'. The consistency of the feed slurry is measured as the weight of solid material in a given volume of water, usually as a percentage (known as the 'solids content'). For example, 10 grams in 100 ml is 10% (w/v, weight/volume). If the consistency of the slurry is too 'thick' (ie a high solids content) gold will not settle out of the stream as it will be buoyed upwards by other less-dense particles and will ultimately be carried over the sluice box to the tailings. Ideally, **feed slurry should have a solids content of less than 15% (w/v)**. This can be measured accurately by using the following simple method:

Percentage Solids Measurement

Obtain a large (at least 500 ml) straight-sided, graduated measuring cylinder. If such a vessel is not available then obtain a fairly large, straight-sided, clear bottle with a relatively small opening; 1.5 or 2 litre mineral water bottles are ideal for this. Mark the top of the straight section with a scratch or using an indelible marker. Then divide the length of the parallel section into 10 equal lengths, marking them out in the same way. The top mark will represent 100% and the remaining marks will represent 90% down to 10%.

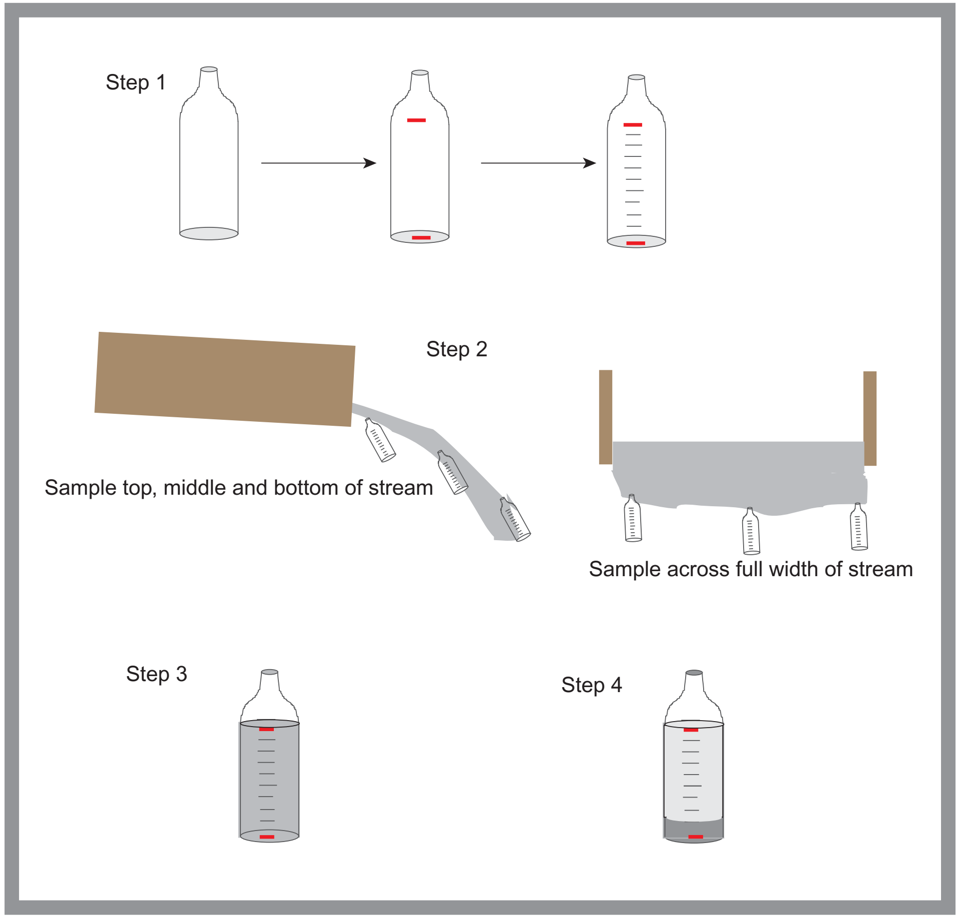


Figure 5 How to measure the solids content of the slurry.

7 The sluice box

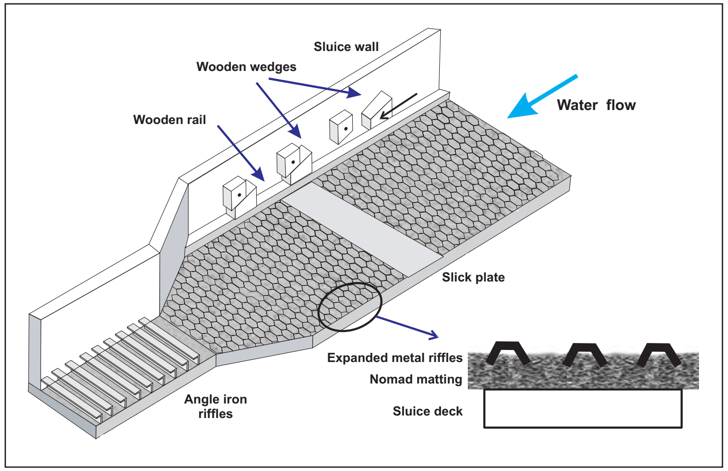


Figure 6 Schematic diagram of a sluice box.

CONSTRUCTION OF THE SLUICE BOX

A sluice box is a sloping channel with a flat bottom. The construction material is not critical but the box should be rigid enough to resist twisting and sagging. Typically, sluice boxes are made of wood or steel and raised above the ground on posts but can also be dug into the ground. The bottom of the box is usually covered with matting that is kept in place by riffles or wooden strips; together these are the gold trapping mechanism.

Removal of the gold–bearing concentrate from a sluice involves cleaning out the gold trapping mechanism. In order to minimise the clean out period, which puts the sluice box out of operation, it is important that the trapping mechanism can be removed and reinstalled rapidly. Figure 6 shows a simple method for holding the trapping mechanism in place in the sluice box by using wooden blocks and wedges along the side of the box.

Guidelines for the sizes of the various parts of a sluice box are shown in the Appendix at the end of the report.

WIDTH OF THE SLUICE BOX

The width of the sluice box is a critical operational parameter that is often overlooked. Miners have a tendency to use the same width of box irrespective of the feed-rate and/or the ore type. If the feed rate remains constant, changing the width of the box will change the velocity and depth of the feed slurry stream, which in turn will affect the amount of gold recovered.

A sluice box should be built to suit the rate at which the feed is delivered to it. Constructing a sluice box with the most appropriate width, for the feed rate and ore type, will ensure that the velocity and depth of the slurry stream are within the ranges required for optimum gold recovery. The main adjustment of the speed of flow is by altering the width, while fine-tuning of the slurry speed and depth can be achieved by varying the slope of the sluice box.

NARROW SLUICE BOXES SHOULD BE USED WHEN WATER IS IN SHORT SUPPLY AND FEED RATES ARE LOW. WHEN WATER IS PLENTIFUL AND FEED RATES ARE HIGH, BIGGER, WIDER BOXES CAN BE USED

There are many types of gold trapping mechanisms used in sluice boxes, each of which requires different speeds and depths of slurry stream. Therefore, in order to achieve optimum sluice box performance the width of the sluice box must be matched to the type of trapping mechanism used. The traps used for coarse gold recovery may need high slurry speeds and be in a narrow part of the box whilst those used for finer gold recovery may need slower speeds and to be positioned in a wider section.

SLOPE OF THE SLUICE BOX

Most sluice boxes are used with a slope of around 10 to 15 degrees. The exact slope is worked out in combination with other parameters whilst fine-tuning the performance of the sluice box. Usually, the width of the sluice box and slurry feed rate are used as the main controls on the properties of the feed slurry, but minor alteration of the speed and depth of the slurry stream can be achieved by adjusting the slope.

LENGTH OF THE SLUICE BOX

The sluice box needs to be long enough to capture all of the recoverable gold. **Miners have learnt from experience that most of the gold recovered is found on the first two or three metres of the sluice box.** This was confirmed by a study which indicated that successive sections of a sluice box, split into three equal parts, contain 90%, 9% and 1% respectively of the gold recovered as one goes from the top to the bottom of the box. However, contrary to popular belief, this type of distribution does not give an indication of sluice box efficiency. It would seem logical to assume that the sluice box is working efficiently if the proportion of gold recovered diminishes further down the box. However, trials have shown that irrespective of the overall recovery efficiency of the sluice box, whether it is as low as 30% or as high as 80%, most of the gold recovered would still be found in the first $^{1}/_{3}$ of the sluice box length.

For a large alluvial gold operation with high throughput it is recommended that sluice box sections should be at least three metres long and preferably up to five metres long. If more than one riffle type is being used each should be three to five metres long. A smooth, riffle-free, section (known as a 'slick plate') is inserted between each riffled section, to allow the slurry stream to re-stratify.

8 The Gold Trapping Mechanism

The gold trapping mechanism is the way in which gold is captured from the slurry stream and retained on the sluice box. A sluice box with a flat plain bottom is the simplest but least effective trapping mechanism. As the slurry stream is fed over the sluice box, gold settles to the bottom of the channel. The gold then travels slowly along the box and is eventually discharged over the end of the sluice box. If there is no other trapping mechanism the box needs to be very long to trap much gold.

In order to trap the gold, as it travels along the sluice, some kind of lining such as sacking, matting or fleece is used. More sophisticated trapping mechanisms also use riffles to create localised turbulence (boiling) which, when coupled with an appropriate lining material, can greatly enhance the trapping efficiency of the sluice box. This section discusses some of the simpler types of riffles and gives an indication of the optimum operating conditions for each and the situation when they are most applicable.

IT IS MOST IMPORTANT TO HAVE THE CORRECT TYPE OF TRAPPING SYSTEM

Gold trapping mechanism should be easy to assemble and dismantle so that down time for clean up can be reduced to a minimum. Complex or difficult fixings may discourage the operators from cleaning regularly. This may mean that clean up only occur long after the box efficiency has deteriorated to the point where gold losses are high. The fixing assembly must hold the lining down securely to prevent gold from escaping underneath the lining. This is especially important when using unbacked matting. If the riffles are not held down tightly over the matting, the sluice box concentrate may penetrate the matting and migrate underneath the matting to the end of the sluice box.

THE LINING

A good lining enables the sluice box to retain more concentrate than bare wood, rock or steel. It is removable and allows the cleaning of the sluice box to be fast and efficient.

In many places the choice of lining is dictated by the availability of materials, for example old sacking, blankets, animal hide or old matting. These all have a fibrous or hairy structure that can be used for the trapping, and retention, of small gold particles.

THE BEST LINING MATERIALS HAVE AN OPEN FIBROUS STRUCTURE THAT ALLOWS EASY ACCESS OF PARTICLES SO THAT THEY CAN SETTLE DEEP IN THE MAT

Laboratory tests and the experience of many miners has shown that the best mat is a vinyl loop door matting, sometimes known as ‘magic mat’ and sold under various brand names, including Nomad by 3M. The carpet type mats tend to wear very quickly and loose their pile and with it the ability to trap coarser grains of gold. This tends to roll over the surface and be lost.

IN GUYANA CARPET TYPE MATS ONLY LAST ABOUT 1 MONTH. THE COST OF NOMAD MATS MIGHT BE DOUBLE BUT THEY CAN LAST OVER A YEAR

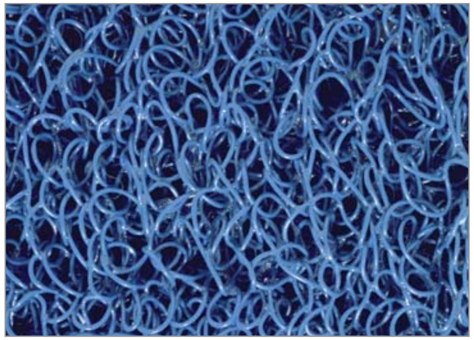


Plate 9 Top view of Nomad matting.

Plate 10 Black carpet matting with backing.

RIFFLE SYSTEMS

The need to secure the lining onto a sluice box may inadvertently have led to the development of the first riffle systems. Cross pieces nailed to hold a sack or a mat in place on the base of the sluice box may have led to the observation that their use resulted in the localised recovery of gold behind the fixings. Rudimentary riffles do not improve sluice box performance significantly. This is because they may cause local turbulence that can break up the stratification of the slurry stream and even reduce the amount of gold recovered. However, coarse or nugget gold can be trapped behind them and this causes great excitement and the perception of improved performance.

Different types of riffle systems are used for recovering gold of different particle sizes. For ore with a range of gold particle sizes, more than one riffle system should be used; one type for coarse gold and another for fine gold. As different riffle systems require different operating conditions it will be necessary to modify the width and slope of the sluice box to maintain optimum sluice box performance for each type of riffle.

Angle Iron Riffles

Angle iron riffles are mainly used for trapping coarse gold. The most important parameters for effective use of these riffles are the flow velocity, riffle spacing and riffle height. Assuming optimum flow speed and spacing, a rotational turbulence or vortex is created between the riffles which keeps the fine, less dense material moving and also prevents the lining from becoming blocked with solids. At the same time, centrifugal forces generated by the vortex push the gold particles down into the open structure of

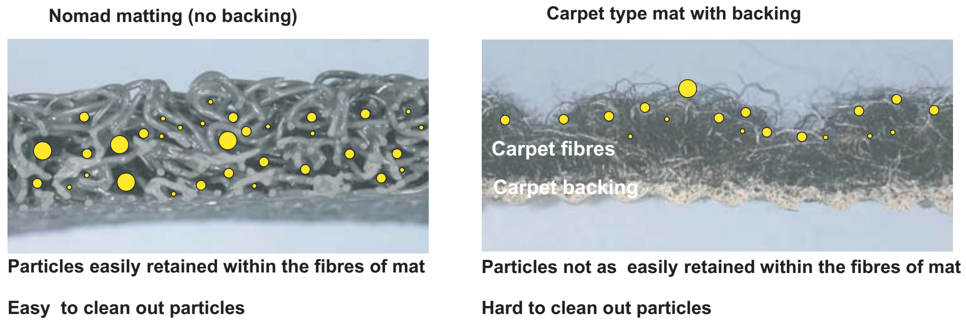


Figure 7 Cross sections through mats showing their gold trapping properties.

the matting. Standard 25 mm (1 inch) angle iron is ideal for many sluice boxes but smaller sizes can also be used.

To construct the riffles, the angle iron should be cut to a length about 25 mm shorter than the width of the box section where the riffles are to be installed. These lengths should then be welded to flat bar (same length as the riffles), with a gap between each riffle length of 40 mm to 65 mm and the flat top of the riffle at approximately 15° to the horizontal top of the flat bar. (Figure 9)

When the flow speed is correct there should be little sand between the riffles. If the gap is packed with sand either the speed is too slow, the spacing is to close or the riffles are too high. Any one of these factors stops the proper vortex forming.

Expanded Metal Riffles

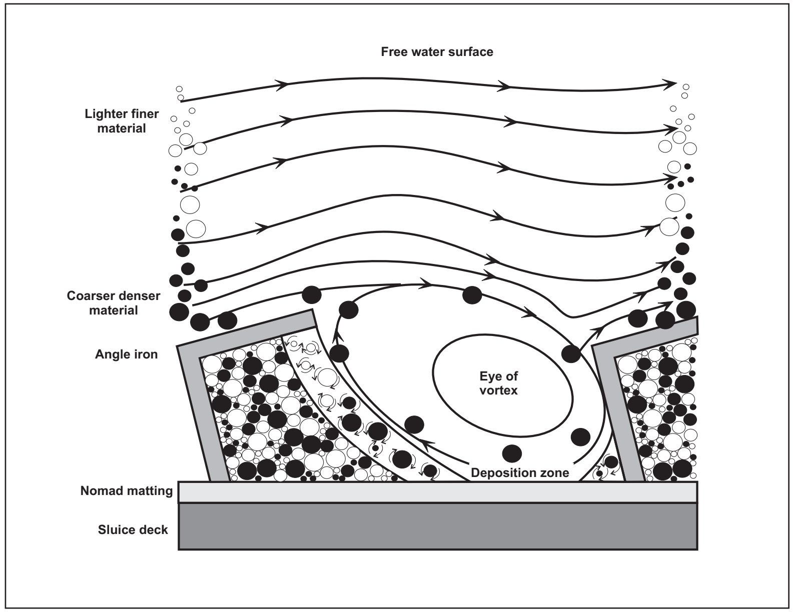
Expanded metal is made from sheet steel that has a series of holes cut through it. The steel is then stretched to pull open the cuts to produce an open structure with lozenge-shaped holes. It is widely used for many industrial purposes such as metal grilles.

Plate 11 A narrow section of sluice fitted with angle riffles to catch coarse gold.

Expanded Metal Riffle

Expanded metal can be used for shallow riffles that are more suitable than angle iron

Figure 8 How an angle iron riffle works. (Modified from Clarkson 1994).



for trapping fine gold. The gaps in the mesh cause lots of local turbulence that helps to keep the sand moving but allows the gold to settle into the mat. **When the flow speed is correct the sand 'dances about' between the riffles and keeps moving**, if it is too slow the gaps soon clog up.

The riffles also hold the lining firmly against the sluice box to prevent trapped gold from being lost under the matting. It is important to use a gauge of steel that is correct for the size of the sluice box.

Lighter steel mesh can bow and leave gaps between it and the matting, allowing the mat to lift and gold to be lost. If the metal mesh does warp then this can often be fixed by nailing a wooden batten along the centre line of

GOOD HEAVY GAUGE MESH IS NECESSARY IN LARGE BOXES TO HOLD THE MATS DOWN FIRMLY AND IT ALSO LASTS A LONG TIME

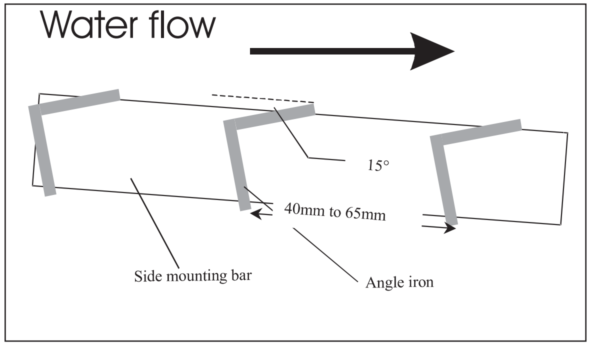


Figure 9 Cross section through angle-iron riffles.

the box. Narrow sluice boxes can use much lighter steel than wide ones.

Plate 12 Photo of expanded metal riffles.

Expanded metal riffles also serve several other useful purposes. In areas where security is a problem bolts and padlocks can be used to securely fasten the metal to the box to prevent the mats from being removed. Boxes that are fed from gravel slurry pumps have high throughputs that can very rapidly wear away the pile of the mats and leave them bald and very inefficient at trapping gold. The riffle protects the mats from abrasion by sharp stones and sand and can increase the useful life of the mats by many times. This saving is usually much greater than the cost of the riffles. **A sluice box in Guyana refitted with Nomad mats and expanded metal riffles was still using the same mats after 15 months**.

Other types of riffles

Many other materials and designs are used to make riffle systems but generally

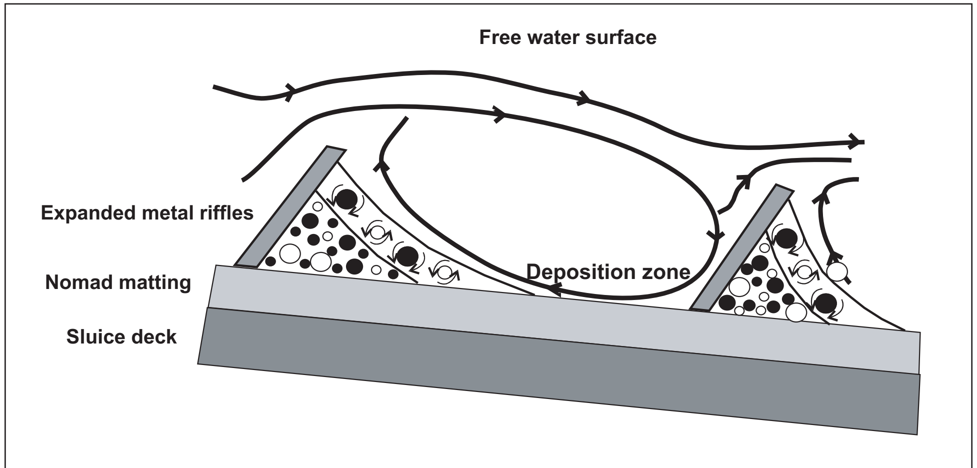


Figure 10 Cross section of expanded metal riffle (After Clarkson 1994).

Process Parameters	*Gold Trapping System*	
	Angle Iron Riffles	*Expanded Metal Riffles*
Gold particle size	Coarse gold recovery (+1 mm particles)	Fine gold recovery (-1 mm particles)
Flow velocity	2 m per second	1 m per second
Depth of stream above riffles	25 mm to 30 mm	15 mm to 20 mm
Riffle spacing	40 mm to 60 mm gap (25 mm angle iron)	Fixed by grade of expanded metal (20 to 30 kg/m^2 recommended)
Length of section	3 m to 5 m minimum	3 m to 5 m minimum
Slope (Gradient)	12° to 15° (210 to 265 mm vertical drop per 1 m horizontal length)	7° to 12° (120 to 210 mm vertical drop per 1 m horizontal length)

Table 2 Guidelines for angle iron and expanded metal riffles.

these are not suitable for small-scale mining. In Guyana metal 'Hungarian' or 'dredge riffles have been used but these are unsuitable. The riffles are about 2 inches (50 cm) high and require a very high water speed to produce a vortex between the riffles to keep the sand moving and allows gold to get down to the mats. This speed is not produced in smaller sluice boxes and the riffles just clog with sand and have little effect.

Plate 13 Hungarian or dredge riffles.

Some larger scale alluvial gold mines in Canada and New Zealand use hydraulic riffles produced by powerful jets of water from pipes running across the sluice box. These can be an effective system but due to the cost and complexity are not suitable for small-scale miners.

Good riffles trap more gold
protect the mats
make the gold more secure

9 Clean up (Wash down)

This is the process whereby the concentrate that has accumulated in the sluice box is recovered. **Clean up should be performed whenever the gold trapping mechanism is filled with sediment**. Overloading of the mats will cause a deterioration of performance as the gold particles cannot work their way down into the mat and be securely trapped. Different gold trapping mechanisms have different characteristics and capacities and the operator should familiarise him/herself with the appearance and feel of the system at various stages in its cycle. Systems with angle iron or expanded metal riffles over "Nomad" matting are best assessed by feel. When first installed, the matting has plenty of 'give' (i.e. it feels relatively soft and flexible) but, as the matting is loaded with sediment, it becomes harder. If the matting is monitored frequently the operator will become familiar with the feel of its open structure and it will be evident when the matting needs to be cleaned up.

Alluvial ores often have the richest gold in the bottom layers of the gravel. By the time this stage of the mining is reached the box can often be packed from processing of the overlying poorer grade material. This problem can largely be avoided if overburden is stripped away before the gold mining and ore processing starts. **It is very important to clean the box and have it working at its most efficient when processing the richest ore.**

CLEAN THE BOX REGULARLY, THE GOLD MUST BE ABLE TO GET INTO THE MATS IF IT IS TO BE TRAPPED

The main objective of the clean up is to ensure that none of the concentrate is lost. The clean up operation is therefore carried out, where possible, in a 'closed system', some type of box or tank.

It is normal practice to remove the oversize and general debris from the sluice box before attempting to recover the trapped concentrate. The sluice box is usually cleaned out from the top to the bottom, which is blocked off to prevent any concentrate from being lost over the end.

The general cleaning procedure involves removal of the fixings (wedges, nailed retaining strips, etc) which are then washed. The riffles are then washed and removed before the matting is carefully taken out and placed in a closed tank of water. The bottom of the box can then either be carefully washed down or swept clean with a hand brush to remove the gold and black sand remaining on the base of the box.

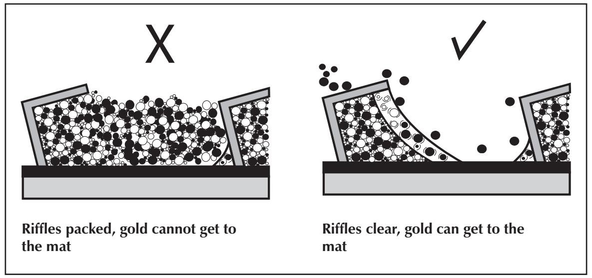


Figure 11 Cross section of angle iron riffles, showing packed and clear riffles.

Figure 12 Top view of expanded metal riffles showing clear and packed riffles.

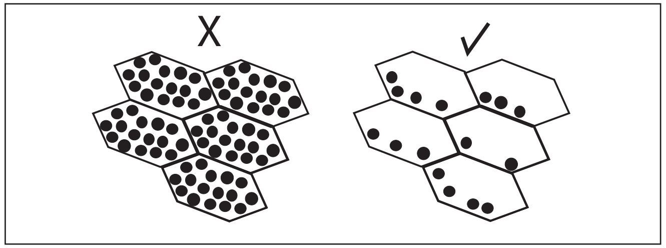
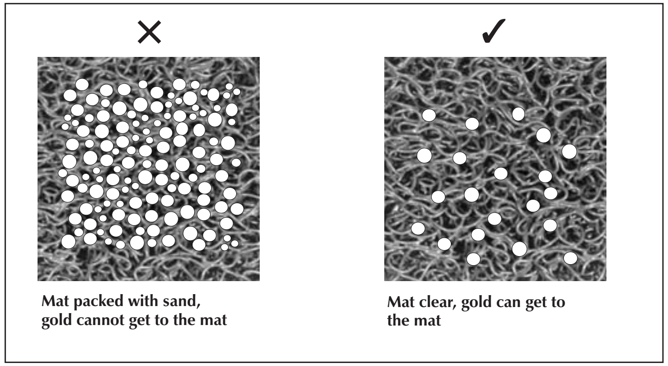


Figure 13 Top view of Nomad mats showing clear and packed mats.



The matting should be cleaned using the most effective method. For example, the open structure of "Nomad" matting allows it to be cleaned by hosing with water or slapping small areas sharply against the surface of water. However, "Nomad" matting must be treated with care, as it can tear. Other types of carpet matting are relatively tough and can be treated far more roughly. Gold particles either occur on the surface or buried within the pile of the mat such that aggressive shaking and slapping on the water is required to release the gold particles.

Plate 14 Washing mats in steel tanks (Guyana).

10 Recovery of gold from the sluice box concentrate

The concentrate collected from the sluice box typically consists of black sand (which consists of 'heavy minerals') that contains a small proportion (a few percent) of gold particles. Sluice boxes will produce a large volume of black sand (many kilograms) which needs to be processed further to recover the gold it contains. The concentrate could be processed with a small test sluice such as that shown in Plate 17 or passed over a small shaking table. However, the commonest method used is careful hand panning, which removes most of the black sand to produce a gold-rich concentrate. The gold has to be separated from the remaining black sand so that it can be sold. At this stage mercury amalgamation is usually used to pick up the fine gold particles and stick the coarser ones together. Unfortunately mercury amalgamation is the only really effective means of recovering the gold (the few real alternatives are not practical for most small-scale miners).

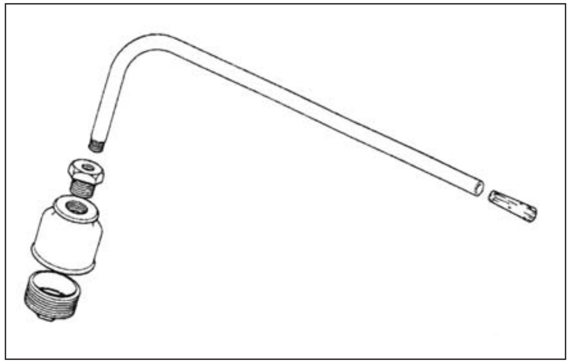
MERCURY IS A POISONOUS SUBSTANCE THAT REQUIRES EVERY POSSIBLE PRECAUTION TO MINIMISE ITS USE, REDUCE WORKERS EXPOSURE TO IT AND TO PREVENT ITS RELEASE INTO THE ENVIRONMENT

The following guidelines will help reduce the risk to human health and the environment from the use of mercury:

- **Never put mercury in the pit or sluice box.** It does not significantly increase gold recovery but it does pose a serious threat to miners and the local environment
- **Never use mercury to recover gold from the first sluice box concentrate.** Hand panning of the sluice box concentrate is generally very efficient and little gold is lost. Use of mercury at this stage is hazardous to the workers.
- **When handling mercury always wear gloves, work in a well-ventilated area and when possible wear a face mask.**
- **Always use a retort to recover mercury from the amalgam.** When removing the mercury from the gold-amalgam cake use a retort and capture the mercury vapour; do not release it to the atmosphere.
- If a retort is not available burn the mercury in a well ventilated area and never use utensils that are used for preparing or cooking food.

There are various designs of retort around and these will vary from country to country. ITDG designed a simple retort that is suitable and very effective for treating small volumes of concentrate Figure 14. Figure 15 illustrates the principles on which the retort works. The gold mercury amalgam is heated in the small

Figure 14 Simple retort designed by ITDG made from plumbing fittings.



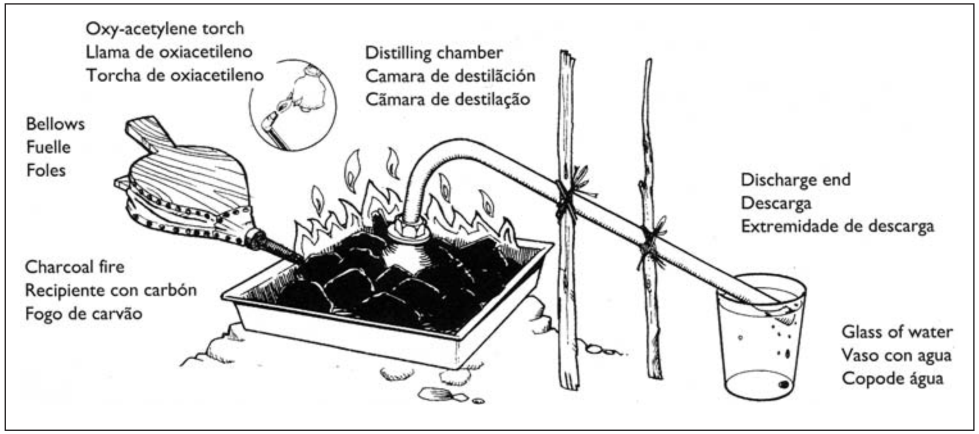


Figure 15 Showing how the retort can be used on a charcoal fire.

pot so that the mercury 'boils off' and leaves clean gold behind. The mercury vapour condenses in the pipe, which is cooled by air or water and the condensed liquid mercury runs down the pipe and is collected under water. It is collected under water in case any mercury vapour has not condensed in the pipe. The liquid mercury can then be collected and used again.

The use of mercury to recover gold is one of the main environmental concerns associated with small-scale gold mining.

ALL EFFORTS MUST BE MADE TO MINIMISE THE USE OF MERCURY

The amount of mercury used is roughly proportional to the volume of gold produced.

11 Water Recycling and Tailings Disposal

There are two main reasons for careful use of water by small-scale miners:

- **The Environment** — The tailings produced by mining can be a serious environmental hazard. Tailings slurry discharged directly into a watercourse causes local problems due to the build up of sand and gravel which can block or divert the river. Further away the fine silt and mud cause many problems. The increase in the amount of suspended solids in the water suffocates fish and plants, which has a terrible effect on local people who rely on fish as a major food source. Often a greater problem is caused by spoiling the water used by people downstream for drinking, cooking and washing, as the mud travels many kilometres.
- **Efficiency** — In many areas, where small-scale mining is practised, water is either scarce or is brought a long way to where it is needed. If considerable effort and cost has been invested in getting water to the mining and processing locations then it makes good practical and economic sense to make the best possible use of it.

These two objectives can often be achieved by a planned system of tailings disposal and water recycling.

The principle of operation is simple. Tailings slurry is delivered to the settling pond. The solids settle to the bottom and a layer of clear water forms at the top. The amount of time it takes for the particles to settle is largely controlled by their size. Large particles are heavier and settle quickly, whereas smaller lighter particles take longer to settle. Therefore, it takes longer to produce clear water from suspensions of very fine particles such as clay. Fortunately sluice boxes can be operated with water that is not perfectly clear. The main drawback of using water with a small amount of fine-grained suspended solids for the high pressure monitor jets is that the solids are abrasive and accelerate wear of the pump parts.

The clear water should be extracted from a point in the settling pond that is as far away as possible from where the tailings slurry is put in the pond. However, the water that is extracted might still contain a significant amount of suspended solids. To overcome this it is possible to improve the system by building a barrier that would restrict the movement of tailings within the pond and increase the effective distance between the tailings delivery point and the clear water extraction point.

The construction of tailings ponds and barriers requires planning and earth moving equipment. This makes it difficult for small-scale miners to do unless there is co-ordinated communal action or intervention and assistance from the mining authorities. Miners working in isolation can give careful thought to where they put the tailings from their early mining so that water and mud drains through the soil rather than straight into streams and rivers. They can then use the pits created as a settling pond and place for disposal of later tailings. This reduces the damage to the local environment.

Plate 15 Old mine pits being used for storing, settling solids and recycling water, the water is much clearer at the right hand side away from the tailings.

12 Problems and Remedies (Operational Considerations)

SLUICE BOX PACKED WITH SOLIDS

- *Riffled sluice box* The sluice box may become packed with solids if the slurry flow is too slow or the gap between the riffles is not set at the correct distance or the riffles are too tall. It is vital that the correct turbulence is formed between the riffles that keeps the sand and mud moving. The speed and depth of the slurry flow can be modified by altering the slope and/ or width of the sluice box. Make the box narrower to increase flow or wider to decrease flow. If the problem persists it may be solved by changing the gap between the riffles or making the rifles lower.
- *Unriffled sluice box* The sluice box may become packed with solids if the flow rate is not fast enough to keep the large particles moving. This could be resolved by narrowing the sluice box, which would have the effect of increasing the speed of the slurry. However, in preference to this, it is recommended that the feed be screened to remove coarse particles before the slurry is fed onto the sluice box.

UNEVEN DISTRIBUTION OF FEED ACROSS WIDTH OF BOX

- The feed slurry stream may flow along one side of the sluice channel instead of flowing evenly across its entire width. This may be caused by the sluice box tilting to one side or by introduction of the feed slurry to one side.
- The feed slurry stream may be diverted away from certain areas of the sluice box due to a build up of material. Regular cleaning of the sluice box, or pre-screening to remove coarse particles, will solve this problem.

CLAY BALLS

- A reduction in the amount of gold recovered can be caused by the presence of 'clay balls'. These can physically remove gold by rolling over the gold particles which then become stuck to the sticky surface of the clay. If the clay balls roll off the end of the box they take gold with them. The 'clay balls' can either be removed by screening or disaggregated (broken down into the fine-grained clay particles). The latter option can be carried out either on a screen, using a scrubber, a pump or a trommel.

WATER LEAKS

- If any holes or cracks in the bottom of the box are not sealed properly water will escape. The water is likely to carry with it fine particles of gold which are effectively lost. It is recommended that every time the sluice box is set up any holes and cracks in the base of the box are sealed.

GOLD UNDER THE MATS

- A mat should always be used as the means of trapping gold on the base of the sluice box. The mat must be firmly secured to the base of the box to avoid a loss of gold. If it is not secured, water may find its way gets underneath the mat and lift it away from the base of the box. Fine gold will be carried along the base of the box and lost. This is a particularly serious problem if backed mats are used or riffles are not used to hold the mats down.

Plate 16 Problems with box because no riffles are fitted.

This box has been fitted with Nomad mats that are generally good but there are no riffles to hold them down and protect them for wear by sharp stones.

Riffles also create turbulence to keep sand moving. Here the sand has worked its way under the mat so that it is packed full and bulges up. Little gold can get into the mat to be trapped.

13 Monitoring and Sampling

In order to maintain a sluice box at optimum process efficiency it is important to measure, and continually monitor, its operating parameters.

Methods for the measurement of many of the important operating parameters (solids content of the ore slurry, slope of the sluice box and slurry flow rate) have already been described in this handbook. These parameters should be measured and recorded as part of the regular operating routine. Other parameters that should also be included in this routine include the depth of the slurry stream; the “fixed” parameters like the length, width and type of gold trapping system; and physical observations like packing between riffles (if used), the presence of ‘clay balls’ and the build-up of material.

Careful study of the monitoring record will make it easier to diagnose and solve any problems that may occur during the operation of the sluice box. For example, it would be readily apparent that variations in the slurry flow rate are responsible for blocked riffles and that the solution to this problem would be to increase the flow rate. However, other problems may be less obvious to identify and, in cases like this, it may be necessary to measure the efficiency of the gold recovery.

Many miners are aware that their gold mining operations are not perfect however, very few can put a figure on their current operating efficiency i.e. the proportion of gold recovered from that which is present in their ore. One means of evaluating performance is to relate the amount of gold lost to tailings to the total amount of gold recovered in the sluice box concentrate. Observations on the size and shape of the gold particles occurring in the concentrate and tailings can also be very informative. Information on the amount of gold produced from a sluice box concentrate will be readily available. However, it would still be useful for at least part of the sluice box concentrate to be panned down to pure gold. The pan tails should also be sampled and carefully panned to indicate the panning efficiency.

Tailings are harder to evaluate because of their sheer volume and low gold content. The low gold content means that a large sample of tailings is required to produce a significant amount of gold.

It should be noted that the perfect sample does not exist unless the whole product is taken. However, it is possible, given adherence to certain guidelines, that a close approximation to the ‘perfect sample’ can be taken; this is known as representative sampling.

It is important that a sample must represent the whole period of operation and the full process stream. It is recommended that a small sample should be taken from the tailings stream every hour throughout the operational period. This should be used to make up a composite sample. The vessel used for measuring the percentage solids of the slurry can be used as a sampling vessel. The sample will only be representative if it is taken from across the full width of the stream and from the full depth of the stream (top, middle and bottom).

This tailings sample should, like the concentrate, be reduced to a manageable volume by using either a mini sluice box (for example, a ‘warrior’) or a pan. Careful panning should then be carried out to produce a final concentrate consisting mainly of gold but also some black sand.

The amount, and the characteristics (mainly shape), of gold recovered from the tailings will give an indication of the operating efficiency of the sluice box. A direct correlation of the amount of gold found to occur in the tailings and concentrate gold to the total gold content of the ore will be difficult to achieve. However, systematic record keeping will reveal trends in the amount of gold recovered that could be related to the operating efficiency of the sluice box and also to the natural variability of the ore deposit itself.

14 Assessment of alluvial gold deposits

The distribution of gold in alluvial deposits is extremely variable from place to place. In a river valley there is usually a main channel where the river deposits coarser sediments, sand and gravel and a flood plain where sand and mud are deposited in times of flood. In general most gold is found in the coarser channel deposits. Over a period of years the channel trends to change its course so that beneath the current river channel there are flood plain deposits and beneath the flood plain there are probably older buried channel deposits. A pit dug through the sediments will reveal a profile of various types of sediment overlying the bedrock and the detail of the succession and proportions of the type of sediment will vary from one place to another.

The assessment of the gold potential of an area of alluvial sediments is extremely difficult due to this large variability. Even when drilling equipment is available and large number of holes are drilled it is difficult to make accurate predictions. Simpler methods can be used to find some idea of the gold potential. Probably the most accurate way to estimate the total amount of recoverable gold at a particular site is to set up the actual equipment that is going to be used and to carry out a trial mining operation excavating a large pit down to the bedrock. Using this method it will be difficult to estimate gold content of the different layers unless the sluice box is cleaned after each layer has been excavated.

An alternative is to dig smaller hand dug pits, which gives much better control over the source of the sediment from particular

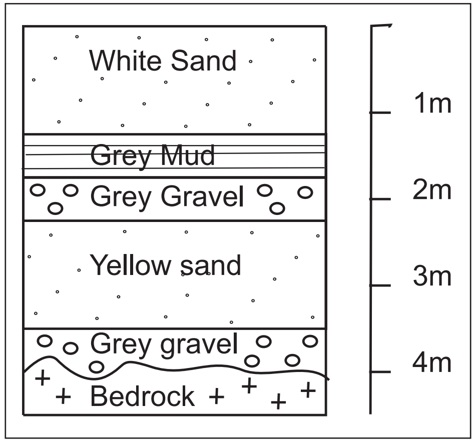


Figure 16 Profile through alluvial sediments.

layers. The sediment is then either hand panned or processed with a small test sluice. A sluice similar to the one shown can process at least half a ton, 1 cubic metre, per hour. This would enable representative sampling to be done as the pit is dug. Ideally the same volume of sediment from each horizon should be processed to make comparison easy. Large (20 litre) plastic buckets make a convenient measure and 15 buckets, gives a weight of about 500 kg which is a good size sample. It is important to record the thickness of the various sediment layers and to wash down the test sluice after the material from each layer has been processed. The heavy concentrate from each layer can then be very carefully hand panned to produce a gold-rich concentrate.

The most accurate way to determine the gold content of these gold-rich concentrates

Figure 17 A simple test sluice.

Figure 18 Mine officers using the test sluice.

would be to carry out assay analysis but reasonable estimates can be made by using a small set of sieves to separate the gold into specific size ranges and then counting the gold grains in each sieve. The coarser grains can easily be counted using a hand lens but the smaller grains are very difficult to see and really require a simple binocular microscope. This may not be possible at the mine site but concentrates could be examined at the local mine station.

After counting the gold grains collected on each sieve Table 3 can be used to calculate the weight of gold (grams) in each size range by multiplying the number of grains by the weight conversion factor. The weight conversion factor has been calculated by sieving gold samples, collecting a large number of grains on each sieve, weighing the grains and calculating the average weight of a single gold grain in that sieve size. The following table shows the results from a sample of 'pay gravel' from the Mahdia gold deposits in Guyana. The sample was seven 20 litre buckets giving a weight of about 250 kg.

Collected on sieve mesh (UK size)	Particle size range(mm)	Weight conversion factor
8	-2.4 + 2.0	0.06041
16	-2.0 + 1.	0.02299
30	-1.0 + 0.5	0.00191
60	-0.5 + 0.25	0.00029
120	-0.25 + 0.125	0.00009
240	-0.125 + 0.063	0.00003
	<0.063	0.00001

Table 3 The weight of gold particles collected on various sieve sizes.

This data has been plotted on a graph, which could be used to calculate the weight of any roughly spherical gold particle of any size within the range shown (Figure 17).

Particle size (mm)	Sieve mesh (UK size)	Weight conversion factor	Number of grains	Weight of grains (gm)	% by weight
-2.4 + 2.0	8	0.06041	0	0	0
-2.0 + 1.0	16	0.02299	3	0.06898	33.6
-1.0 + 0.5	30	0.00191	19	0.03635	17.7
-0.5 + 0.25	60	0.00029	192	0.05622	27.4
-0.25 + 0.125	120	0.00009	434	0.03920	19.1
-0.125 + 0.063	240	0.00003	131	0.00394	1.9
<0.063		0.00001	58	0.00058	0.3
		Total	837	0.20526	

Table 4 Data from gold size distribution test from Mahdia, Guyana.

The data in Table 4 from a real sample, gives a lot of important information.

- The grade is 0.2 grams in 250 kg or 0.8 grams per ton (approximately 2 gm/cubic metre or 1 pennyweight/cu yard), which is a good grade for an alluvial deposit.
- The recovery efficiency of big sluice boxes drops off rapidly for gold finer than 100 microns. In this example from the more efficient test sluice, only a small proportion is less than 125 microns so a well set up miners sluice box should get very good recovery.
- Although there are only a few larger gold grains these form a large proportion of the total amount of gold. Three grains larger than 1 mm account for 33% of the gold, while nearly 600 grains less than 0.25 mm account for 22%. It is very important to have a gold trapping system that is effective for coarser gold or losses could be high.

From a series of pits a good idea of the distribution of gold in the area can be built up. It will show which types of sediment contain the most gold, possibly gravel, and when this type of material is being mined particular care should be taken to make sure the box is working properly. If this is at the bottom of the profile the box might be clogged with mud and silt from the overlying sediment and it could be advisable to clean the mats before passing the richest ore. The upper parts of the profile might be very low grade and in this case it may be possible to remove this overburden before passing the richer material over the sluice.

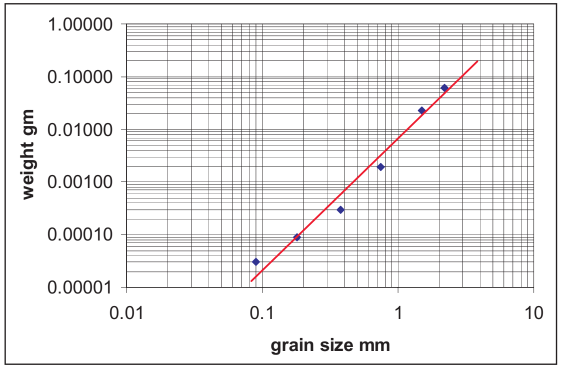


Figure 17 Graph showing the weight of a gold grain against the size.

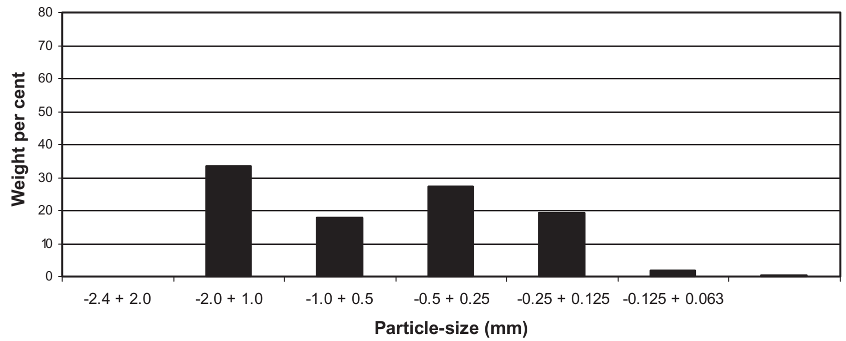


Figure 18 Histogram showing the proportion of gold by weight present in each size range in the sample from Mahdia, Guyana.

It is very important to take adequate safety precautions when digging pits. If the alluvial sediments are thick, 3 metres or more, the pits will have to be quite large so that the sides are not too steep and liable to collapse. They may need to be supported with timber planks to make them safe.

THE VALUE OF TESTING

The alluvial gold fields in the Potaro district of Guyana have been worked and reworked on many occasions over the last 100 years. It was widely assumed that the fine-grained nature of the gold made it difficult or impossible to capture on sluice boxes. This was thought to be responsible for the poor recoveries and gold being present in tailings. Miners could do little to improve recoveries with the equipment available.

BGS and GGMC carried out a series of tests to examine this assumption. Many samples were collected and concentrated by several methods including the minisluice, a Knelsen concentrator and hand panning. The gold from the concentrates was sieved into size ranges as described previously. This data showed that there was very little evidence for the presence of significant amounts of gold finer than 0.1 mm. Testing of tailings showed that gold covering the whole size range was being lost, including grains as coarse as 1 mm. A well set up sluice box should be capable of good recovery. They were not chasing after the impossible. Simple modifications to incorporate the type of equipment recommended here has been demonstrated to produce improvements in efficiency of at least 20%.

Appendix

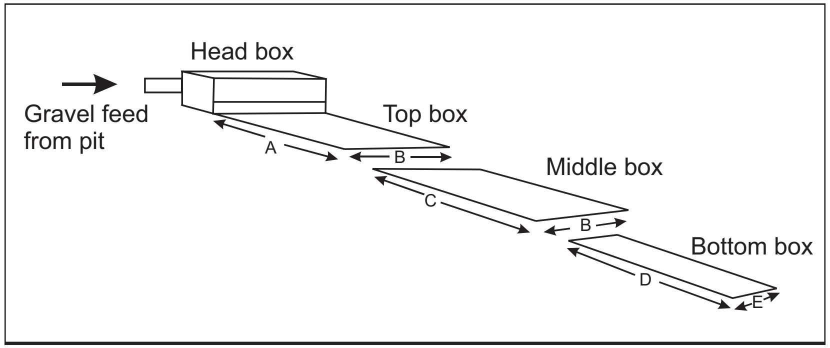


Figure 19 Guidelines for the sizes of sluice boxes fed by slurry pumps.

Guidelines for the size of a sluice box fed by a slurry pump

This section contains guidelines for the size of the various parts of a sluice box that is fed by a slurry pump. The size of box required depends on the flow rate of slurry to the box which largely is governed by the size of the pump and the power of the engine driving it. It is also affected by the distance between the pit and the box and whether the slurry is pumped uphill. It will always be necessary to follow the advice given in this handbook to check that the correct operating conditions are being achieved. The size recommendations given here are for two sizes of pumps and are based on the successful results of field refits carried out in Guyana. The 6 inch pump refers to a pump with 6 inch inlet and outlet pipes and is powered by a four cylinder diesel engine of about 2 litres capacity shown in the photo earlier in the report. The 4 inch pump refers to a pump with 4 inch inlet and outlet pipes powered by a smaller 'portable' diesel engine of around 1 litre capacity.

The box is designed to be constructed in several sections to house the different types of riffle system. The top two boxes are designed to trap the finer gold and contain expanded metal mesh covering Nomad mats, while the bottom box contains angle iron riffles over Nomad matting. The angle iron riffles need a flow rate about twice the speed required for expanded metal riffles so the box has to be about half the width. The sizes here are in imperial units and based on the size of materials available in Guyana but can be used as a guide for use elsewhere.

	4 inch pump		**6 inch pump**	
	Contents	Size	Contents	Size
Top box	1 * 4ft sheet expanded metal	A = 6ft B = 3ft	1 * 4ft sheet expanded metal	A = 6ft B = 4ft 6 ins
Middle box	2 * 4ft sheets expanded metal	C = 10ft B = 3ft	2 * 4ft sheets expanded metal	C = 10ft B = 4ft 6 ins
Bottom box	8ft angle iron riffles	D = 10ft E = 1ft 6 ins	8ft angle iron riffles	D = 10ft E = 2ft

Table 5 Guidelines for the sizes of sluice boxes fed by slurry pumps.

References

Clarkson, A. 1994 The use of nuclear radiotracers to evaluate the gold recovery efficiency of sluice boxes. CIM Bulletin, 29–37.

Styles, M T, Mitchell, C J, Bugnosen, E, Calow, R and Evans, E J. Gold recovery by small-scale miners: A summary of field investigations and literature review. WC/99/6.

The aim Project R7120 'Recovering the lost gold of the developing world' is to identify and introduce better working practices to small-scale gold miners to give improved gold recovery, lessen environmental damage and increase wealth and well being in mining communities. This handbook contains information for Mining Engineers, Mines Officers and Mines Technicians to enable them to give good advice to small-scale miners about the construction and operation of sluice boxes to maximise the recovery of gold and minimise environmental damage. Field observations, trials and demonstrations carried out in Guyana with GGMC form the basis of the advice given in this report.

This report is produced as part of DFID KAR Project R7120. The project was carried out in partnership with ITDG with the Guyana Geology and Mines Commission as the principal collaborator

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