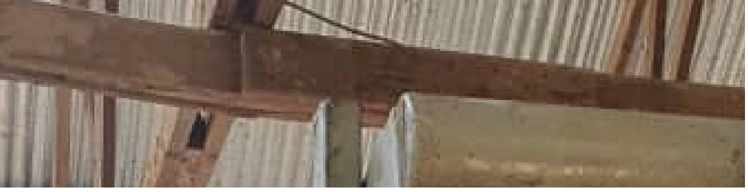
High Banker Sluice with Direct Smelting

Towards Mercury-Free Gold Processing

FIELD TEST

REPORT



Design, Fabrication, and Testing of the High Banker Sluice with Direct Smelting for Mercury-Free Gold Processing in Tanzania

March, 2025

CLIENT

THE IMPACT FACILITY

THE IMPACT FACILITY
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2nd Floor, Geita, Tanzania

PREPARED BY

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EXECUTIVE SUMMARY

In recent years, gold prices have risen, but Tanzanian Artisanal and Small-scale Gold Mining (ASGM) methods remain basic, with mercury still widely used. This leads to financial losses and serious health and environmental risks. The Impact Facility proposed the High Banker Sluice with direct smelting as a practical solution to boost gold recovery and eliminate mercury use.

The High Banker Sluice was designed by Mkemia Mineral Services and fabricated by Benjamin Kubeja Fabricators, then tested at Nsangano Gold Mine in Nyarugusu. During testing, 98.24 kg of primary ore was concentrated, panned, and directly smelted to produce a gold bead.

The field test observed that the High Banker Sluice had a user-friendly, flexible design, achieving 63.18% recovery and a 25.73 ppm concentrate from a 5.65 ppm feed—outperforming local sluices. The panning stage recovered 20.67% but accounted for 57.33% of total gold losses.

The direct smelting stage achieved a 96.55% recovery, producing a 0.07g gold bead which was better than mercury recovery under similar conditions.

The field test confirmed that the High Banker Sluice with direct smelting can improve gravity concentration and serve as a practical, mercury-free solution for Tanzanian ASGM miners. These results clearly show the need for an improved version with standardized components, better concentrate grades, and reduced manual labor.

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1 INTRODUCTION

1.1 Project Background

The Impact Facility, as part of its program, identified inefficiencies in the equipment and processes used by artisanal and small-scale miners. These inefficiencies are exemplified by traditional local sluices, which suffer from low recovery rates, inefficient carpets, and high labor demands. Furthermore, in the recovery stage, artisanal miners rely on mercury to extract gold from the sluice concentrates, posing significant environmental and health risks. These combined inefficiencies and dangerous practices have fueled a vicious cycle of poverty, poor living standards, and health problems within the artisanal mining community.

1.2 Project objectives

This project was designed to create a gold recovery method that would enhance the gravity concentration stage, a process of separating gold from ore, and establish a mercury-free final recovery stage.

1.3 Project Scope

The project focused on implementing an improved sluice setup and a direct smelting process for the recovery of gold from the concentrate. Mkemia Mineral Services was tasked with designing and field-testing the High Banker Sluice with Direct Smelting process, while Benjamin Kubeja Fabricators handled fabrication.

1.4 Project Execution

The project began with a detailed design phase to define key specifications and performance requirements. Then the fabrication was completed in January at Benjamin Kubeja Metal Workshops, Geita.

On January 31, 2025, a field test at Nsangano Gold Mine, Nyarugusu, evaluated the High Banker Sluice's performance with direct smelting. The sluice produced a concentrate, which was panned and directly smelted. Performance data and samples were collected, analyzed at Njema Geochemical Laboratory, and reported on February 20, 2025.

This report presents the findings and recommendations based on the field test.

2 DESIGN OF THE HIGH BANKER SLUICE

2.1 Design Objective

The High Banker Sluice was designed to enhance the sluicing process for artisanal miners in Tanzania. This improvement supports mercury-free gold extraction, offering a more efficient and environmentally friendly alternative.

2.2 High Banker Sluice Design Criteria

Table 1 is a summary of the design criteria that were considered in the design of the High Banker Sluice.

Table 1: The High Banker Sluice Design Criteria

FEATURE	DESCRIPTION
Gold Recovery	Captures >150µm gold from various ores Optimized for efficient retention.
Capacity	1.3 tonnes/hour (pumped) 0.5 tonnes/hour (manual)
Operation	Adaptable batch process With adjustable settings.
Durability	Corrosion-resistant Modular and lightweight for remote portability.
Resource Efficiency	Low water consumption Adaptable to manual or pump operation.
Sustainability	Mercury-free Compatible with direct smelting and water recycling.

2.3 Design Expectations

The High Banker Sluice was expected to:

- Achieve gold recoveries above 50%.
- Produce high-grade concentrate for mercury-free direct smelting.
- Reduce manual labor.
- Provide portability for remote operations.

2.4 Design and Drawings

The 3D model of the High Banker Sluice is presented in Figure 1, while its detailed technical drawing is provided in Appendix E.

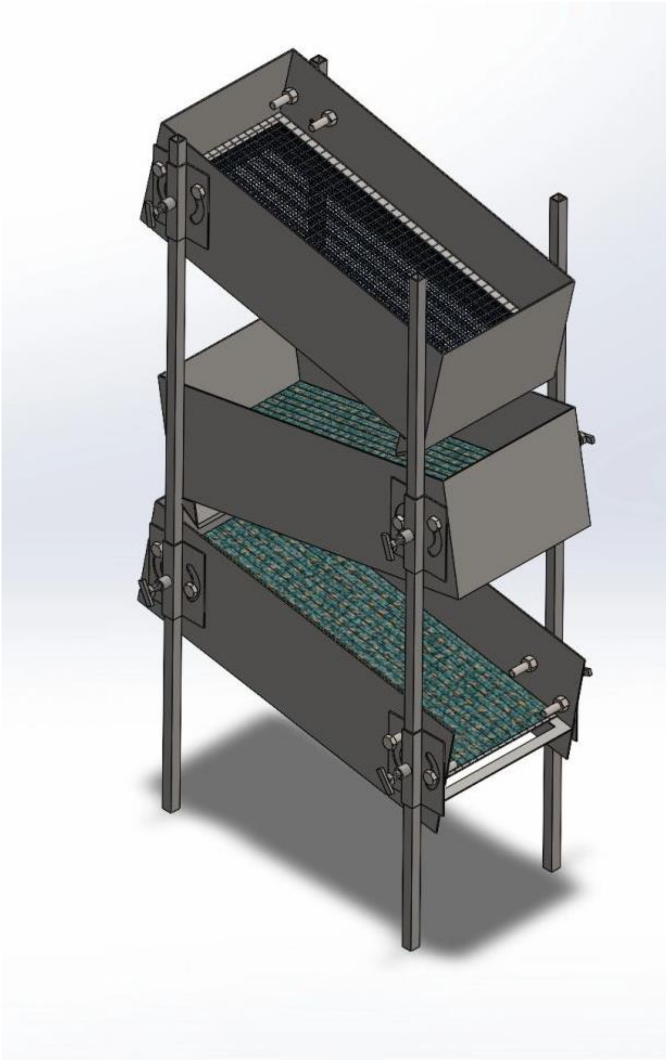

Figure 1: 3D Model of the High Banker Sluice

3 HIGH BANKER SLUICE FIELD TEST

3.1 Preparation and Setup

The day before the test, 100 kg of primary gold ore was crushed, dried, and ground using local dry ball mills for one hour to achieve the desired particle size. The processed ore was stored in sacks, ready for use.

At the start of the test, the High Banker Sluice was assembled on-site in 35 minutes, and the deck angles were adjusted to match the ore type and fineness of the ground ore as shown in Figure 2.

3.2 Testing Process

The ground ore was transferred into a holding container and fed onto the sluice's upper deck. Then water was sprayed to create a slurry with approximately 20% solids, ensuring proper flow following the design operating conditions detailed in Appendix A.

Tailings were directed to a collection chamber, while gold and heavy particles were captured by the carpets. And once saturated, the carpets were removed and cleaned to obtain a gold concentrate.

Figure 2: Testing of the High Banker Sluice at Nsangano Gold Mine.

3.3 Final Concentration stage

At this stage, the concentrate from the High Banker Sluice was panned to further refine it, producing a smeltable gold concentrate, which was then collected in a cotton cloth for direct smelting.

3.4 Sample Collection

Along the test, three samples were collected and labeled:

1. Feed Ore – Labeled **FEED**
2. High Banker Sluice Tailings – Labeled **MFUKO T1**
3. Final Concentrate – Labeled **T3**

Then the samples were prepared and submitted to Njema Geochemical Laboratory for gold analysis.

4 DIRECT SMELTING FIELD TEST

The direct smelting process used the concentrate from the panning stage, and proceeded as shown in the pictures in Figure 3. First, borax was mixed with the concentrate in a 1:1 ratio. Then the mixture was smelted at high temperatures (approximately 1,200°C) using a local setup with an oxy-acetylene gas burner. After fusion, the molten mixture was poured into a mold, where gold settled at the bottom and impurities formed a slag layer, which was separated after cooling. The gold was then cleaned with dilute acid and weighed. However, along the procedure, waste materials were disposed of according to environmental guidelines, and adequate ventilation and PPE were used to ensure safety.

Detailed standard procedures are provided in Appendix B.

A. Mixing the gold concentrate and flux

B. Smelting the concentrate – flux mixture

C. Pouring the molten mixture

D. The Gold bead recovered

Figure 3: Procedure for Direct Smelting

5 RESULTS AND DISCUSSION

5.1 The High Banker Sluice

5.1.1 Design performance

During field tests, the High Banker Sluice was assembled in just 35 minutes, demonstrating its user-friendliness. The sluice's design ensured even slurry distribution, enhancing gold recovery. Miners favored the carpet over traditional sisal sacks and towels, and appreciated the adjustable deck angles, which allowed adaptation to various ore types.

After sampling, preparation and submission of the samples to the lab, the gold assay results were collected as in Appendix C then used to develop Table 2.

As shown in Table 2, the High Banker Sluice captured 13.63 kg of concentrate with a gold content of 25.73 ppm, yielding a recovery rate of 63.18%, significantly higher than the 40% recovery rate of conventional sluice boxes as reported by Veiga & Gunson (2020). In contrast, panning recovered only 20.67% of the feed, with the remaining 79.30% reporting to the tailings at a grade of 20.45 ppm.

Table 2: Distribution of the Mass and Grades of Various Streams of the Process

Stage	Mass	Grade	Mass of gold present	Distribution in stage
	kg	ppm	g	%
High Banker Sluice				
Feed	98.24	5.65	0.555	100.00
Concentrate	13.63	25.73	0.351	63.18
Tailings	84.17	2.43	0.205	36.85
Panning				
Concentrate	0.025	2900	0.073	20.67
Tailings	13.6	20.45	0.278	79.30
Direct Smelting				
Gold bead			0.07	96.55
Slag			0.002	3.45

5.1.2 Operation performance

As shown in Figure 4, the High Banker Sluice achieved a gold recovery of 63.18%, the panning stage had a recovery of 20.67% with the direct smelting stage had a recovery of 96.55%.

The inefficiency of the panning stage resulted from the low-grade concentrate produced by the High Banker Sluice's high recovery rate. In gravity concentration processes, there's often an inverse relationship between concentrate grade and gold recovery (Veiga et al., 2014). To improve outcomes, enhancing the sluice's ability to produce higher-grade concentrates is advisable, and exploring alternatives to panning, such as shaking tables or flotation methods, may further optimize gold recovery as suggested by Weishaupt & Jacobson (1989).

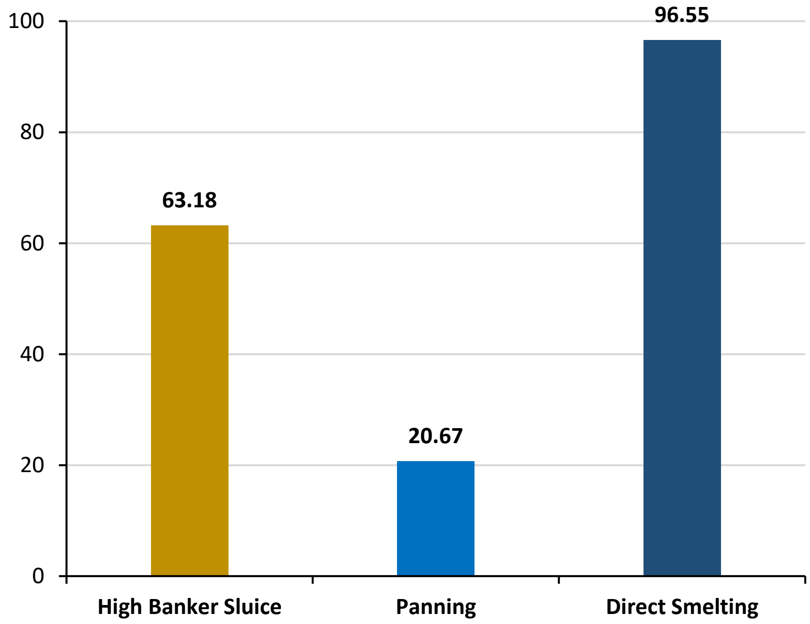

Figure 4: Recoveries at Each Stage of the Process

Figure 5 illustrates the distribution of gold losses across the three-step process: panning accounted for 57.33% of the losses, the High Banker Sluice for 42.16%, and direct smelting for 0.5%. Notably, the High Banker Sluice demonstrated lower losses compared to traditional sluices. For instance, studies by Grayson (2007) have shown that traditional sluices can lose up to 50% of the total gold content when processing primary gold ore.

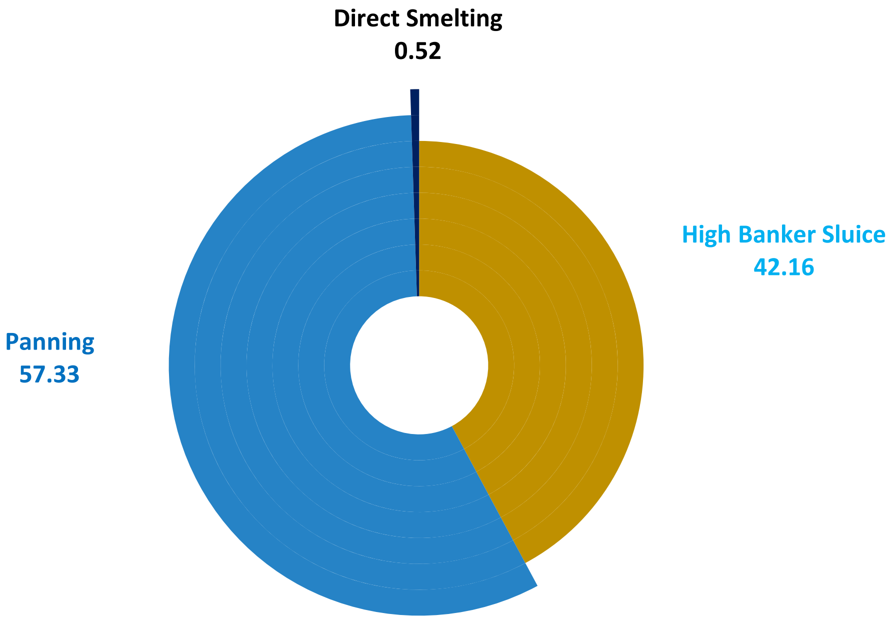

Figure 5: Distribution of the Gold losses at Each Stage.

5.2 Direct smelting

Figure 6 shows a 0.07-gram gold bead obtained after direct smelting of the panning concentrate using borax as flux. This step achieved a gold recovery rate of 96.55%, as shown in Figure 4. This result aligns closely with the 98.3% recovery reported in field tests by Amankwah et al. (2010), highlighting the effectiveness of direct smelting in small-scale gold mining operations.

Figure 6: Gold Bead Recovered from the Direct Smelting Stage

6 CONCLUSION

The field test of the High Banker Sluice demonstrated its potential to enhance gravity concentration in artisanal gold mining, achieving a gold recovery rate of 63.18%. This efficiency surpasses traditional methods and demonstrates that it can be practical when combined with mercury-free final recovery processes, such as direct smelting, yielding positive results.

The direct smelting was successful, achieving a 96.55% gold recovery rate—surpassing the typical performance of mercury amalgamation methods, which often yield lower recoveries. This advancement supports environmental and health objectives, providing artisanal miners with a viable and safer alternative for gold extraction.

7 RECOMMENDATIONS

The user experience, field performance, and technical operation have highlighted areas for design improvements. The next version should focus on standardizing components, selecting optimal carpets, and reducing manual labor.

The improvement should modify the HBS design to produce higher-grade concentrates suitable for direct smelting, minimizing the need for additional processing steps like panning. Then conduct side-by-side evaluations with traditional sluicing methods to highlight the advantages of the HBS, encouraging miners to transition to this more efficient technology.

Additionally, it is important to establish precise dosages for borax and other reagents to ensure consistent and efficient smelting outcomes.

Finally, a comprehensive cost-benefit analysis comparing the HBS-direct smelting process with mercury amalgamation should be performed to emphasize the economic viability and environmental benefits of mercury-free methods.

Design details, performance, and improvement suggestions are provided in Appendix D.

A way forward

The HBS coupled with direct smelting demonstrates significant potential to facilitate a mercury-free ASGM sector. An improved version will not only enhance efficiency but also provide an affordable and user-friendly alternative for low-capital ASGM operations in Tanzania. The next phase of this project should focus on refining the design to improve performance and reliability, ensuring the HBS-direct smelting process offers a clear advantage over traditional sluice-amalgamation methods.

8 REFERENCES

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9 APPENDIXES

APPENDIX A: Design Operating Conditions of the High Banker Sluice

Table 3: Designed Operating Conditions

VARIABLE	UNIT	VALUE
% Solids	%	10 to 30
Sluice Angle (Coarse Feed)	Degrees	10 to 15
Sluice Angle (Fine Feed)	Degrees	5 to 8
Capacity (Pumped)	Tonnes/hour	1.3
Capacity (Manual)	Tonnes/hour	0.5

APPENDIX B: Methodology for Direct Smelting of Gold Concentrate for Small-scale Mining Operations

Sample Preparation

The gold concentrate obtained from the High Banker Sluice is first cleaned using panning to remove excess gangue material. The concentrate is dried to ensure proper smelting efficiency.

Flux Preparation and Mixing

A flux mixture is prepared to enhance smelting efficiency and optimize gold recovery. The standard flux composition includes borax ($Na_2B_4O_7$), sodium carbonate (Na_2CO_3), silica (SiO_2), and lead oxide (PbO) or litharge. However, for resource-limited settings and process simplification, borax alone can be used as an effective flux material. The flux is thoroughly mixed with the gold concentrate in a 1:1.

Smelting Process

A local smelting setup consisting of oxy-acetylene gas burner, a crucible, holding tray in a ventilated room was used for smelting.

The flux-concentrate mixture is placed in a clay crucible and smelted at high-temperatures between 1,200 to 1,400°C. The material is heated until complete fusion occurs, allowing gold to settle at the bottom while impurities form a slag layer on top.

Pouring and Cooling

Once smelting is complete, the molten material is carefully poured into a conical mold. The gold settles at the bottom while the slag solidifies on top. The slag is mechanically separated from the gold bead after cooling.

Gold Recovery and Refining

The recovered gold bead is cleaned using dilute acid to remove residual impurities. The final gold product is weighed and recorded for process evaluation.

Waste Management and Safety Considerations

The slag and other waste materials are properly disposed of in compliance with environmental guidelines. Adequate ventilation and personal protective equipment (PPE) are used to ensure worker safety during smelting.

APPENDIX C: Laboratory Gold Assay Results for Submitted Samples

VERIFY/HAKIKI

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NGPS "For quality analytical services"

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Analytical Report

Job No : **NGL/2025/01/03687**
Lab Ref No : **NGL/2025/01/03687**

Client/Company Name : **DAVIS ANACLET**
Address : **NYARUGUSU**
Contact : **0787071072**
Date Received : **2025-02-18 17:30:23**

Type of Sample : **SOIL,**
Number of Sample(s) : **3**
Status : **Final Report**
Analysis Date Completed: **2025-02-18 20:42:38**

#	SAMPLE ID	SCHEMES								
		ARE-AA			CBN-AA			SOLN-AA		CBN-AC
		Au (ppm)	AuR (ppm)	Cu (ppm)	Au (ppm)	AuR (ppm)	Cu (ppm)	Au (ppm)	Cu (ppm)	%
1	FEED	5.65		395.20						
2	MFUKO T1	2.40	2.46	285.92						
3	T3	20.45		565.97						

Laboratory Manager,
Name: **Masoud Jumanne**
Signature:

Laboratory Chemist,
Name: **Suzana George Masanja**
Signature:

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Geochem Laboratory
P.O.BOX 574- GEITA

Printed : 2025-02-18 20:42:48

ANALYTICAL METHODS AND DEVIATIONS		
ARE-AA	Aqua Regia Digestion AAS Analysis	Au +/- 0.3ppm
CBN-AA	Carbon Ashing >> ARE >> AAS Analysis	Au +/- 50ppm
CBN-AC	Carbon Activity >> AAS Analysis	+/- 5%
BOTT-AA	Bottle Rolling >> AAS Analysis	Au +/- 0.3ppm
SOLN-AA	Solution In Acqueous >> AAS Analysis	Au +/- 0.1ppm
SOLN-EX	Solution DIBK Extraction >> AAS Analysis	Au +/- 0.2ppm

APPENDIX D: Design Details, Performance, and Improvement Suggestions

A. The High Banker Sluice

Design Improvements

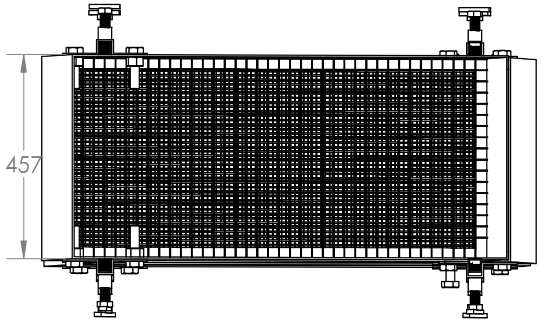
- Select an optimal sluice bed carpet or mat that balances gold recovery efficiency with concentrate grade
- Standardize components to simplify manufacturing, maintenance, and repairs.
- Simplify the water pump and spraying system, and upgrade the flowmeter for better monitoring and control.
- Incorporate an ore screening stage prior to sluicing.
- Simplify the angle adjustment mechanism to improve material flow and recovery efficiency.
- Improve mobility by incorporating durable tires or exploring alternative transport solutions.
- Apply anti-rust coatings and implement routine greasing to enhance durability and longevity.

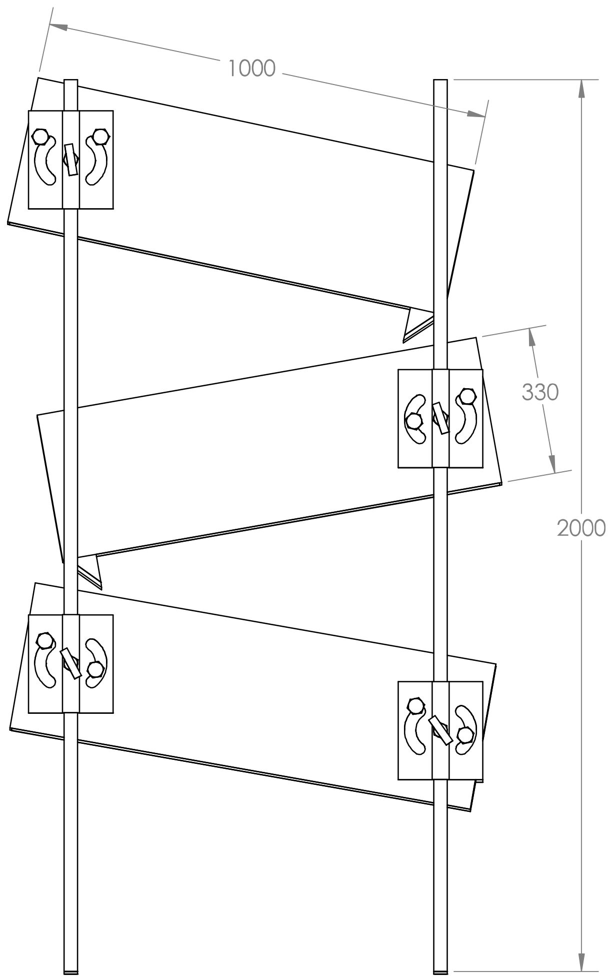
Performance and Operation Improvements

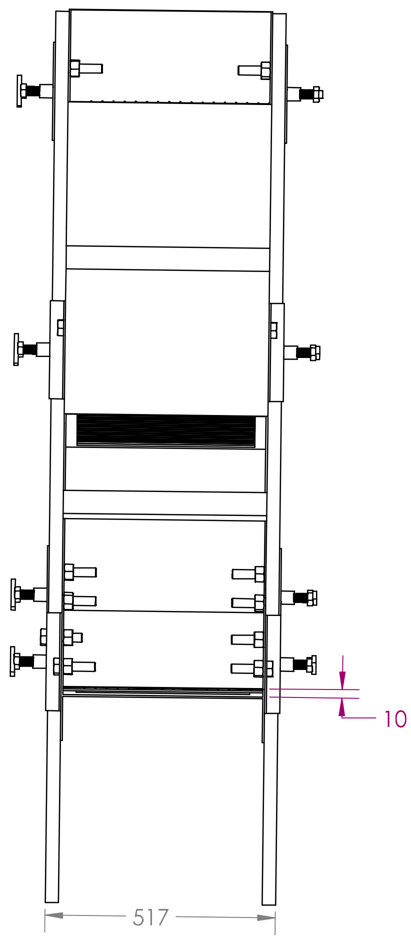
- Conduct direct performance comparisons between the High Banker Sluice and traditional sluicing methods to highlight efficiency gains.
- Develop a user-friendly manual to ensure effective operation and training for miners.
- Optimize concentrate grade by refining the process to reduce unnecessary material handling and potentially eliminate the panning step.
- Streamline the concentration process to reduce overall operation time.

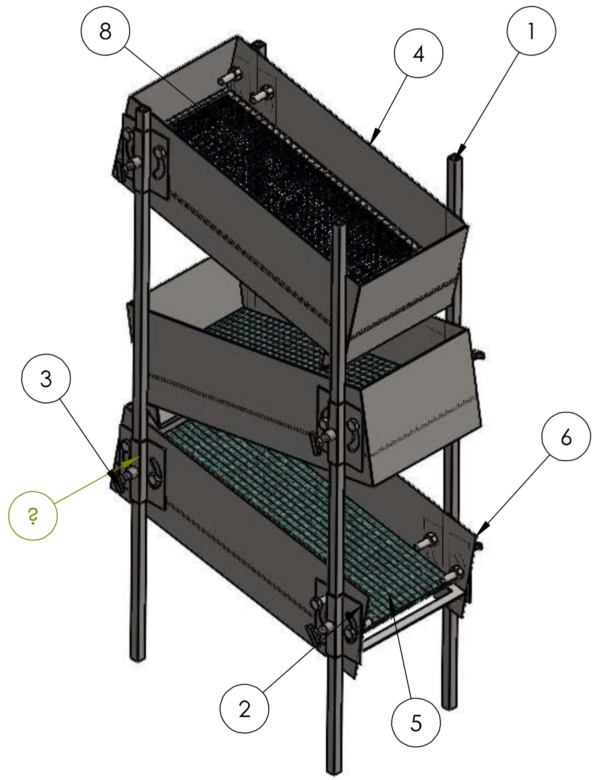
B. The Direct Smelting Process

- Establish standardized borax and reagent dosing guidelines tailored to different ore types.
- Evaluate and compare the efficiency and speed of direct smelting versus mercury amalgamation.
- Conduct a cost-benefit analysis to assess the economic and environmental advantages of this mercury-free processing method.









BILL OF MATERIALS			
ITEM	PART NO	MATERIAL	QTY
1	STAND	MILD STEEL	4
2	CLAMP	MILD STEEL	
3	CLAMPING BOLT	MILDSTEEL	8
4	WASHING BIN	MILD STEEL	2
5	CARPET	PLASTIC	2
6	WASHING BIN 2	MILD STEEL	1
7	HEX BOLT M20	MILD STEEL	8
10	WIRE FRAME	MILD STEEL	5

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

CLIENT: THE IMPACT FACILITY

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	EDWARD ZACHARIA		14.NOV.24
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE: HIGH BANKER SLUICE

COMPANY:MKEMIA MINERAL SERVICES

DWG NO. VERSION 3 FINAL

A3

WEIGHT:

SCALE:1:20

SHEET 1 OF 1