

METHODS AND TOOLS

DETERMINING MERCURY USE IN THE ARTISANAL AND SMALL-SCALE GOLD MINING (ASGM) SECTOR



ARTISANAL
GOLD COUNCIL



UN
environment

Lecture 2 Introduction to ASGM Baseline



Introduction to ASGM Baseline

*Producing a baseline to inform the
National Action Plan (NAP)*

Overview

- What is an ASGM Baseline? Why carry one out?
- What information are we looking for?
- General baseline process
- Methods for:
 - collecting data in the field
 - producing baseline estimates from data
 - cross-checking data for quality and confidence

What is an ASGM Baseline?



ARTISANAL
GOLD COUNCIL

*Requirement of Minamata Convention Article 7,
Annex C:*

1. National ASGM Baseline Estimates
2. Overview of ASGM Practices



What information are we looking for?

1. National ASGM Baseline Estimates



Mercury Use *



Gold Production



Workforce



and the geographic distribution of these
(site-specific, regional, national)



What information are we looking for?

2. Overview of ASGM Practices

Spatial Distribution

Governance

Mineralogy

Gold & Mercury Trade

Technology (Extraction & Processing)

Socioeconomics, Health & Environment

Knowledge Gaps

What information are we looking for?

2. Overview of ASGM Practices

In general,

- Where does ASGM occur?
 - What are the mining and processing practices in different regions?
 - Which areas require the most attention?
-



Why mercury baseline?

- To inform the development of the National Action Plan (NAP) in order to improve ASGM sectors and reduce mercury use
 - Limited information exists on the sector
- To produce baseline estimates against which progress can be measured

The Baseline Process

1. Initial information gathering and national scoping
2. Country specific methodology development
3. Data acquisition (field work)
4. Data analysis
5. Production of local, regional and national estimates

Cross check information using various sources!

Investigate anomalies

Producing national baseline estimates:



ARTISANAL
GOLD COUNCIL

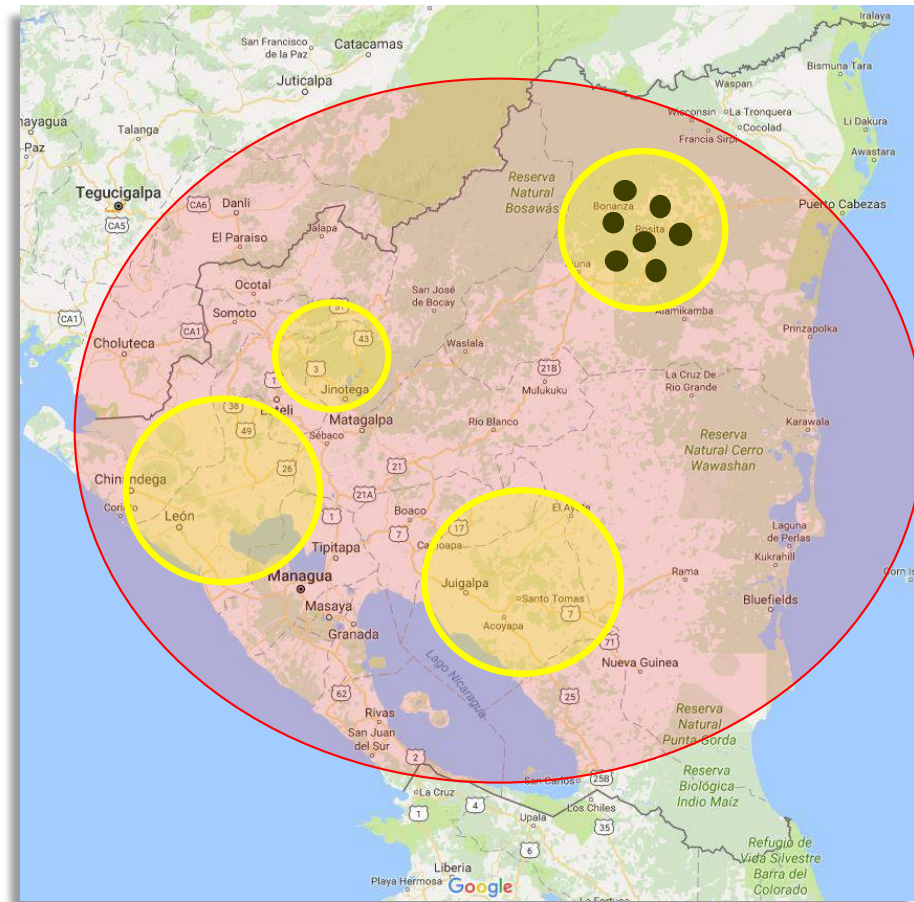
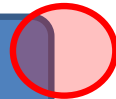
Site Information



Regional Estimates



National Estimate



Four ways of estimating national mercury use:

1. Consult official mercury trade documents
2. Interview sellers of mercury sellers
3. Interview users of mercury (processing workers and owners)
4. Estimate gold production and apply a mercury-to-gold ratio
 - » highest accuracy
 - » many techniques to estimate gold production

Estimating Gold Production



ARTISANAL
GOLD COUNCIL



Three general approaches, based on:

1. Extraction information
2. Processing information
3. Earnings information

Many techniques used under these approaches



Extraction-based Estimates

Use amount of material mined on site to determine inventory estimates

Information Needed

- Number of pits
- Extraction per pit
- Ore grade
- Gold purity
- Days worked per year
- Workers per pit



What does this give you?

- Site Specific Estimates
 - Gold production
 - Miner workforce
 - **USEFUL AVERAGES!** – e.g., average gold production per miner, per pit, grade, purity



Extraction-based Estimates

Use amount of material mined on site to determine inventory estimates



Observations:



$$\begin{array}{ccccccc} \text{Bag} & \text{Bag} & \text{Bag} & \text{Bag} & + & \text{Bag} & \text{Bag} & \text{Bag} & + & \text{Bag} & \text{Bag} & = & \text{Bag} & \text{Bag} & \text{Bag} \\ \hline & & & & & & & & & & & & & & \\ & \text{Pile} & & & & \text{Pile} & & & & \text{Pile} & & & & \text{Pile} & & \end{array}$$



Extraction-based Estimates

Use amount of material mined on site to determine inventory estimates



$$\frac{\text{3 bags}}{\text{1 bag}} \times 10 \text{ bags} = 30 \text{ bags for site}$$



Extraction-based Estimates

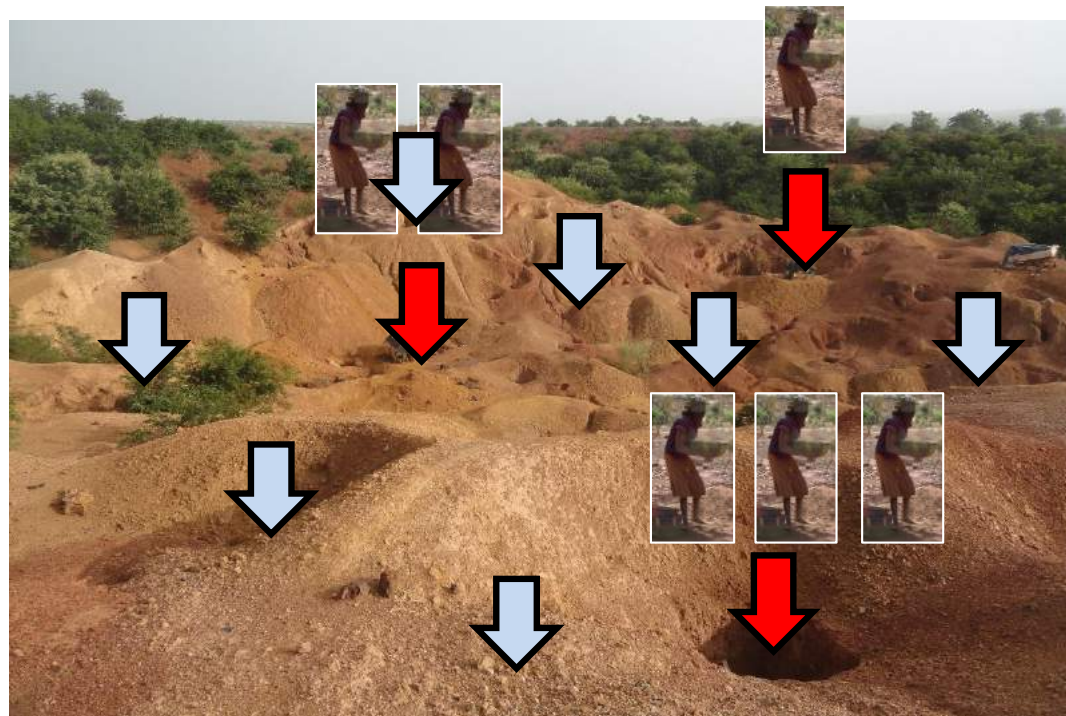
Use amount of material mined on site to determine inventory estimates





Extraction-based Estimates

Use amount of material mined on site to determine inventory estimates



- Miner Workforce
- 2 miners/pit 10 x 10 pits
= 20 miners on site



Extraction-based Estimates

Use amount of material mined on site to determine inventory estimates

Observations:

- 2 miners / pit
- 10 pits
- 3 bags / pit / day
- 1 bag = 100 kg

Interviews:

- Grade = 1 g / bag
- Purity = 18 K
- Days worked = 200 / yr
- A miner earns = 225 g/y
- 1 g Au = \$40





Extraction-based Estimates

Use amount of material mined on site to determine inventory estimates

Knowns:

- 2 miners / pit
- 10 pits
- 3 bags / pit / day
- 1 bag = 100 kg
- Grade = 1 g / bag
- Purity = 18 K
- Days worked = 200 / yr
- A miner earns = 225 g/y
- 1 g Au = \$40

Calculate: Answers:

Total miners	= 20 miners
bags / site / day	= 30 bags / d
kg ore / day	= 3000 kg / d
Grade (g/T)	= 10 g/T
bags / site / yr	= 6000 bags / yr
Yearly Au	= 6000 g / yr
Yearly Au 24 k	= 4500 g (24 k) / yr
Miner Earnings	= 225 g / miner
	= \$9,000/miner/yr

Note: Miners make up only a portion of the ASGM workforce!



Processing-based Estimates

Use amount of material processed on site to determine inventory estimates



Observe:

- 1 operator per sluice
- 4 bags/sluice/d
- 8 sluices



Processing-based Estimates

Use amount of material processed on site to determine inventory estimates

1. Amount of ore processed (throughput)



Sluice observations:

1



4  /day

x8

x8

x8



Site:

8



32  /day



Processing-based Estimates

Use amount of material processed on site to determine inventory estimates



Interviews:

- 1 bag = 100 kg
- Grade = 1 g / bag
- Purity = 18 k
- Days Active= 200 d/y



Processing-based Estimates

Use amount of material processed on site to determine inventory estimates

2. Amount of gold produced



32  /day



throughput = 32 sacks/d x 100 kg/sack

= 3.2 T/day

grade: 20 g/T

gold production = throughput x grade

= 3.2T x 20g gold/T

= 64 g gold/day





Processing-based Estimates

Use amount of material processed on site to determine inventory estimates

2. Amount of gold produced



gold production
daily



300 days worked per year

gold production
annual

19.2 kg /y



correct to
100% purity



Processing-based Estimates

Use amount of material processed on site to determine inventory estimates

Knowns:

- 1 operator each
- 8 sluices
- 4 bags / sluice / d
- 1 bag = 100 kg
- Grade = 1 g / bag
- Purity = 18 k
- Work = 200 / yr
- Earnings = 1 \$ / bag

Calculate:

- Total Processors = 8 processors
- bags / site / day = 32 bags / d
- Kg ore / day = 3200 kg / d
- Grade (g/T) = 10 g/t
- bags / site / yr = 6400 bags / yr
- Yearly Au = 6400 g / yr
- Yearly Au 24 k = 4800 g (24 k) / yr

Answers:

Compare: Production Estimate vs. Processing Estimate

- 24 k Au production: 4500 g vs. 4800 g
- Very close!



Processing-based Estimates

Use amount of material processed on site to determine inventory estimates

Multiple Processing Styles on a site?



- How many of each system?
- Produce estimates for each type



Processing-based Estimates

Use amount of material processed on site to determine inventory estimates

Multiple Processing Styles on a site?



Calculations:

- Total Processors = 8
- Total 24 k production = 4800 g



Processing-based Estimates

Use amount of material processed on site to determine inventory estimates

Multiple Processing Styles on a site?

Knowns:

- 3 operators each
- 2 rastras
- 20 bags / rastra / d
- 1 bag = 100 kg
- Grade = 1 g / bag
- Purity = 18 k
- Work = 200 / yr

Calculations

- Production = 6000 g / yr
- Rastra processors = 6





Processing-based Estimates

Use amount of material processed on site to determine inventory estimates

Multiple Processing Styles on a site?



- Processors = 8
- 24 k Au = 4800 g

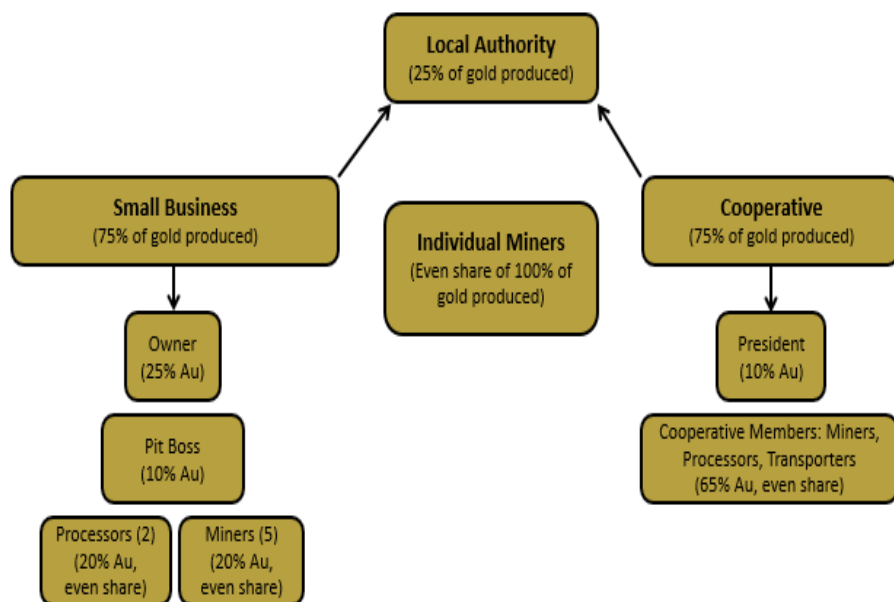


- Processors = 6
 - 24 k Au = 6000 g
- 14**
10800 g



Earnings-based Estimates

Use earnings and revenue distribution to determine inventory estimates



Understand:

- earnings per worker
- distribution of revenues

Then:

- If miner population is known, can estimate gold production
- If gold production is known, can estimate miner population

Earnings based estimates provide very useful cross-checks for extraction- and processing-based estimates



Earnings-based Estimates

Use earnings and revenue distribution to determine inventory estimates

Information Needed

- Earnings per miner
- Share of earnings amongst workers
- Number of miners OR gold production



Earnings-based Estimates

Use earnings and revenue distribution to determine inventory estimates

Known Information

- Miners earn \$20/day
- Operate 300 days/year
- 1 g Au (24 k) = \$40
- Au on site = 12 k
- Miners get 50% gold
- Owner gets 25% gold
- Pit boss gets 25% gold (pays processors out of this!)
- 100 miners on site
- 10 miners / pit
- 10 pits = 10 pit bosses
- 1 owner
- Total 111 workers

Calculate:

1. \$/miner/yr
2. 24 k Au/miner/d
3. 24 k Au/Miners/d
4. 24 k Au/site/d
5. 24 k Au/site/yr

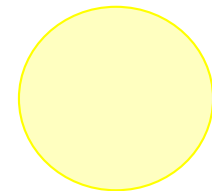
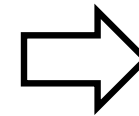
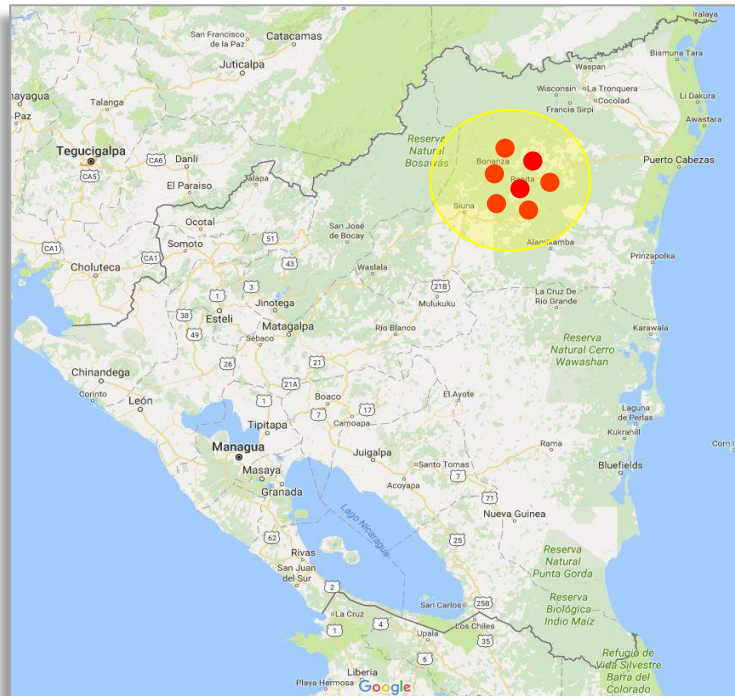
Answers:

- = \$6000/yr
- = 0.5 g / d
- = 50 g / d
- = 100 g/ d
- = 30000 g / yr

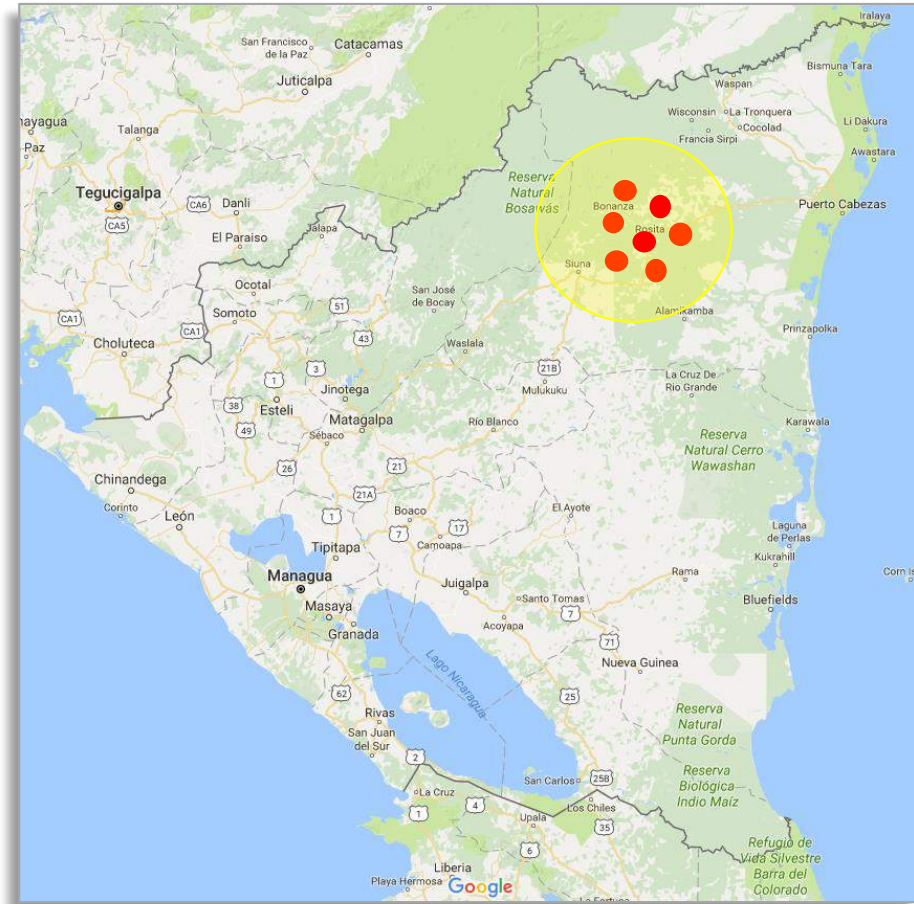
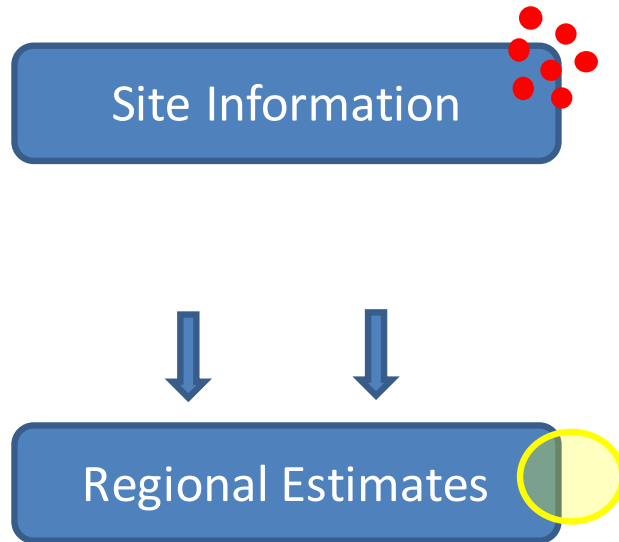
Can we determine the workforce on this site?

This does not include processing workforce!

How do we get from site-level information to an estimate for the region?



Producing regional estimates from site-level averages:



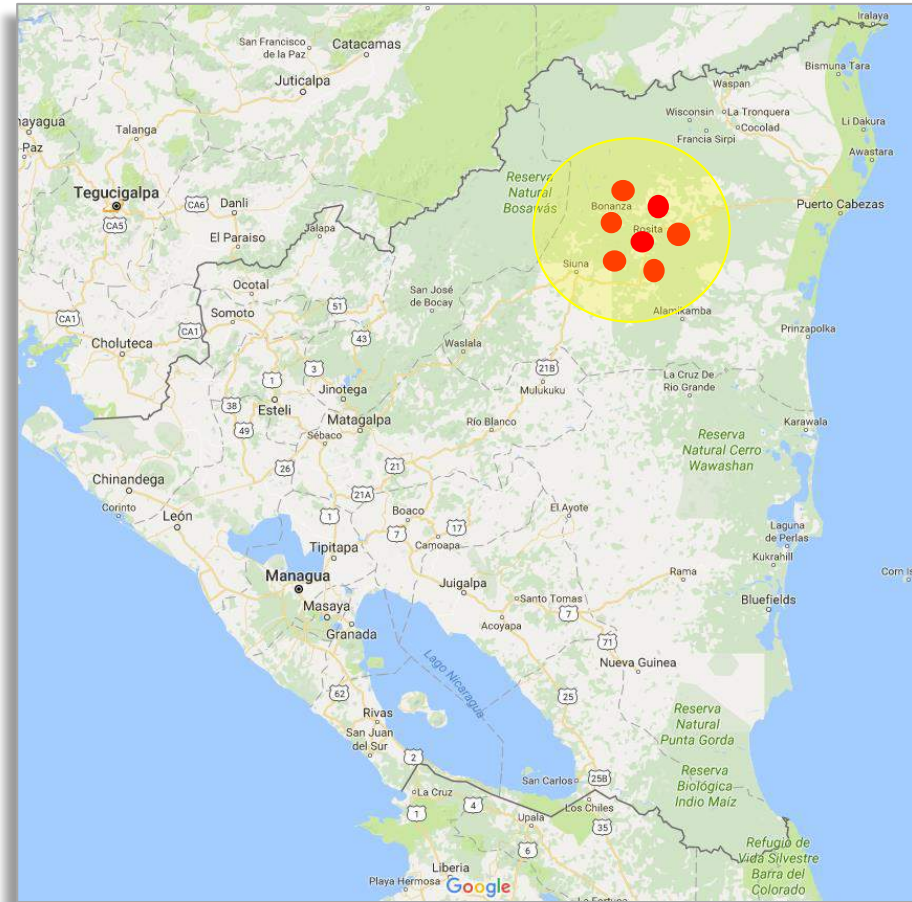
Producing regional estimates from site-level averages:

Site Information

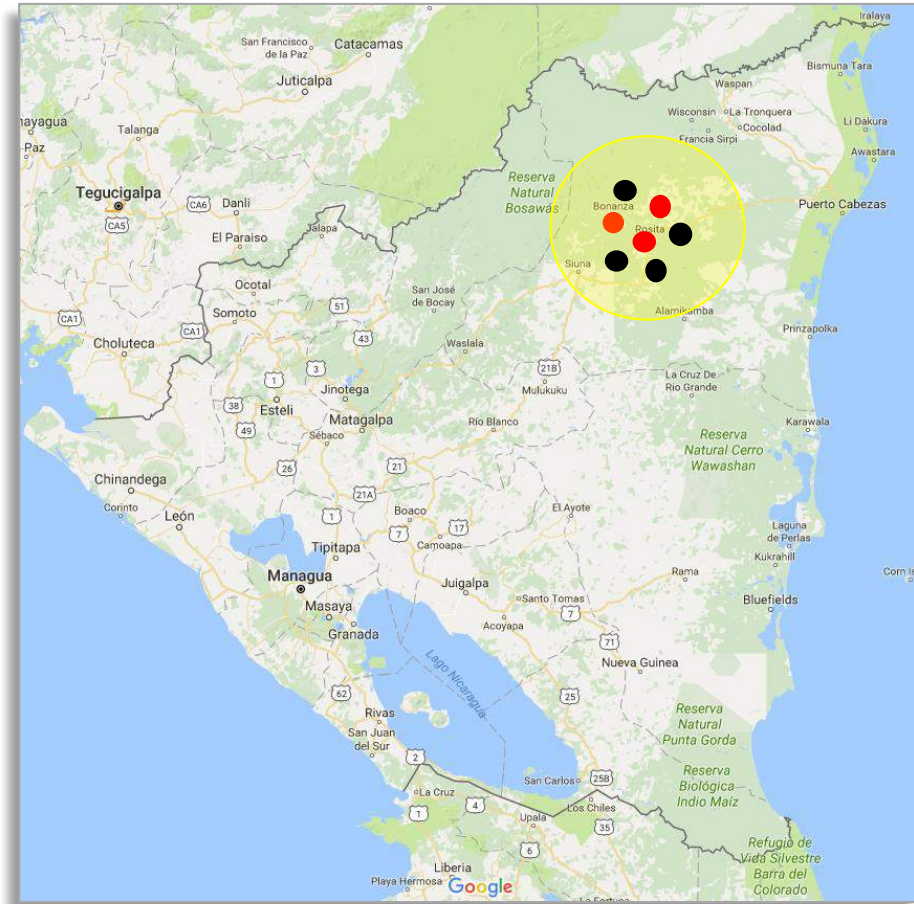
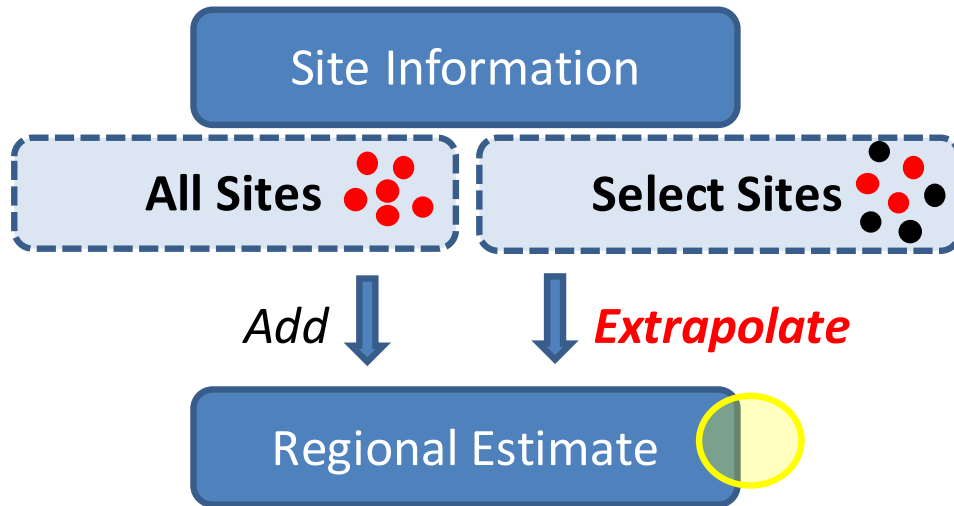
All Sites

Add

Regional Estimate



Producing regional estimates from site-level averages:



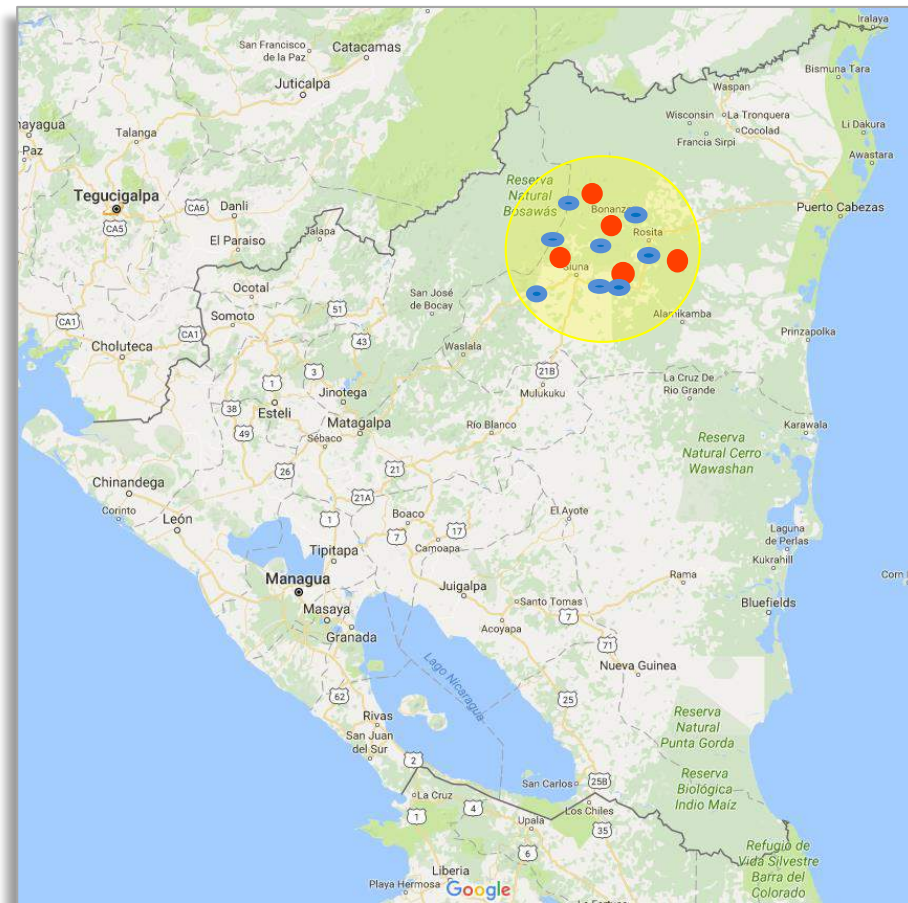
Producing regional estimates from site-level averages:

Extrapolation:

Combine your key site averages, with a *known* for the region to allow extrapolation to the region.

What are these regional *knowns*?

- Regional gold production
- Regional miner population
- Number and size of sites (production or population)
- Number of pits
- Number of processing systems



Producing regional estimates from site-level estimates:

Extrapolation:

Combine your key site averages, with a **known** for the region to allow extrapolation to the region.

What are these regional **knowns**?

- Regional gold production
- Regional miner population
- Number and size of sites (production or population)
- Number of pits
- Number of processing systems

Example:

From processing-based estimate, each sluice produces 1.2 kg of 24K gold per year.

Regional known:

Regional hub has a registry of all sluices in the region.

The total is 230 sluices.

*1.2 kg/sluice/y x 230 sluices
= 276 kg Au /y for the region*

Extrapolating using averages

Example: Average Regional Ore Grade

Site 1

- Survey 5 miners
 - Miner 1: 10 g/T
 - Miner 2: 12 g/T
 - Miner 3: 8 g/T
 - Miner 4: 5 g/T
 - Miner 5: 15 g/T
- **Site 1 Average: 10 g/T**

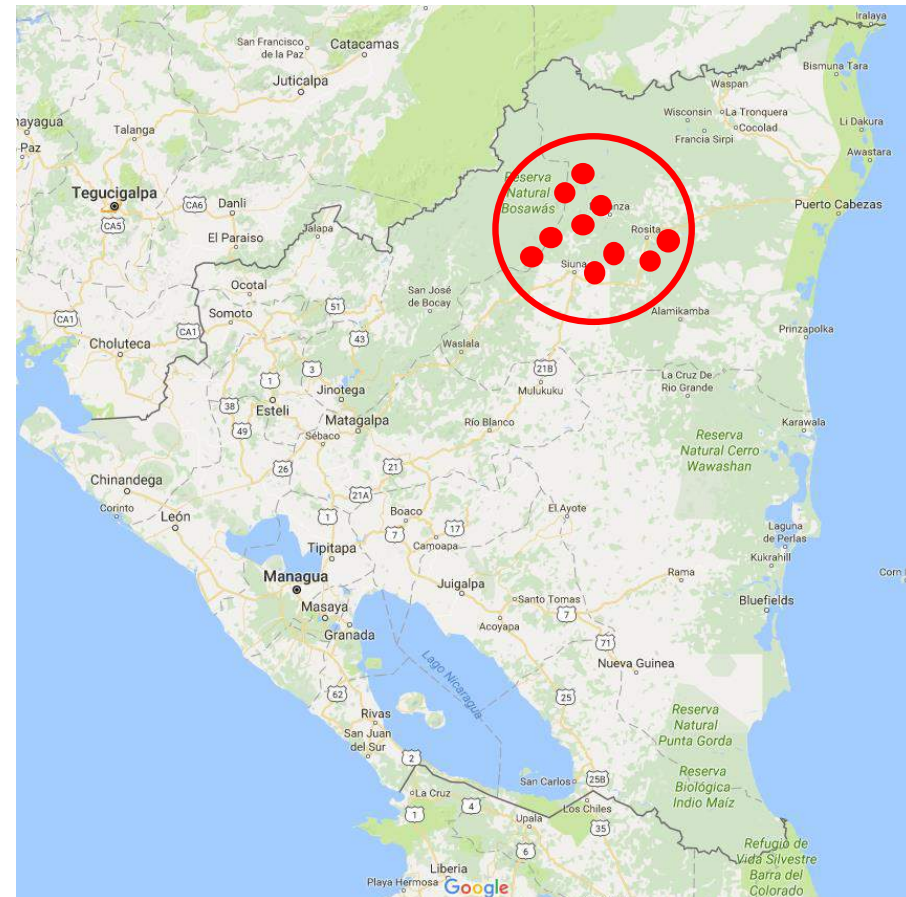
5 Sites Visited (averages)

- Site 1: 10 g/T
- Site 2: 20 g/T
- Site 3: 30 g/T
- Site 4: 20 g/T
- Site 5: 20 g/T
- **Regional Average: 20 g/T**

Extrapolating using averages

Processing capacity known

- 10 processing systems
 - 1 T/d treated by each system
 - Active 100 d/yr
 - Regional Grade = 20 g/T
 - 3 processors per system
 - 1 Miner extracts 0.5 T/d
-
- **Au production: 20000 g/yr**
 - **Processor workforce: 30**
 - **Miner workforce: 20**
 - **Total Workforce: 50**





Many different options!

Cross-check extrapolations where possible!



ARTISANAL
GOLD COUNCIL

Buying house reports

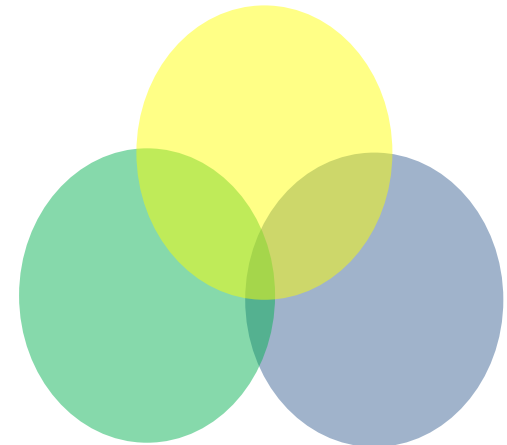
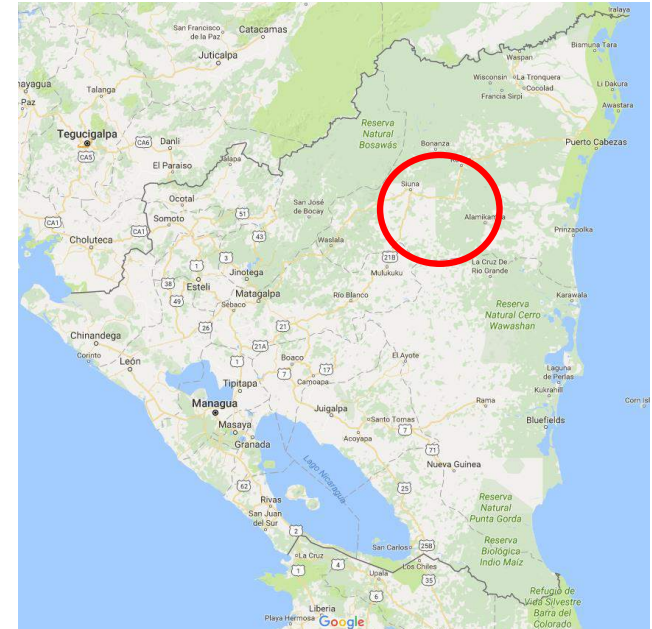
- Gold buying house suggests 18000 g/yr from this region

Worker earnings estimate

- Workers report \$15,000 / yr
 - 1 g Au = \$40
 - 50 workers
 - Worker earning/yr = \$600,000
 - Regional Au = 18,750 g/yr

Processing estimate

- Processing extrapolation = 20000 g/yr



If different, why? Investigate.

Gold
Trader

This region
produces
10 kg
Au/year



Field Officer

But we saw
9.5 kg Au/year
produced at a
single site!



If different, why? Investigate.

Gold
Trader

This region
produces
10 kg
Au/year



Field Officer

But we saw
9.5 kg Au/year
produced at a
single site!



*calculate workforce from gold
production to see if the number
makes sense*

- Production = 10,000 g gold/y
- Miner Earnings: 225 g/miner/y
- Would need ~44 miners to produce this
- Far > 44 miners in the region!

If different, why? Investigate.

Gold
Trader

This region
produces
10 kg
Au/year



Field Officer

But we saw
9.5 kg Au/year
produced at a
single site!



*calculate workforce from gold
production to see if the number
makes sense*

- Production = 10,000 g gold
- Miner Earnings: 225 g/miner
- Would need ~44 miners to produce this
- Far > 44 miners in the region!

Search for more information

162 kg Au/yr



Extraction-based estimate

If different, why? Investigate.

Gold
Trader

This region
produces
10 kg
Au/year



Field Officer

But we saw
9.5 kg Au/year
produced at a
single site!



*calculate workforce from gold
production to see if the number
makes sense*

- Production = 10,000 g gold
- Miner Earnings: 225 g/miner
- Would need ~44 miners to produce this
- Far > 44 miners in the region!

Search for more information

162 kg Au/yr



Extraction-based estimate



- Country produces 20 T Au/y
- 1% comes from ASGM
- = 200 kg Au/y

Ministry of Mines

If different, why? Investigate.

Gold
Trader

This region
produces
10 kg
Au/year



Field Officer

But we saw
9.5 kg Au/year
produced at a
single site!



*calculate workforce from gold
production to see if the number
makes sense*

- Production = 10,000 g gold
- Miner Earnings: 225 g/miner
- Would need ~44 miners to produce this
- Far > 44 miners in the region!

Search for more information

162 kg Au/yr



Extraction-based estimate



- Country produces 20 T Au/y
- 1% comes from ASGM
- = 200 kg Au/y

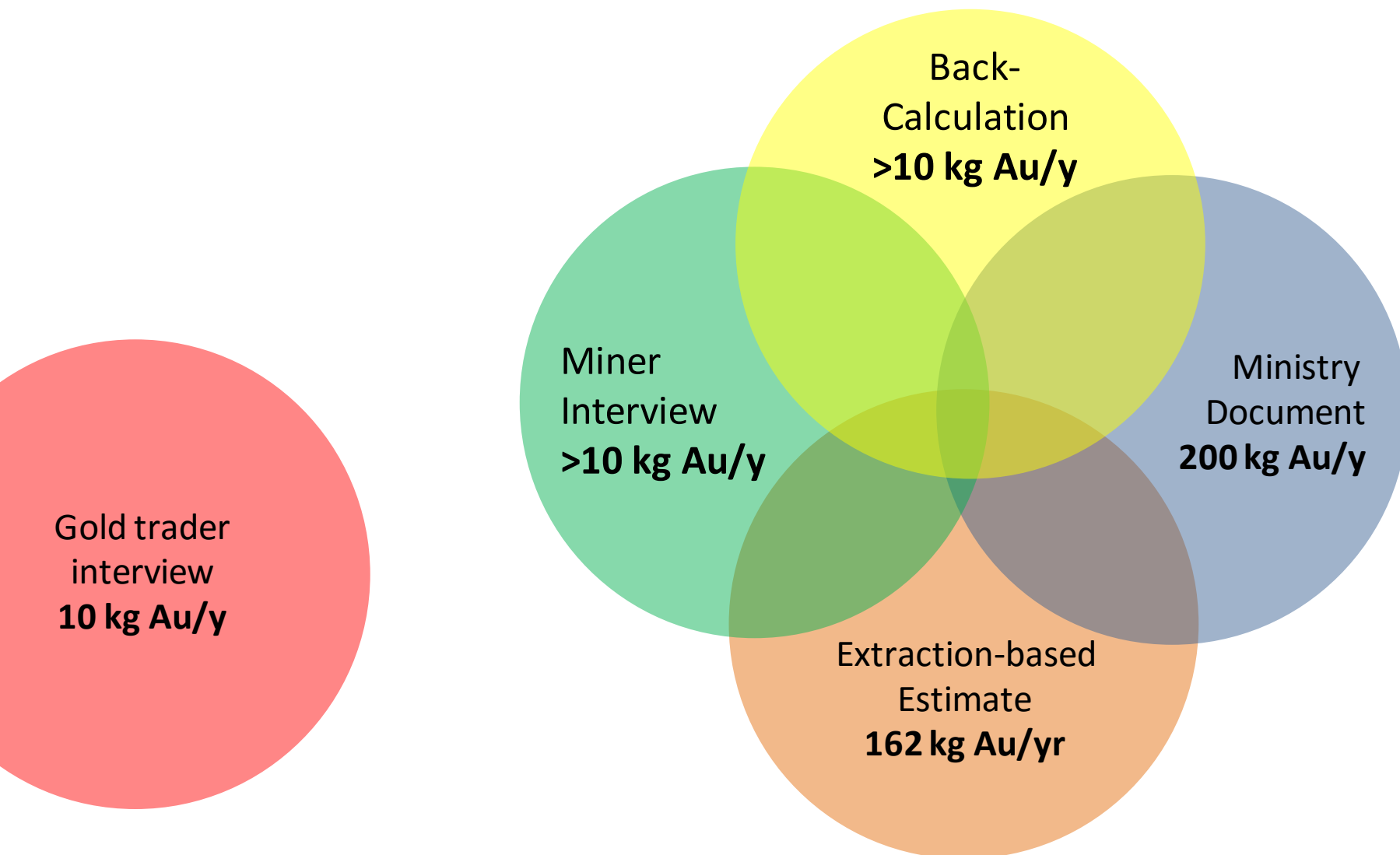
Ministry of Mines

Most miners
save their gold
and bring it to
the capital to get
a better price

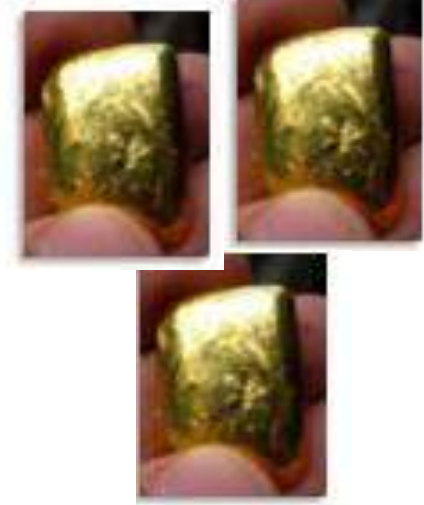
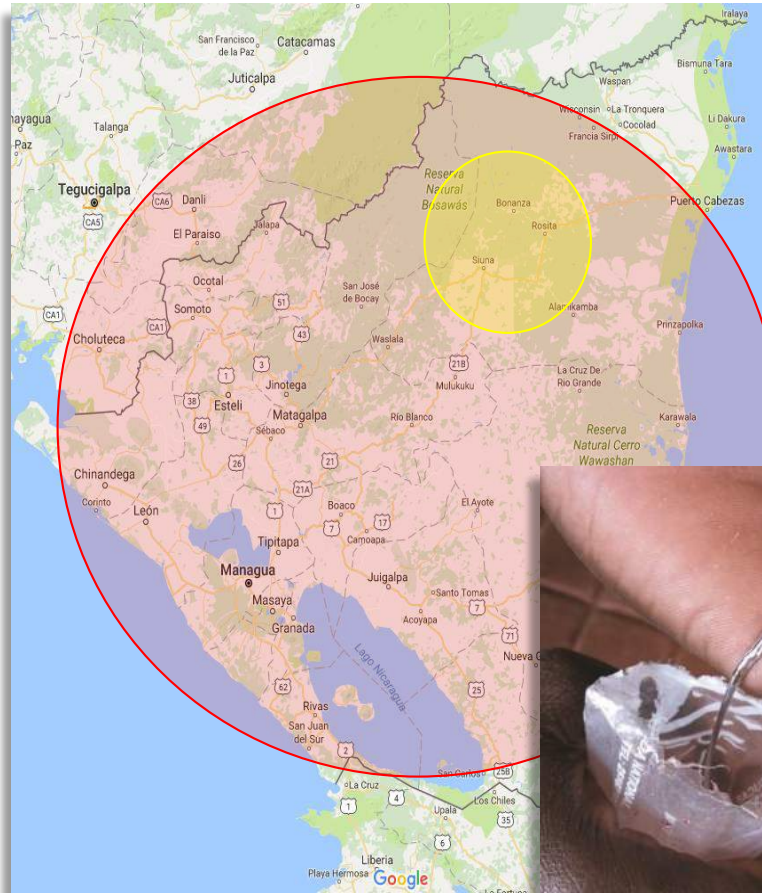


Miner

Triangulation



We now have regional estimates of gold production and work force



The Mercury to Gold Ratio (Hg:Au)

- grams of mercury consumed per gram of gold produced
- Apply to the gold production estimate to get Hg use

$$\begin{array}{ccc}
 \begin{array}{|c|} \hline \begin{array}{c} \text{Au production} \\ \text{estimate} \end{array} \\ \hline \end{array} & \times & \begin{array}{|c|} \hline \begin{array}{c} \text{Hg:Au ratio} \end{array} \\ \hline \end{array} = \begin{array}{|c|} \hline \begin{array}{c} \text{Hg use} \\ \text{estimate} \end{array} \\ \hline \end{array}
 \end{array}$$

The diagram illustrates the calculation of mercury use from gold production and the Hg:Au ratio. It shows three visual components: gold bars, mercury vials, and a gold bar, representing the relationship between these elements.

Mercury Amalgamation



ARTISANAL
GOLD COUNCIL

Mix Mercury
With Sands



Recover
Amalgam



Vaporize
Mercury



Sponge Gold



Take Measurements: Mercury in & Gold out

1) Weigh the Hg added to the ore

2) Weigh the Hg recovered (squeeze)

3) Weigh the amalgam before burning

4) Weigh sponge gold after burning

5) Weigh the Hg recovered (retort)



$$\frac{(\text{initial Hg added} - \text{Hg recovered})}{\text{gold produced}} = \text{Hg:Au Ratio}$$



1 = mercury added, 2+5 = mercury recovered

Different processing type = Different ratio



Rastra mill
Whole ore amalgamation

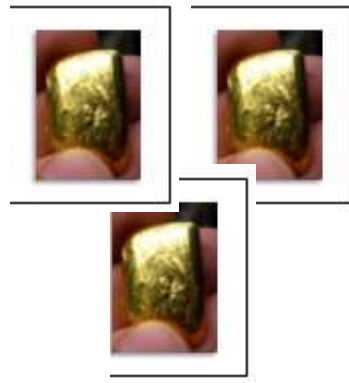


Sluice
Concentrate amalgamation



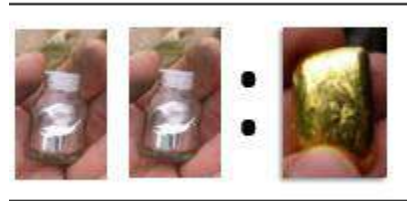
***Measure for every
processing type!!!***

Apply the ratio to the estimate of regional gold production (from that processing type)



Au production
estimate
for sluice

x



Hg:Au ratio
for sluice

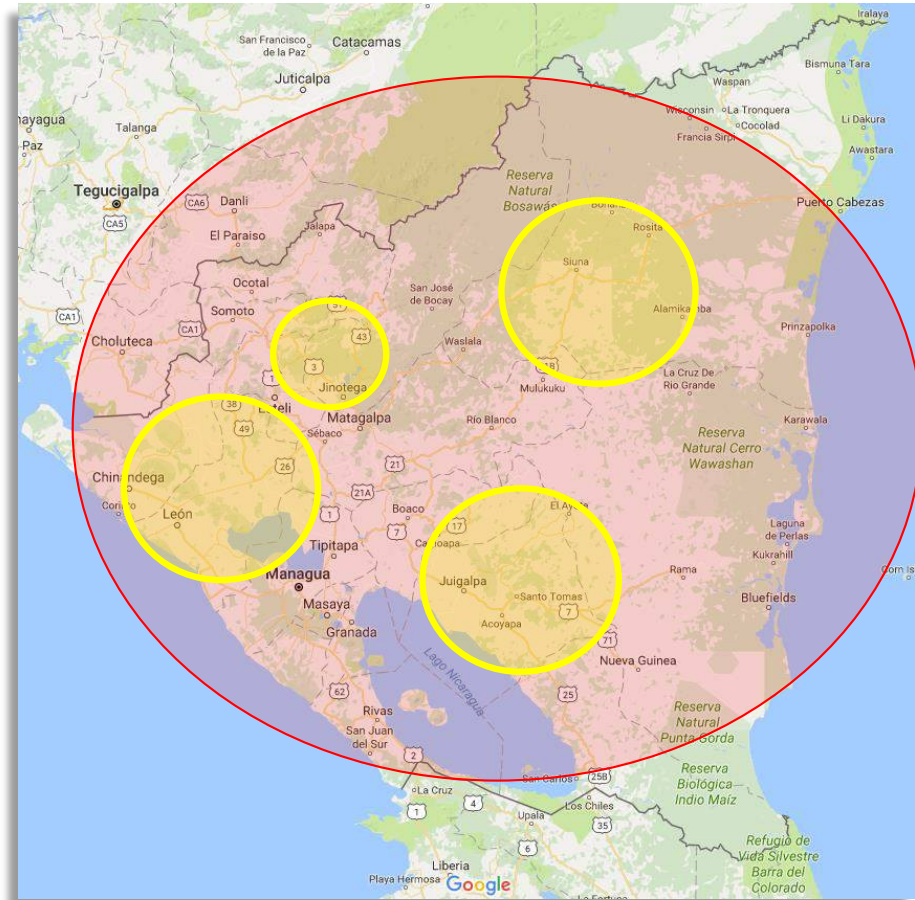
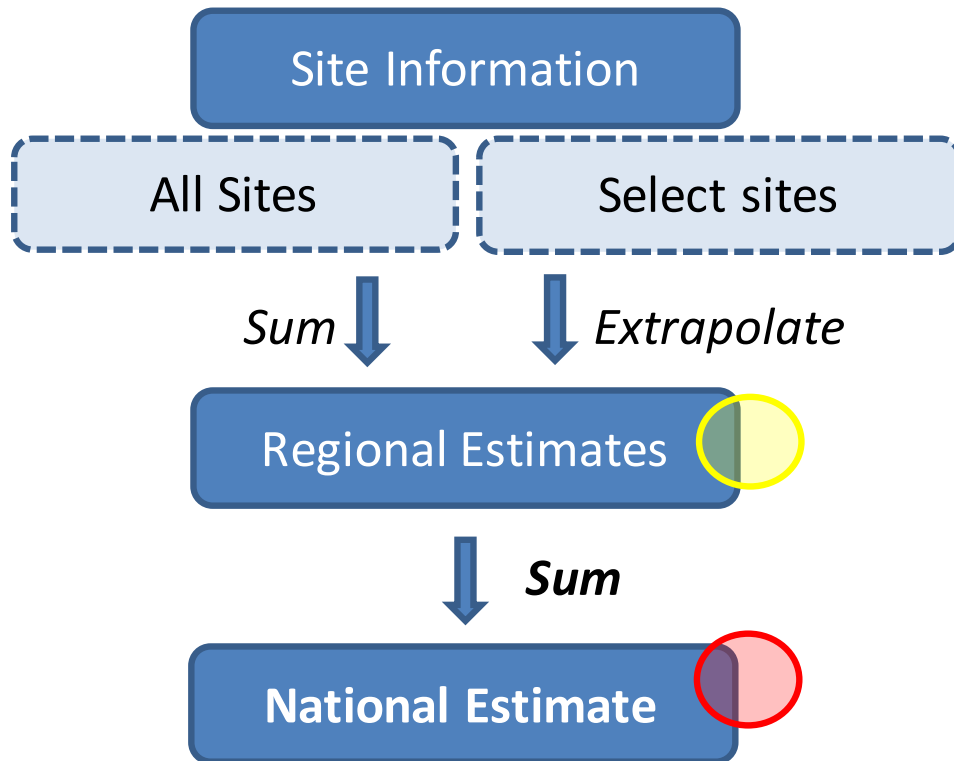
=



Hg use
estimate
for sluice

*Apply correct ratios to
gold production!!!*

Time to produce national estimates from our regional estimates:



Baseline Steps

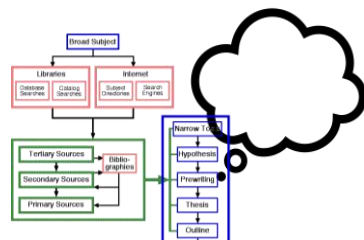


ARTISANAL
GOLD COUNCIL

1. Research for existing information



2. Make a research plan



3. Collect data (field work)



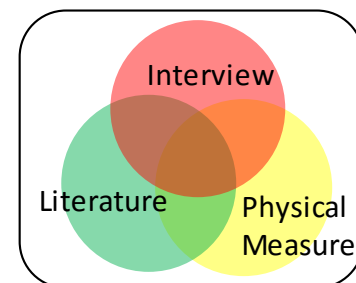
4. Produce local information



5. Scale up to regional estimates from local information



6. **Cross check regional estimates using several approaches!**



7. Add final regional estimates to get national estimate



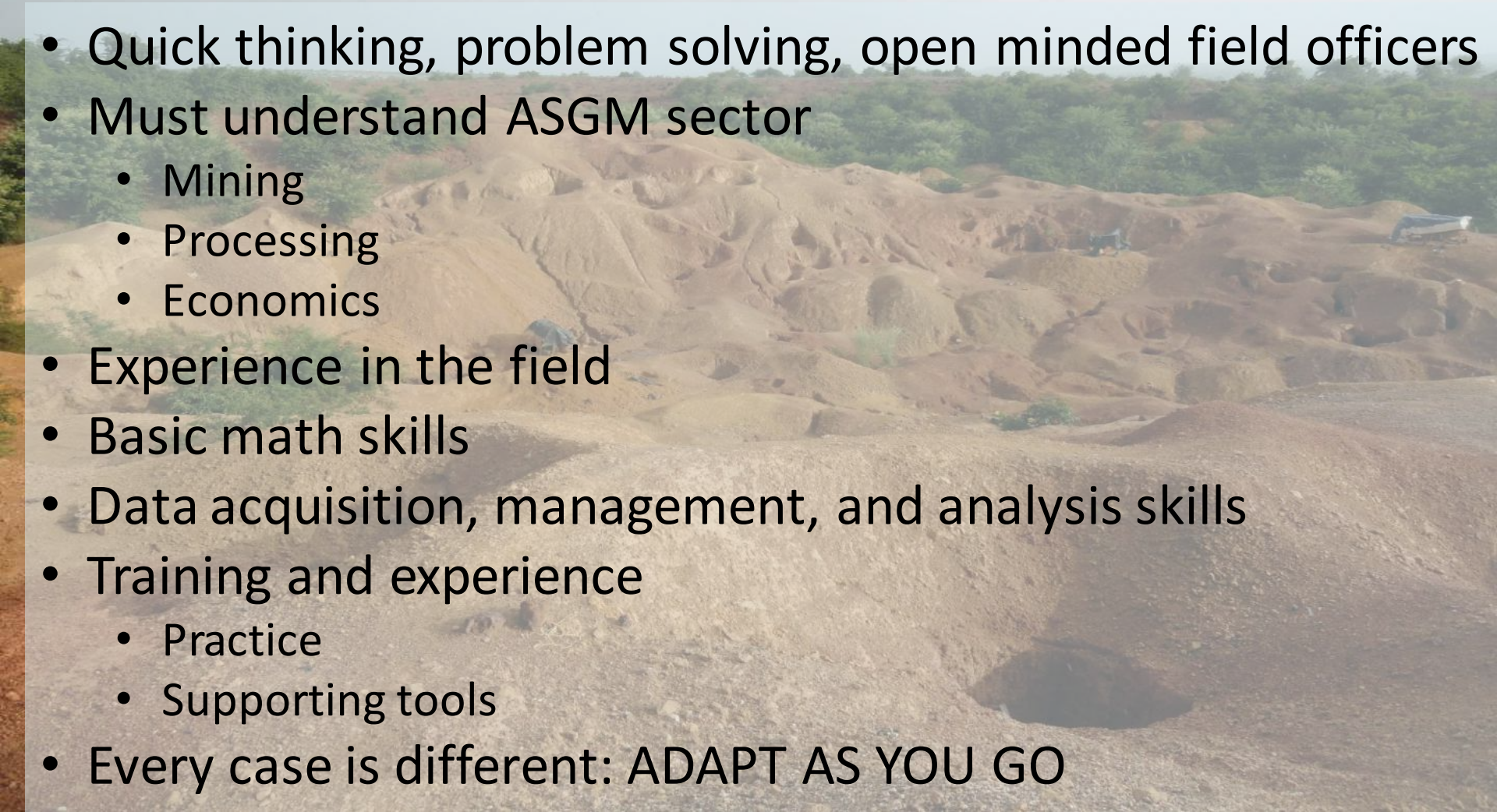
How do we collect all this information?

- Literature Review
- Key stakeholder interviews
 - Government (Mines, Environment, etc), NGOs, National gold buying houses, Universities, LSM companies, etc.
- Mines site counts and observations
- Processing site counts and observations
- Miner and processor interviews
- Gold buyer interviews
- Local authority/site owner interviews
- Physical measurements (weight of an ore bag, Hg:Au ratio calculations, ore assays for grade, etc)
- Any other methods you can think of



What does it really take?

- Quick thinking, problem solving, open minded field officers
- Must understand ASGM sector
 - Mining
 - Processing
 - Economics
- Experience in the field
- Basic math skills
- Data acquisition, management, and analysis skills
- Training and experience
 - Practice
 - Supporting tools
- Every case is different: ADAPT AS YOU GO





NAPs: Suggested Workflow

- Baseline team lead (expert) does scoping
- Team lead develops methodology
- Team lead works with local workers
 - BIG PICTURE IDEA of ASGM
 - Interviews: It's a conversation
 - Physical measurements
 - Important: Cross check all numbers
 - Do analysis everyday after the field to ensure have all info
 - Adjust your methods and ensure you collect the info needed
- Expert analyzes data and produces estimates in collaboration with field team



ARTISANAL
GOLD COUNCIL

Summary

- Difficult, not impossible
- Provides important information to the NAP
- Case specific methodology
- Need to define scope
 - Timeline, capacity and budget
- Every case is unique
- There is no one solution for all regions and all sites. You must adapt as you go – be creative!
- It's fun!



**Thank you!
Questions?**

