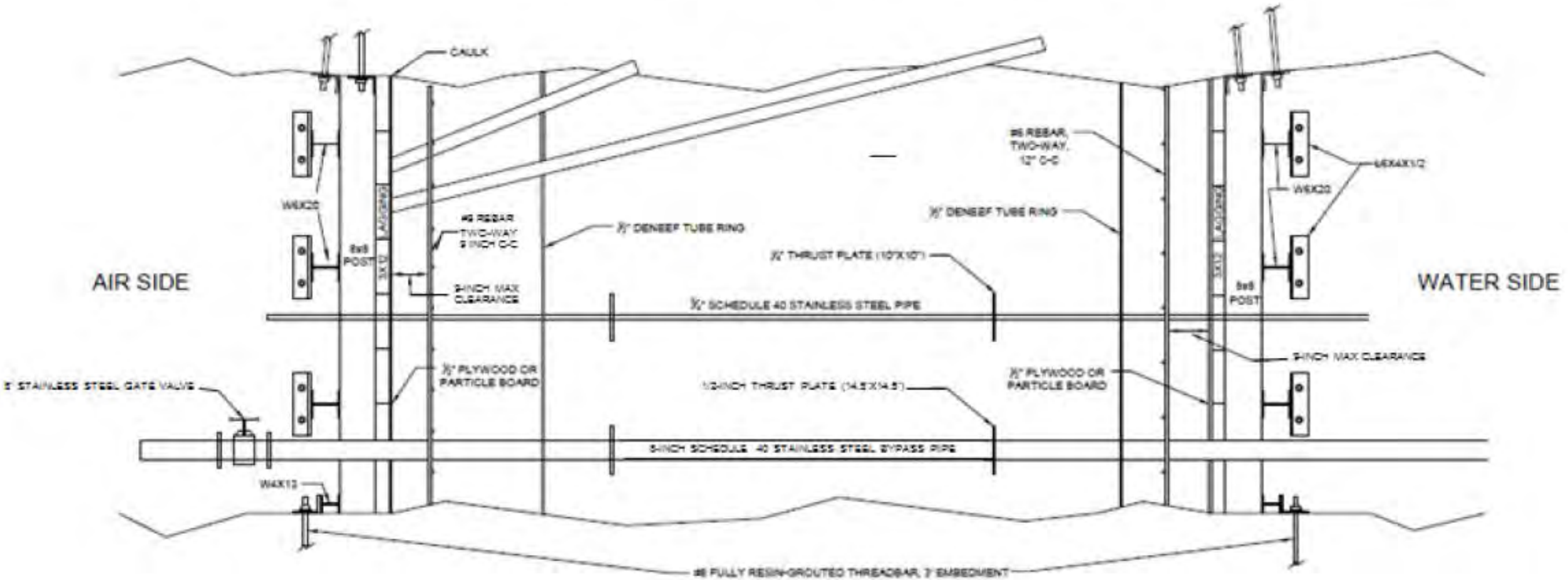

COLORADO
Department of Natural Resources

# *Bulkhead*

A Bulkhead is an engineered concrete wall (ranging from 10 – 20 feet long) placed inside a mine opening to retain water inside the mine workings.

# LONGITUDINAL CROSS SECTION OF BULKHEAD



# Koehler Tunnel Bulkhead

# *Purposes of Bulkheads*

Control and prevent acid mine drainage / Restore hydrology

Water storage and flow control for water treatment

Unplanned Release Prevention

# *Benefits of Bulkheads*

Can prevent the formation of Acid Mine Drainage

Prevent or reduce the need of perpetual water treatment.

The risk of unplanned releases of water is minimized.

- American Tunnel and associated bulkheads impounded 1,500 gallons per minute.
- The amount of water that might be treated has been reduced

# *Drawbacks of Bulkheads*

Water quality could get worse

Acid mine drainage could move to a less desirable location for water treatment

Difficult to monitor the effectiveness of bulkheads on water quality in complex systems

Difficult to monitor the bulkhead structure remedy because it is underground

# *Control Acid Mine Drainage/ Restore Hydrology*

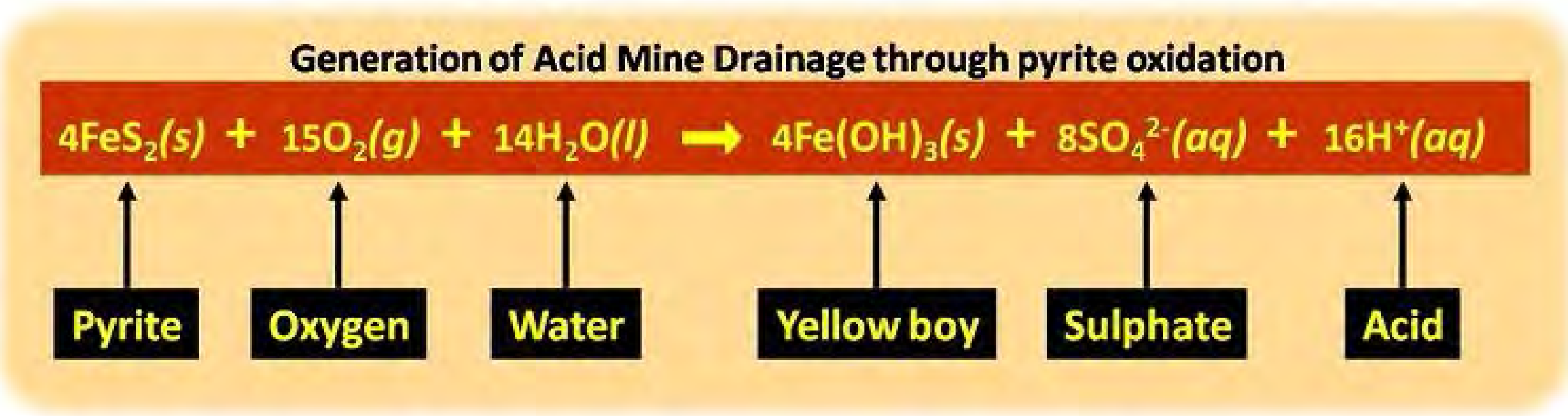
Instead of perpetual water treatment, water is permanently impounded in the mine workings.

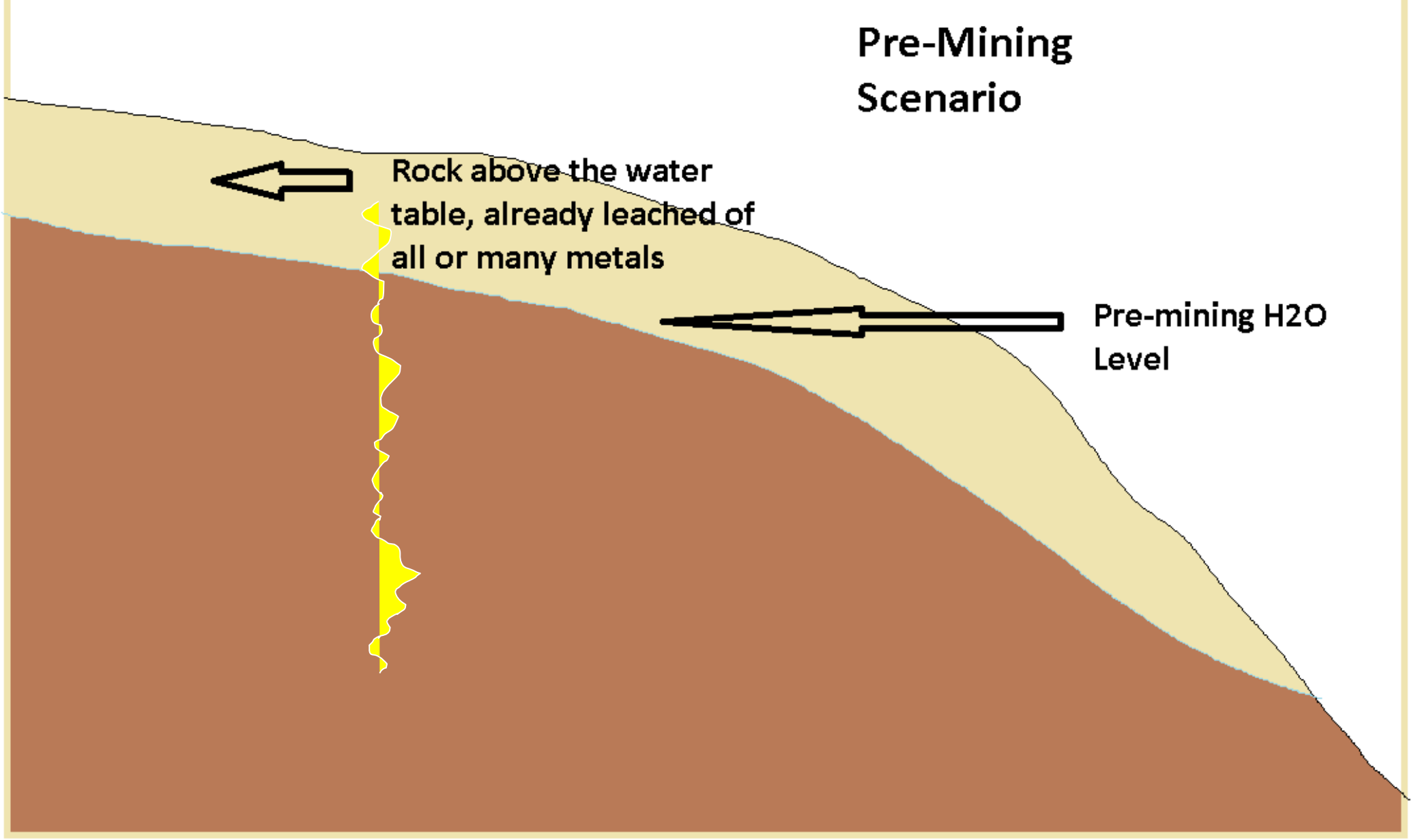
Restores or closely mimics the natural hydrology of the mountain prior to mining

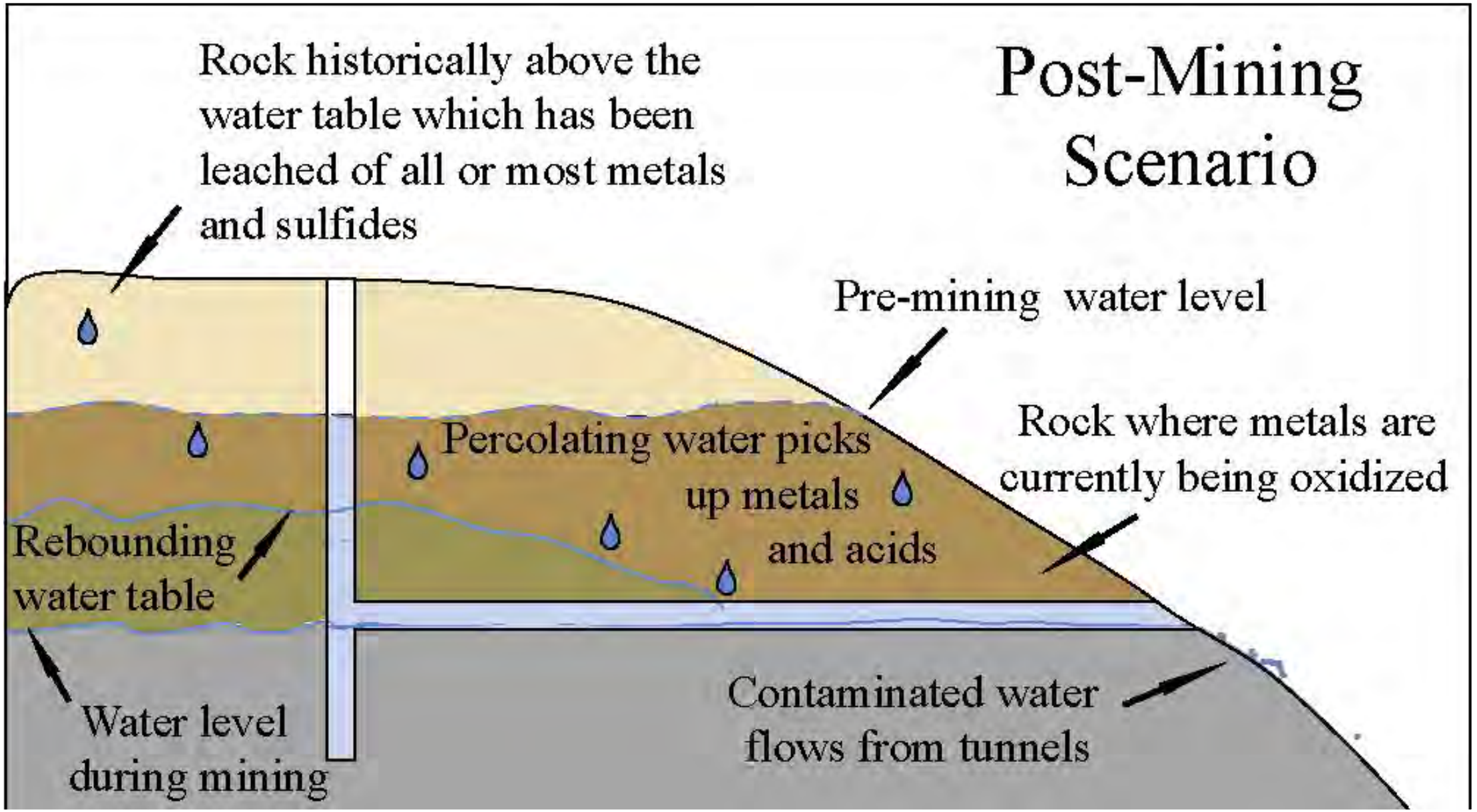
Example: Koehler Tunnel

# *Acid Mine Drainage*

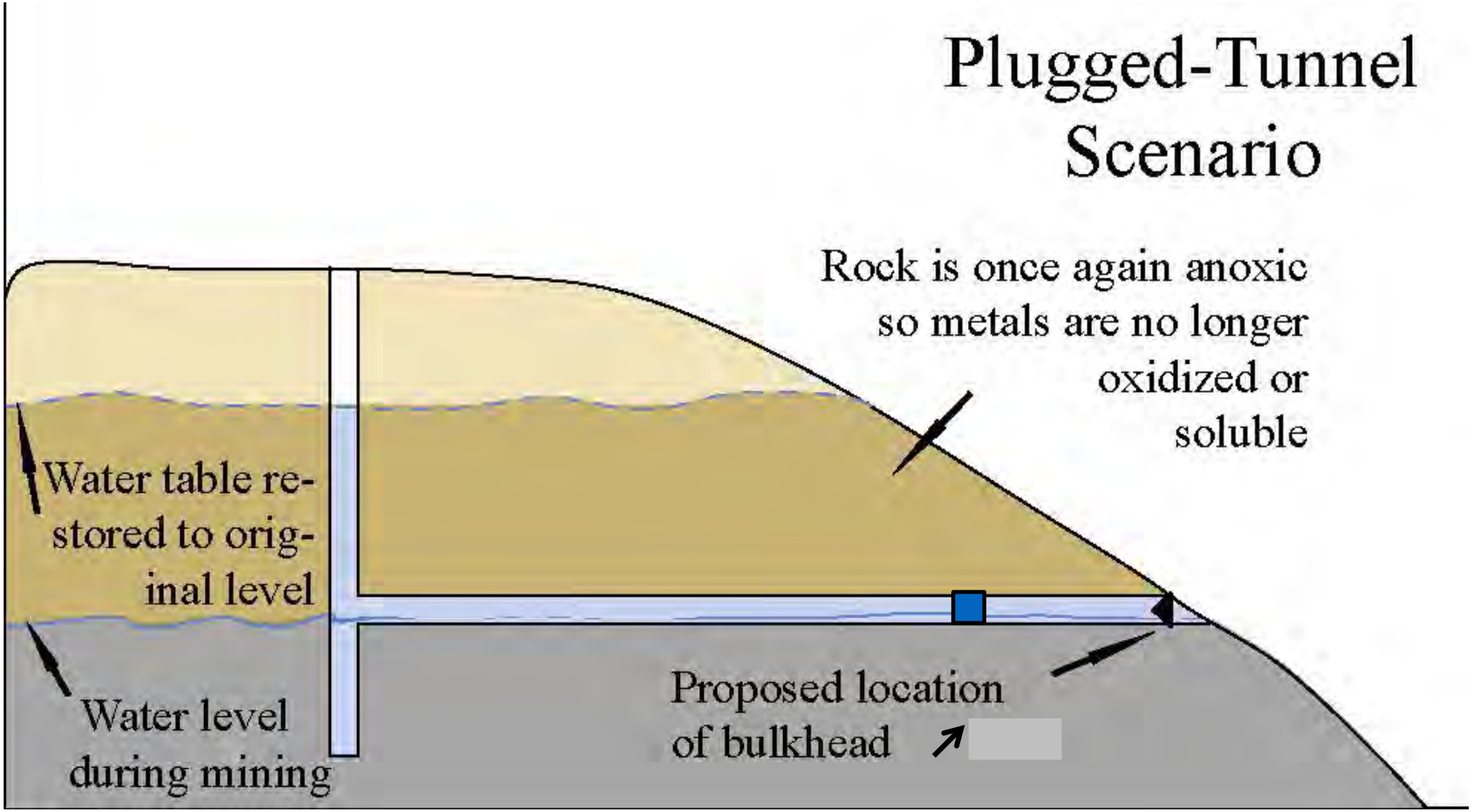
Pyrite + Water + Oxygen = AMD

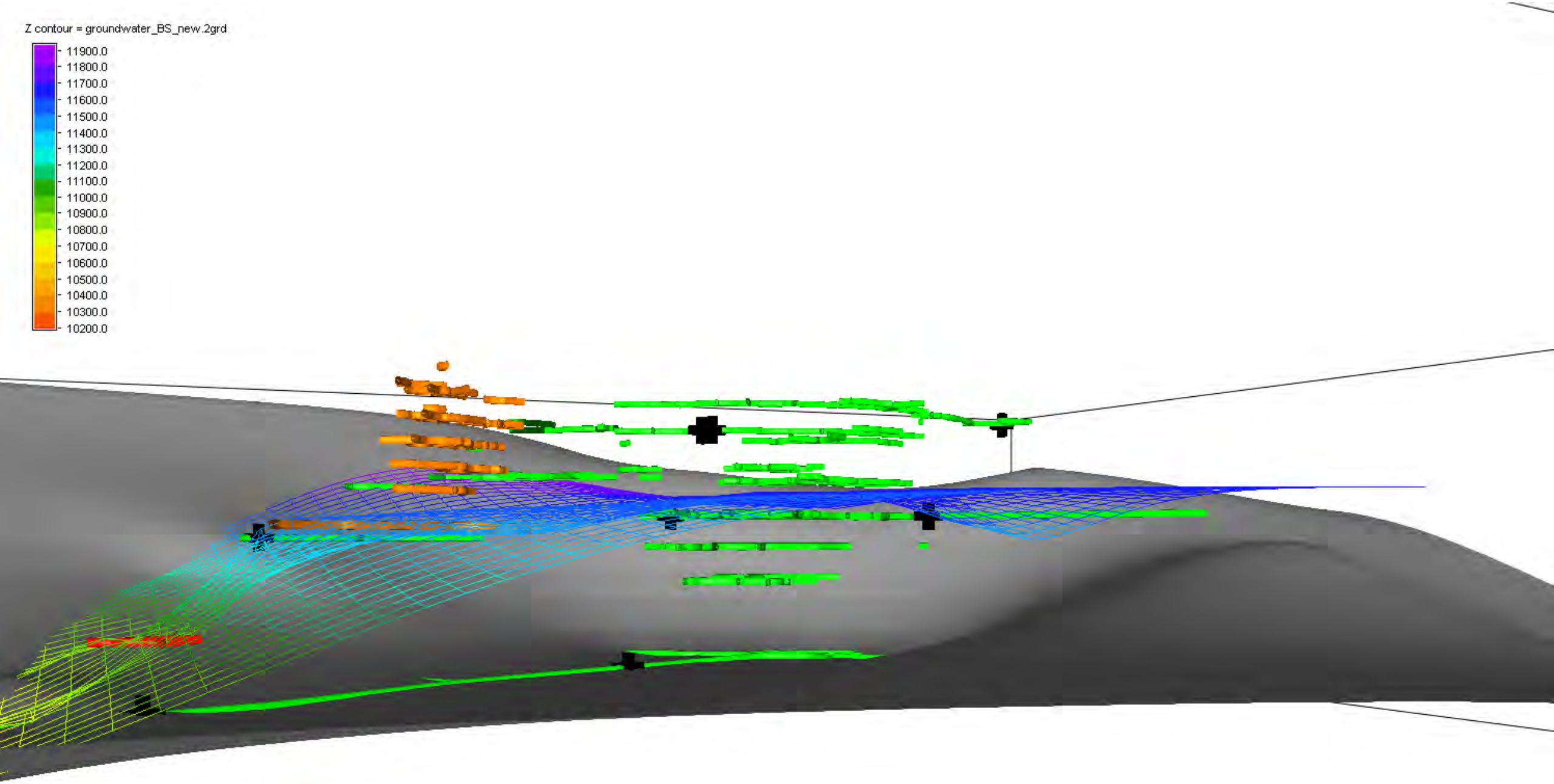



Pre-Mining
Scenario
Rock above the water
table, already leached of
all or many metals
Pre-mining H2O
Level


Post-Mining Scenario
Rock historically above the water table which has been leached of all or most metals and sulfides
Pre-mining water level
Rock where metals are currently being oxidized
Percolating water picks up metals and acids
Rebounding water table
Water level during mining
Contaminated water flows from tunnels

# Plugged-Tunnel Scenario

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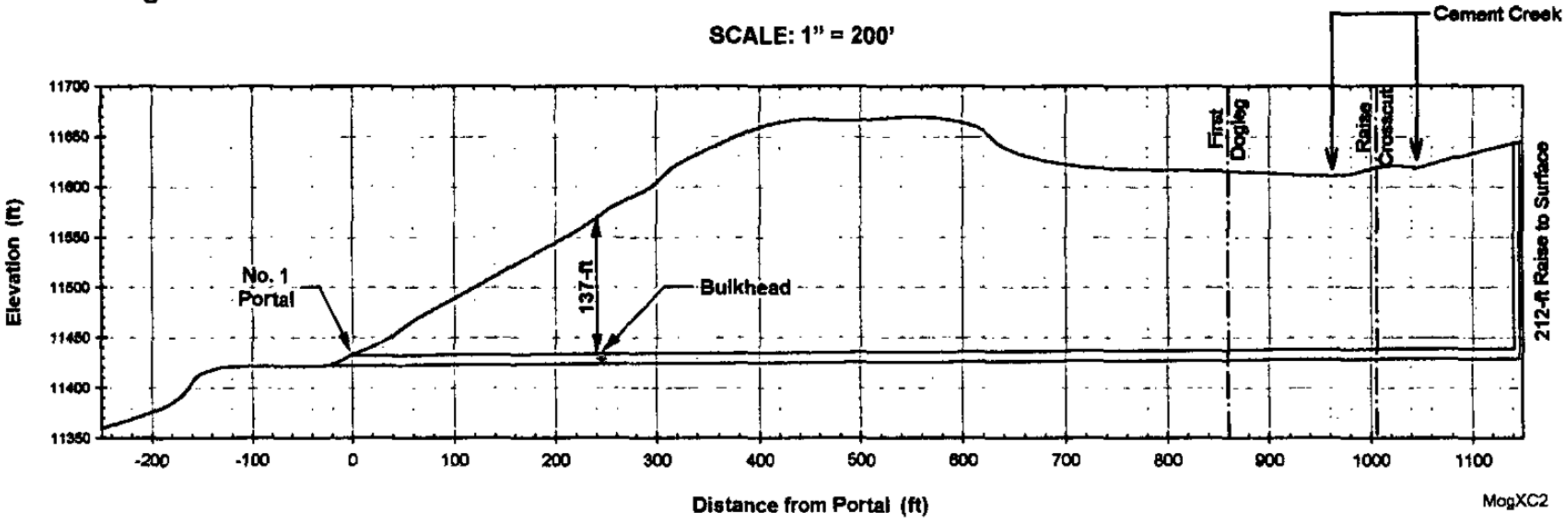
10700.0
10600.0
10500.0
10400.0
10300.0
10200.0

# *Mine attributes advantageous to a bulkheading approach:*

- Reasonably good access to underground workings
- Bulkhead can be placed on lowest adit level of mining
- Simple(r) mine system with little connections with other mines, (may need more than one bulkhead for complex systems)
- Lowest level is a cross-cut haulage/drain tunnel, not a drift on the vein structure
- Adequate overburden to hold expected water pressure.
- Good rock quality
- Good location within workings, free of geologic structures

Figure 2 MOGUL TUNNEL; PORTAL, TO FIRST DOGLEG, TO CROSSCUT, TO RAISE, TO SURFACE



# *Mine Attributes*

Red and Bonita

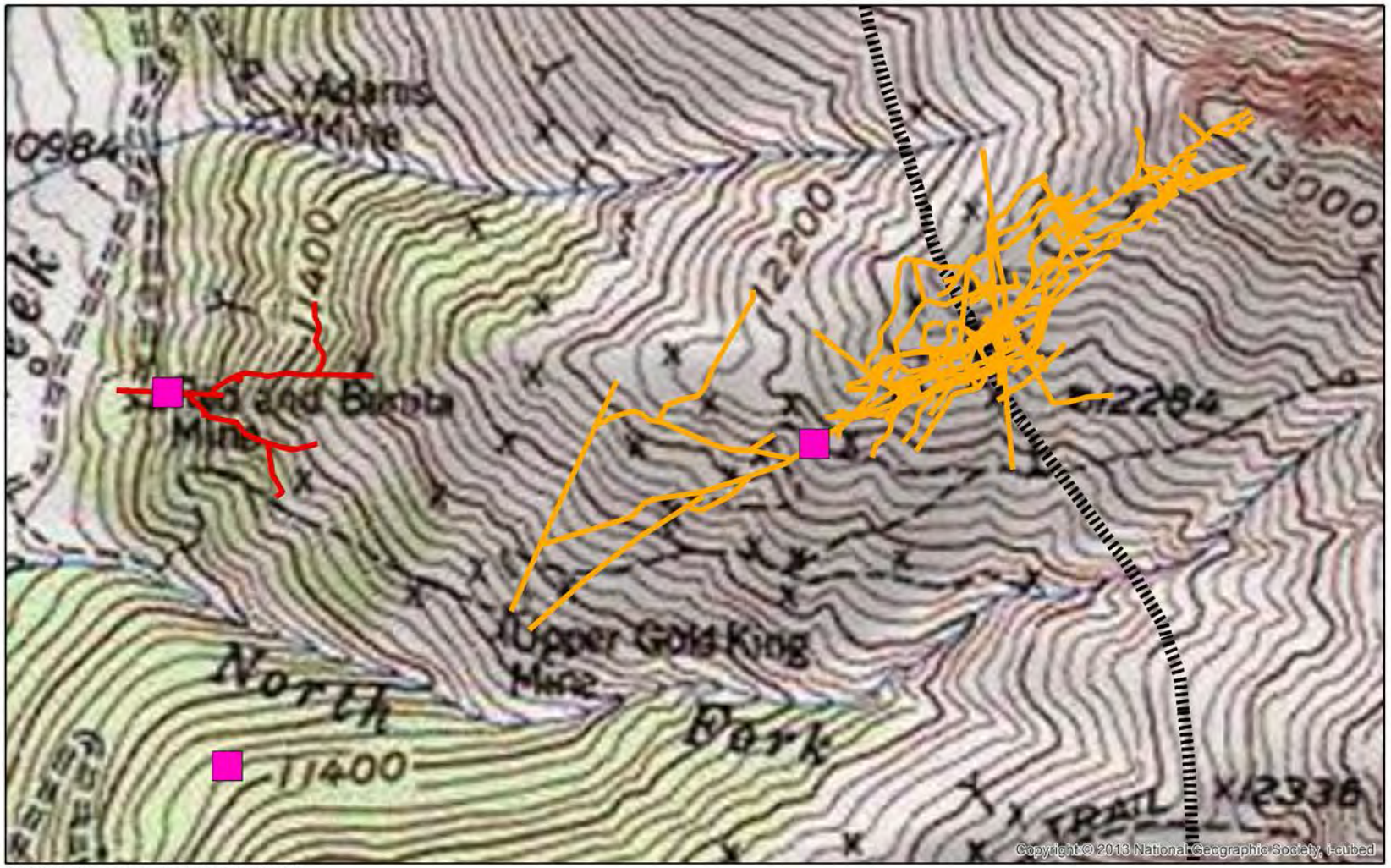
- Lowest level of workings
- Adequate overburden pressure
- Mine workings were easily re-opened are competent and safe
- Good rock quality
- Good location available within workings for bulkhead


Red and Bonita
Just after opening
08/12/2013

# *Mine Attributes*

Gold King Level 7

- Lowest level of workings
- Adequate overburden pressure
- Mine working currently not accessible, potentially a lot of work to re-open
- Unknown rock quality, expecting less than ideal.
- Partly a cross cut, but through poor rock near portal.




4/4/2019, Prepared by Kirstin Brown, CDRMS


0 250 500 1,000 1,500 2,000 Feet

**Legend**

- Bulkhead
- Red and Bonita
- Gold King
- USGS mapped FAULTS - PP1651

# *Water Storage and Water Control*

Water storage and control bulkheads are used to impound water inside the mine workings, but the valve is open to allow a set amount of water out of the workings, typically for water treatment.

There may be an optimal water elevation in the mine to keep the entire hydrologic balance of the mountain stable.

Example:  Red and Bonita (for now), numerous other across the state

# *Minimizing Unplanned Releases*

All bulkheads, if designed and maintained properly, would have the ability to prevent or minimize unplanned releases.

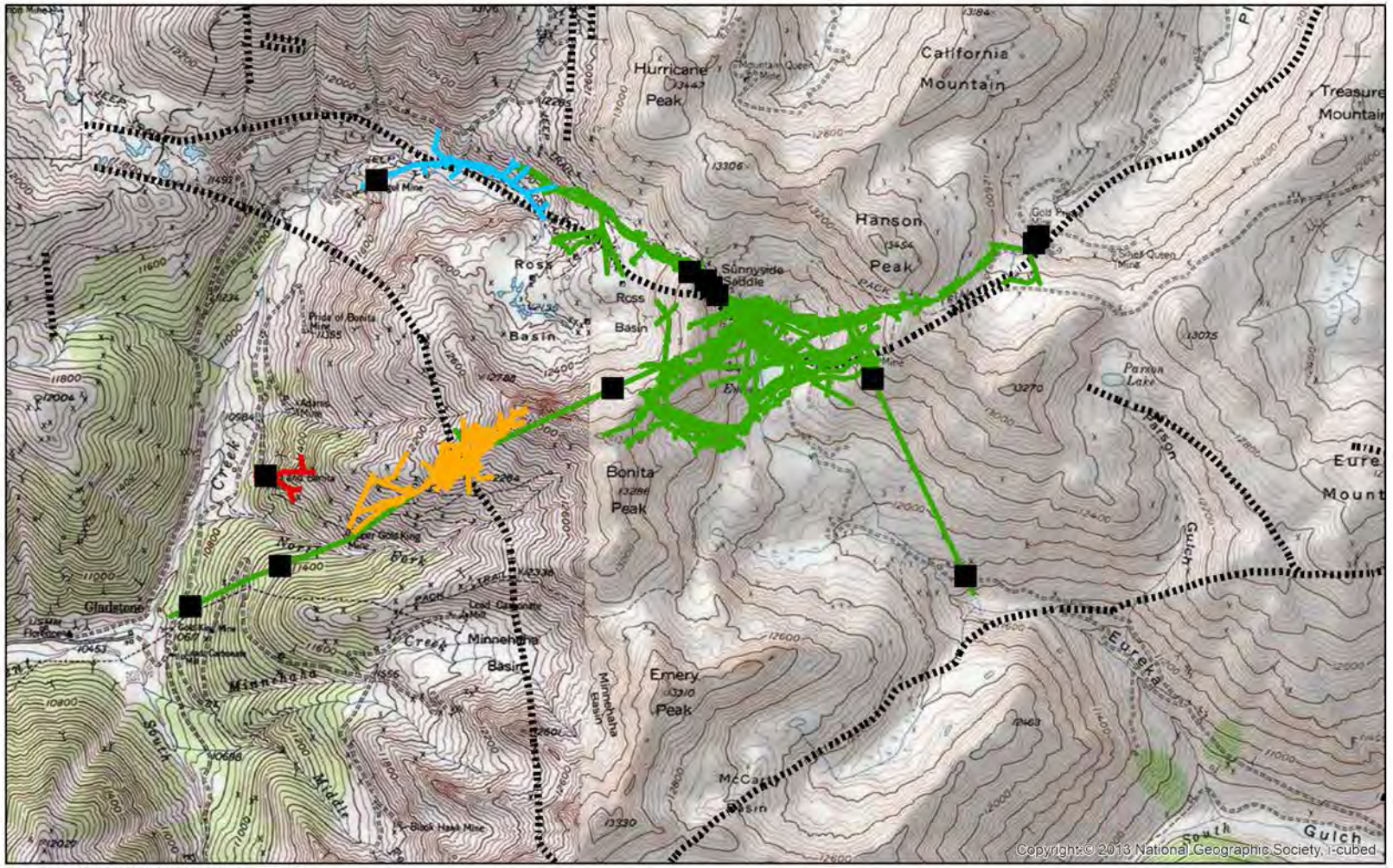
# *Bulkheads in the Upper Animas*

13 Bulkheads in Bonita Peak Area

Koehler Tunnel Bulkhead

Ransom

Sunbank (2)




4/4/2019, Prepared by Kirstin Brown, CDRMS

RED AND BONITA
Mine Workings past cave-ins are only projected to line of sight
SUNNYSIDE MINE
Most recent workings, needs more work
GOLD KING MINE
There is more data that needs to be added on 7 Level
MOGUL AND GRAND MOGUL
Separate mine workings that are connected to Sunnyside Mine

0 0.125 0.25 0.5 0.75 1 Miles

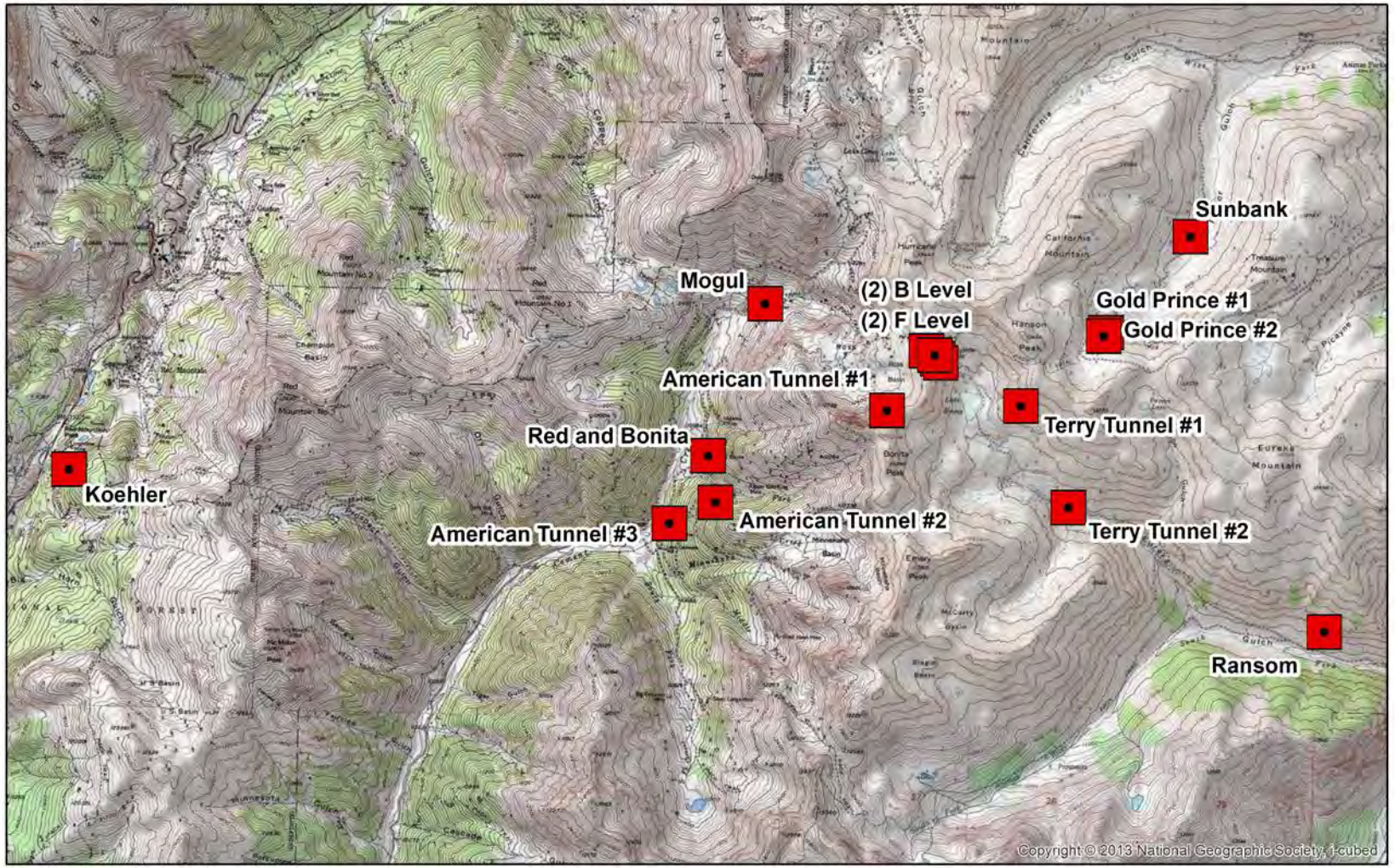
**Legend**

- Bulkhead
- Mogul and Grand Mogul
- Red and Bonita
- Gold King
- Sunnyside
- USGS mapped FAULTS - PP1651

- 3 bulkheads in American Tunnel
- 2 bulkheads on B Level Sunnyside Mine
- 2 bulkheads F Level Sunnyside Mine
- 2 bulkheads in Terry Tunnel
- 2 bulkheads Gold Prince in Placer Gulch
- 1 bulkhead in Mogul Mine
- 1 bulkhead in Red and Bonita

Picture 5. Bypass pipe (lower left) and 3/4-inch water sampling and pressure sampling pipe (right). Note combination thrust plate/waterstops and wire ties. American Tunnel bulkhead #2.

# American Tunnel Bulkhead #2




1/21/2020, Prepared by Kirstin Brown, CDRMS

N
W
E
S

# BULKHEADS IN THE UPPER ANIMAS

0 0.5 1 2 3 4 Miles

**Legend**

Bulkhead

# *DRMS Bulkhead Evaluation of Upper Animas*

9 bulkheads under evaluation.

5 out of the 9 were visually inspected in 2017

- American Tunnel Bulkhead #3
- Koehler Tunnel Bulkhead
- Mogul Bulkhead
- Red and Bonita Bulkhead
- Gold Prince Bulkhead #2
- *Terry Tunnel Bulkhead #1*
- *Ransom Tunnel Bulkhead*
- *Sunbank Bulkheads (2)*


American
Tunnel
Bulkhead #3

# *Bulkhead Failure Mechanisms*

Excessive leaking through rock surrounding the bulkhead

Chemical degradation of the concrete through reactions with acidic mine water

*Highly unlikely to fail structurally due to design inputs*

*Highly unlikely to fail through hydraulic fracturing of the surrounding rock mass due to design inputs.*

# *Bulkhead Review Focus*

Nature and extent of leaks in the surrounding rock mass

The condition of the concrete at the exposed face of the bulkhead

Condition of all penetrations through the bulkhead (pipes, gauges, etc.)

# *When Bulkheads "Leak"*

Impounded water can:

+ Go back to natural fractures and pathways – disseminated through the bedrock.

- Leak around the bulkhead and back into the tunnel and out the portal.

- Preferentially discharge out of a fault or fracture connected to surface – concentrated flow of acid mine drainage at surface.

- Preferentially flow out of a higher mine opening

# *Causes of Bulkhead Leaks*

Constructed in drift *workings-can't seal the structure*

Bad ground; fractured, jointed or bedded formation- *numerous water pathways around bulkhead*

Not enough overburden thickness (distance underground from surface)- *the mine pool leaks into near-surface fractured-rock aquifer*

Poor construction or no formation grouting when it is warranted- *bulkhead leaks badly*

Unknown mining or natural structural connections to other workings- *unanticipated discharges from other mine openings*

# American Tunnel Portal

# *Bulkheads "Leak" back through Natural Pathways*

Ideal Situation – Groundwater returned to pre-mining levels

Groundwater comes out natural pathways, faults, and fractures

What goes in must come out!

The natural pathways can filter and "clean" (natural attenuation) the water.

No need to prevent this type of "leaking"

# *Koehler Tunnel*

# *Leaking Around the Bulkhead*

Approximate Flows Around Bulkheads:

American Tunnel – 80 gpm

Mogul – 50 gpm

**Koehler – 5 gpm**

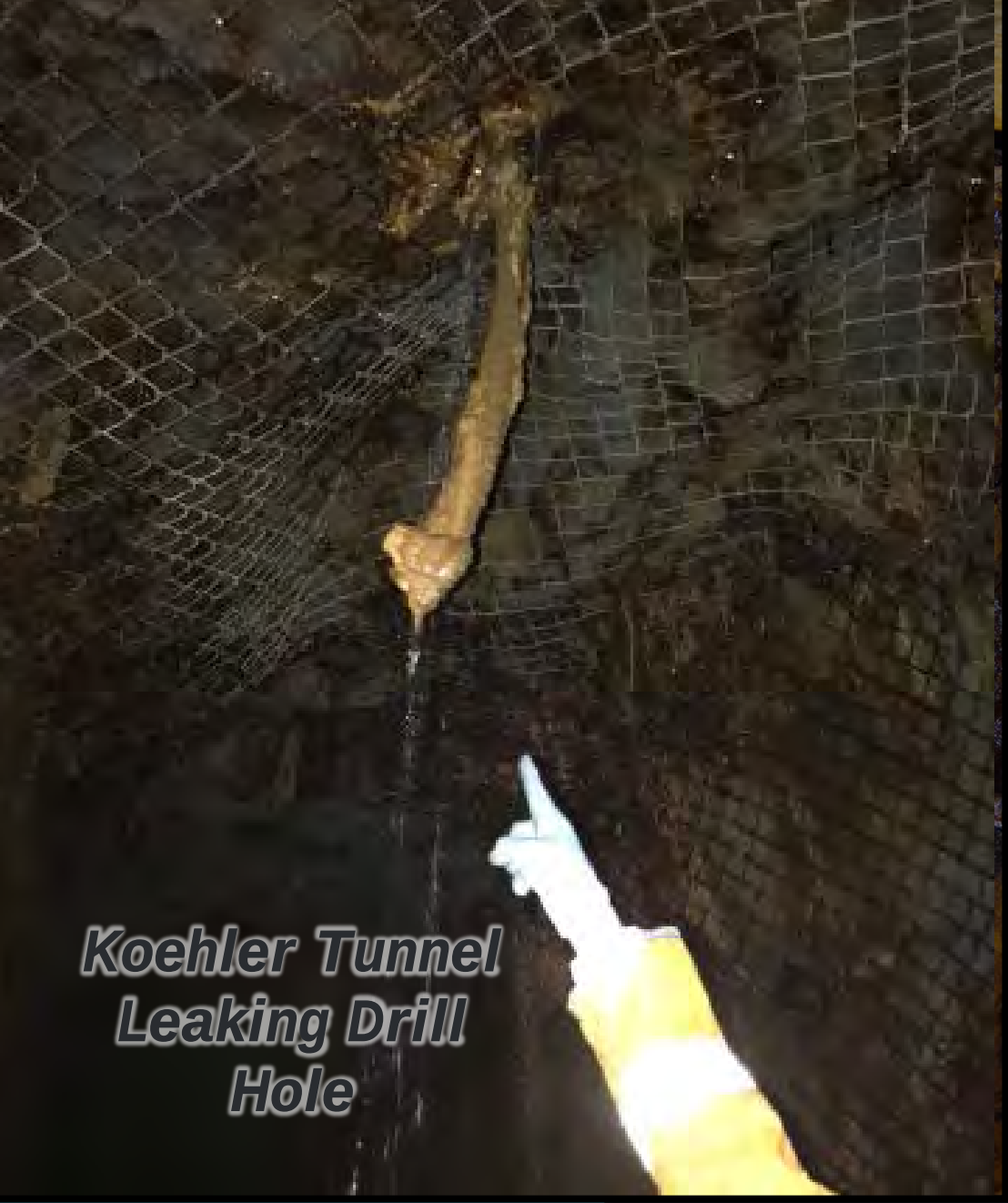
Sunbank – 15 gpm

Ransom – 1 gpm?

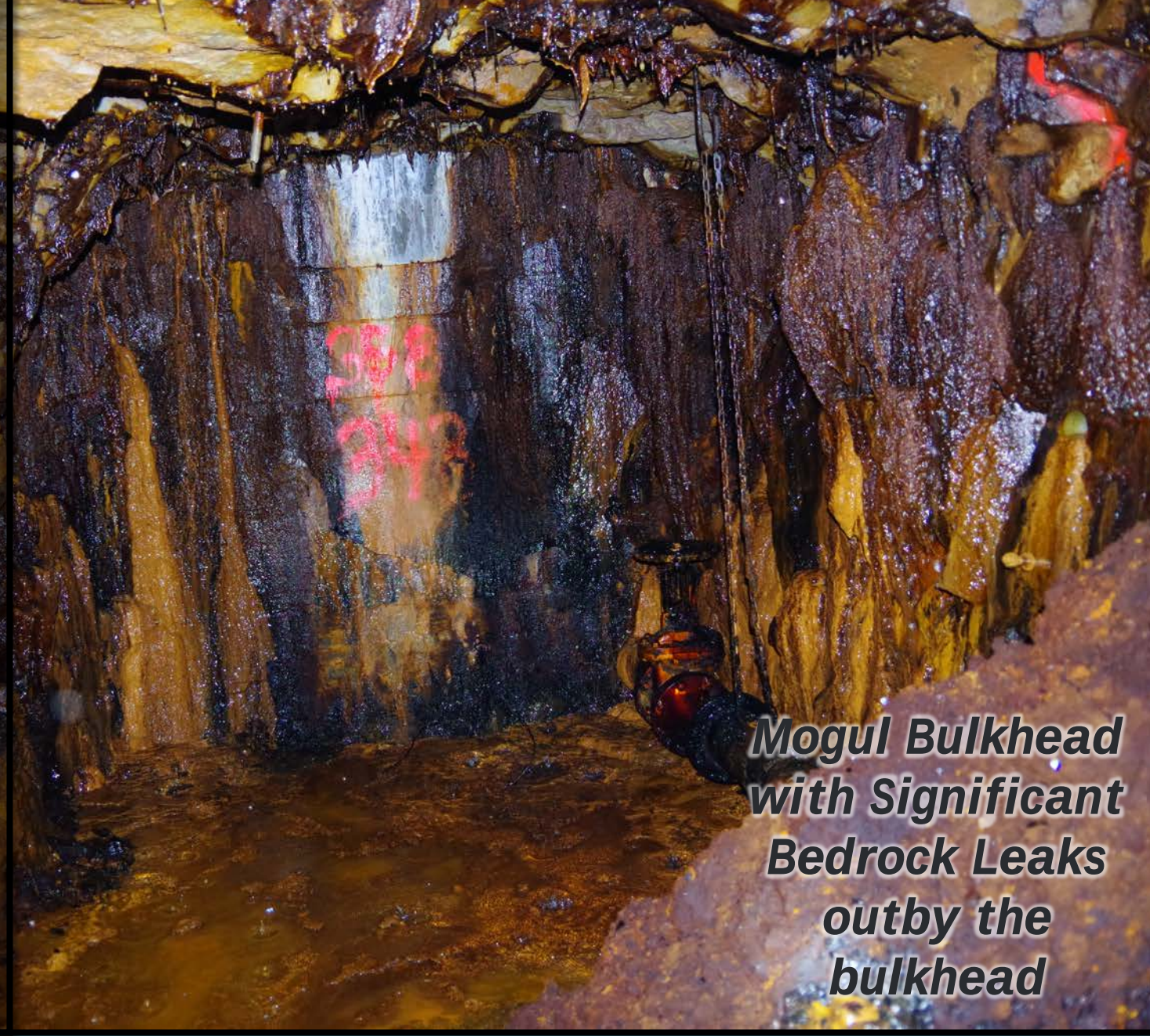
Gold Prince – 3 gpm

**Terry Tunnel – 7 gpm**

*Red and Bonita – 300 gpm – bulkhead open*



Koehler Tunnel Leaking Drill Hole



Mogul Bulkhead with Significant Bedrock Leaks outby the bulkhead

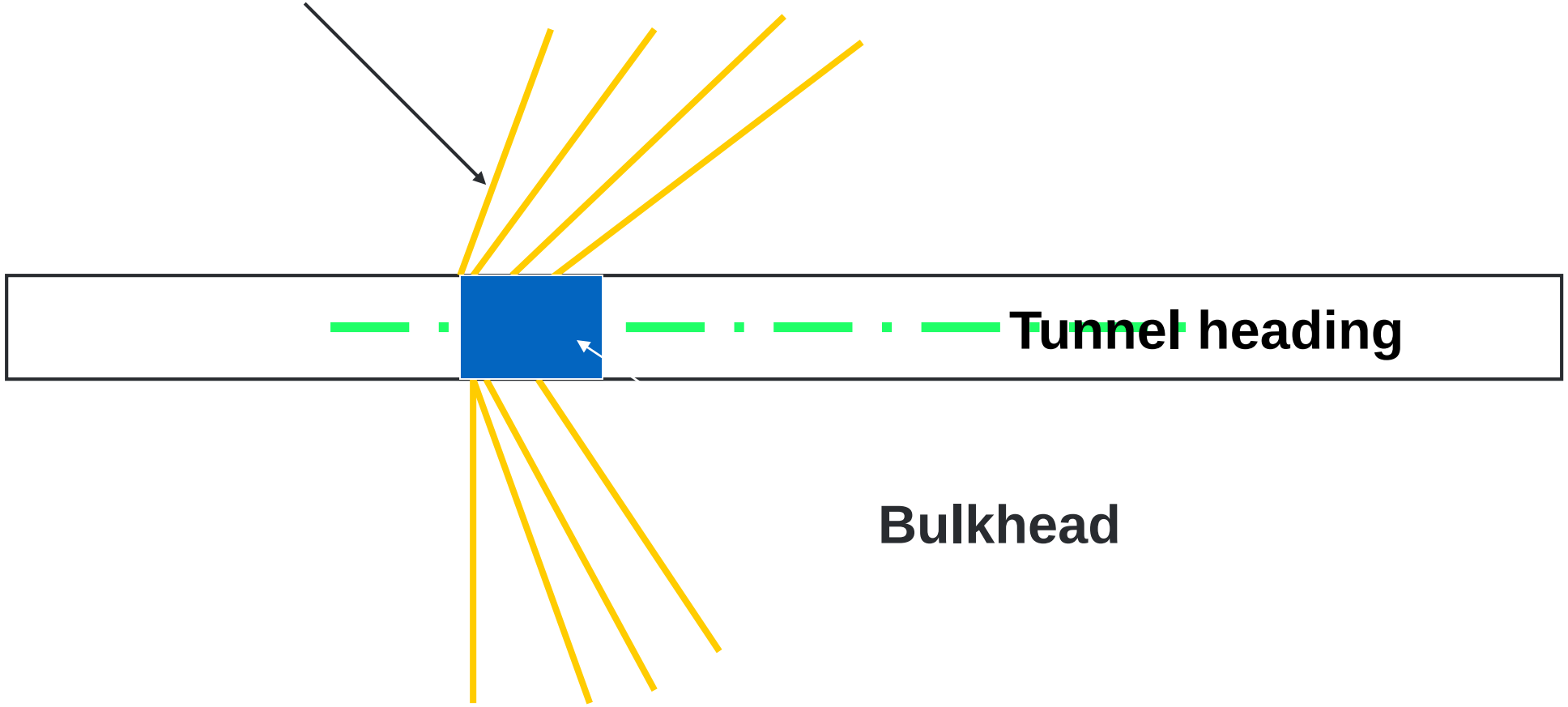
# *Leak Prevention Around the Bulkhead*

Ring Grouting / Formation Grouting

Inject grout into the rock formation around the bulkhead

# DRILLING PATTERN FOR FORMATION GROUTING

**Rings of grout holes used to seal fractures and pathways in rock formation around bulkhead zone**



# DRILLING PATTERN FOR WATER BEARING FAULT OR FRACTURE SYSTEM

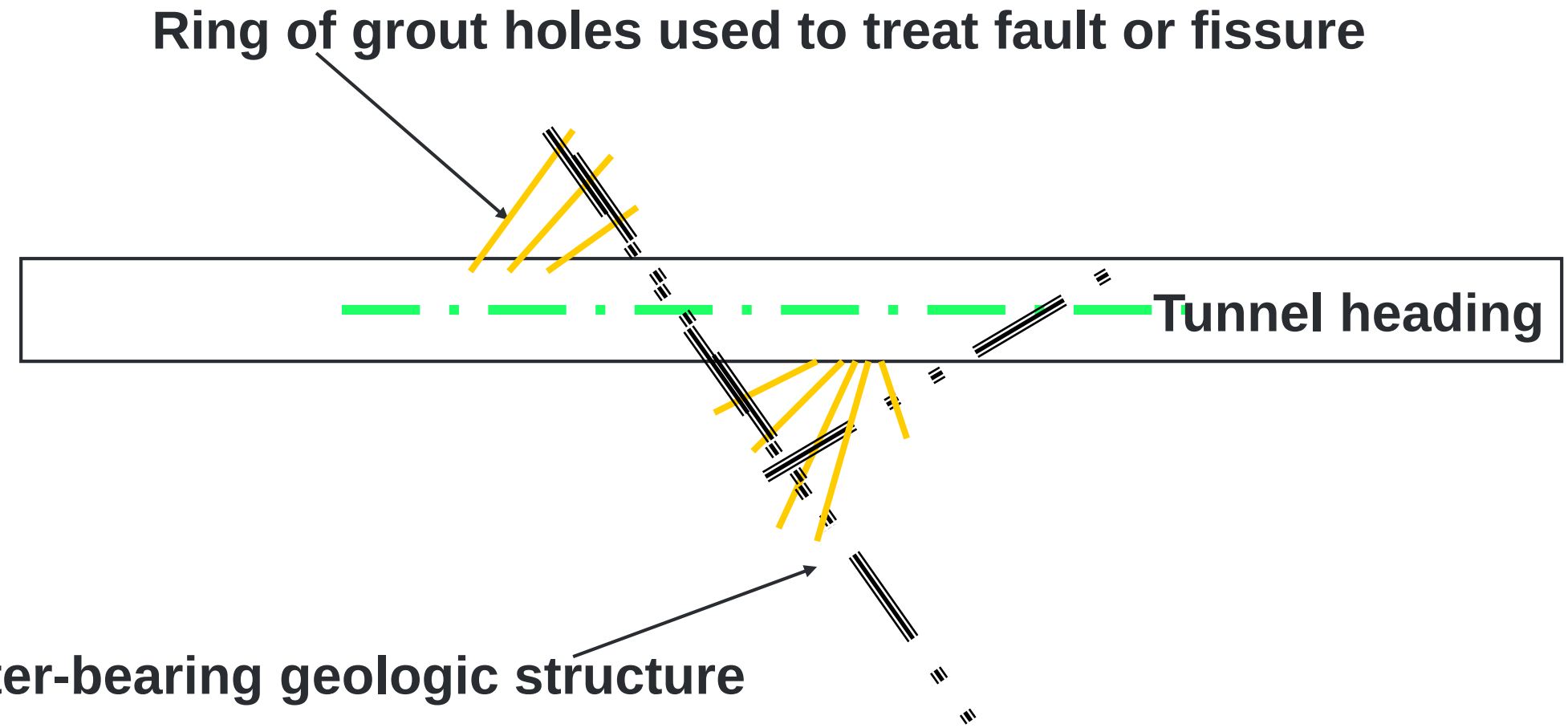
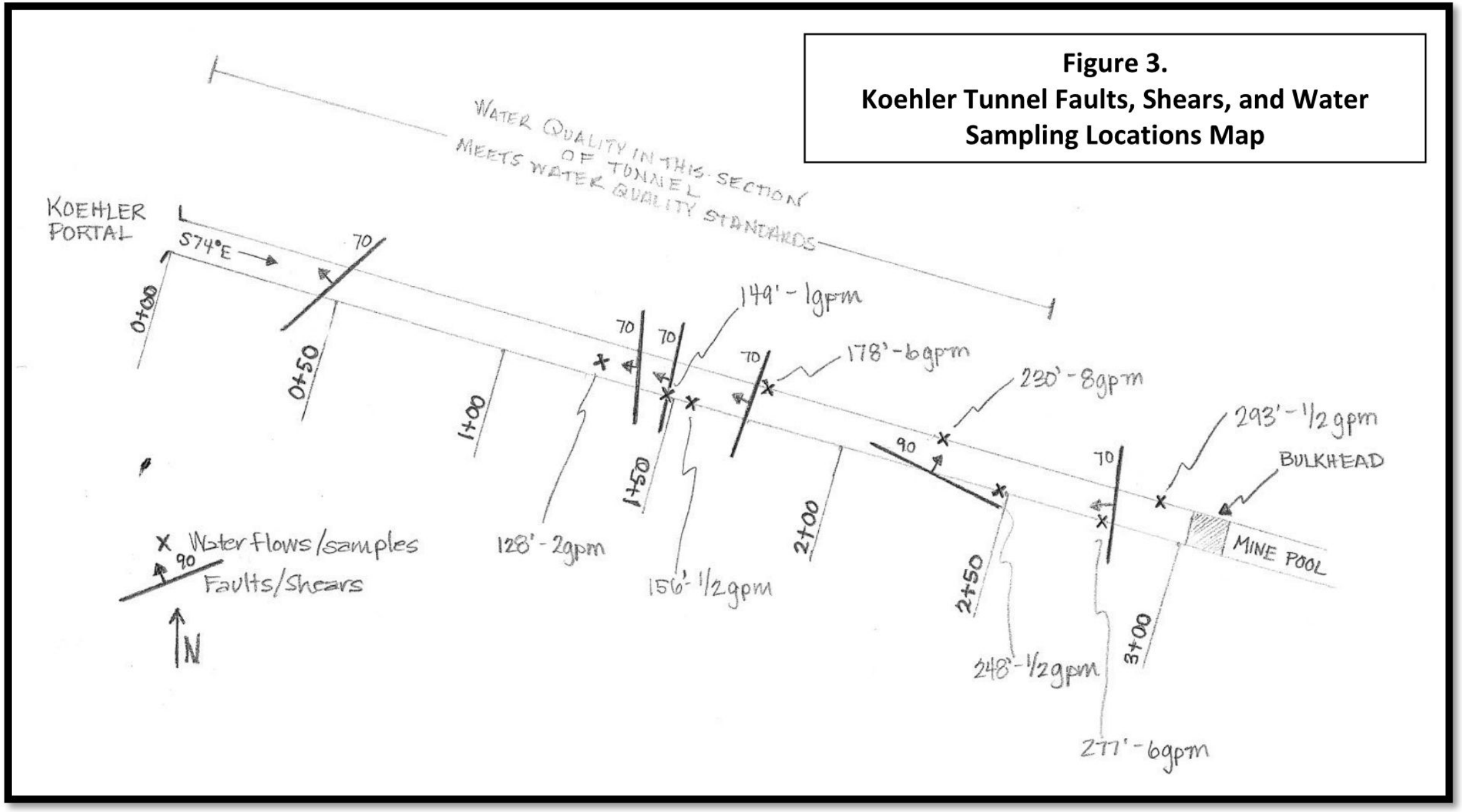
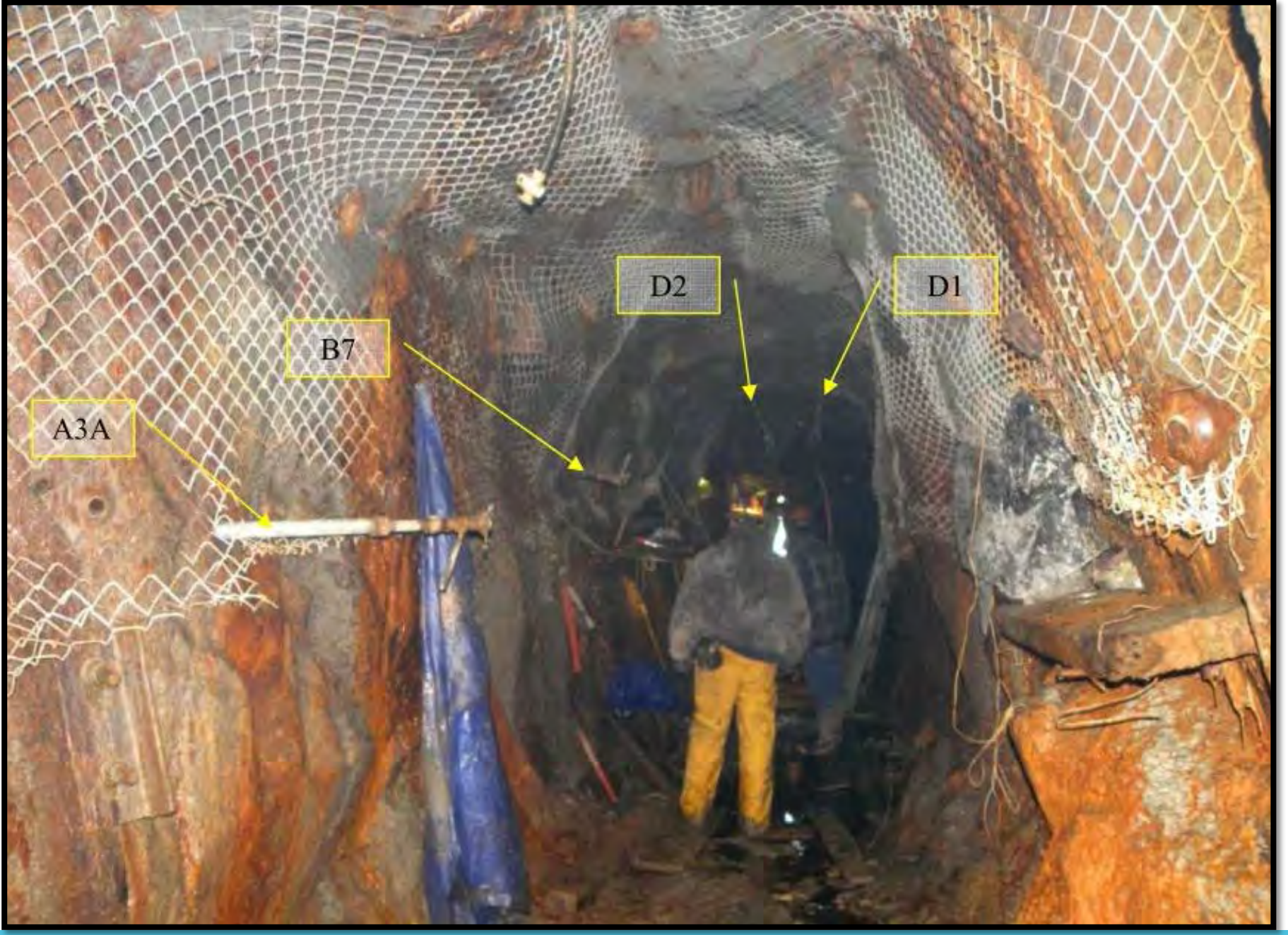


**Figure 3.**
**Koehler Tunnel Faults, Shears, and Water Sampling Locations Map**






Koehler Tunnel during Fracture Grouting

# *Preferential "Leakage" at a Fault or Fracture*

Bulkheads can cause impounded water to preferentially flow out of a fault or fracture connected to surface.

Although the fault/fracture is a natural pathway, a large amount of acid mine drainage could flow from the fault/fracture.

Depending on the location of the fault or fracture, grouting could be attempted.

If grouting is not possible, and the fracture is flowing too much, water levels behind the bulkhead may have to be lowered by releasing water from behind the bulkhead.

# *Flow out of  Higher Mine Openings*

Flow may come out higher mine openings

Other mine openings may be connected through:

- Natural pathways
- Large faults and fractures (also natural)
- Direct mine connections / tunnels / drifts / shafts
- Via drill holes

Continue to bulkhead higher openings or manage the water level in the mountain

# Gold King
# Level 7
# 2008

# *Bulkheads Conclusion*

Bulkheads can be used for different purposes:

- Control and prevent acid mine drainage / Restore hydrology
- Minimize Flows and minimize metals loading, potential for water treatment.
- Water storage and flow control for water treatment
- Unplanned Release Prevention


# IMPOUNDED WATER IN UNDERGROUND MINES

Animas River Watershed, Colorado

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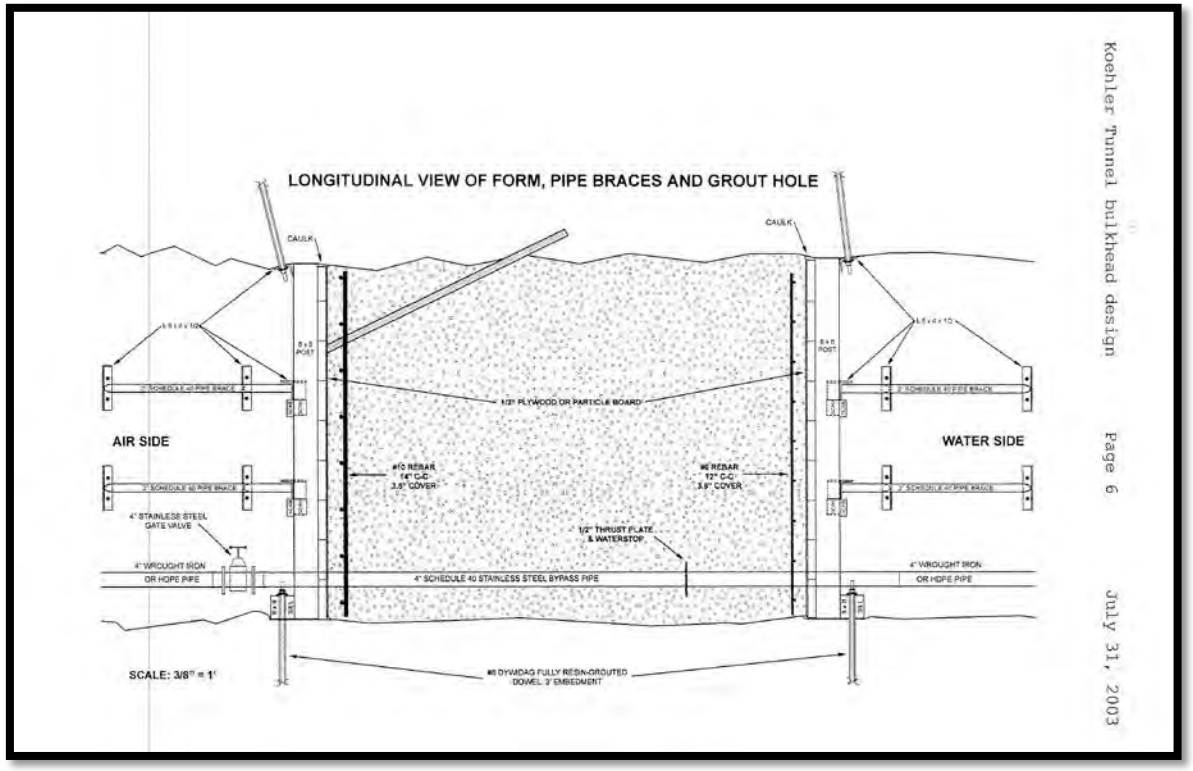
Department of Natural Resources

# Not Bulkheads!




vs.

Black Hawk Portal

# Ponds

# *Underground Mining in Silverton, CO*

Started in 1871 and ended in 1991

Over 3,000 mines located on topography maps

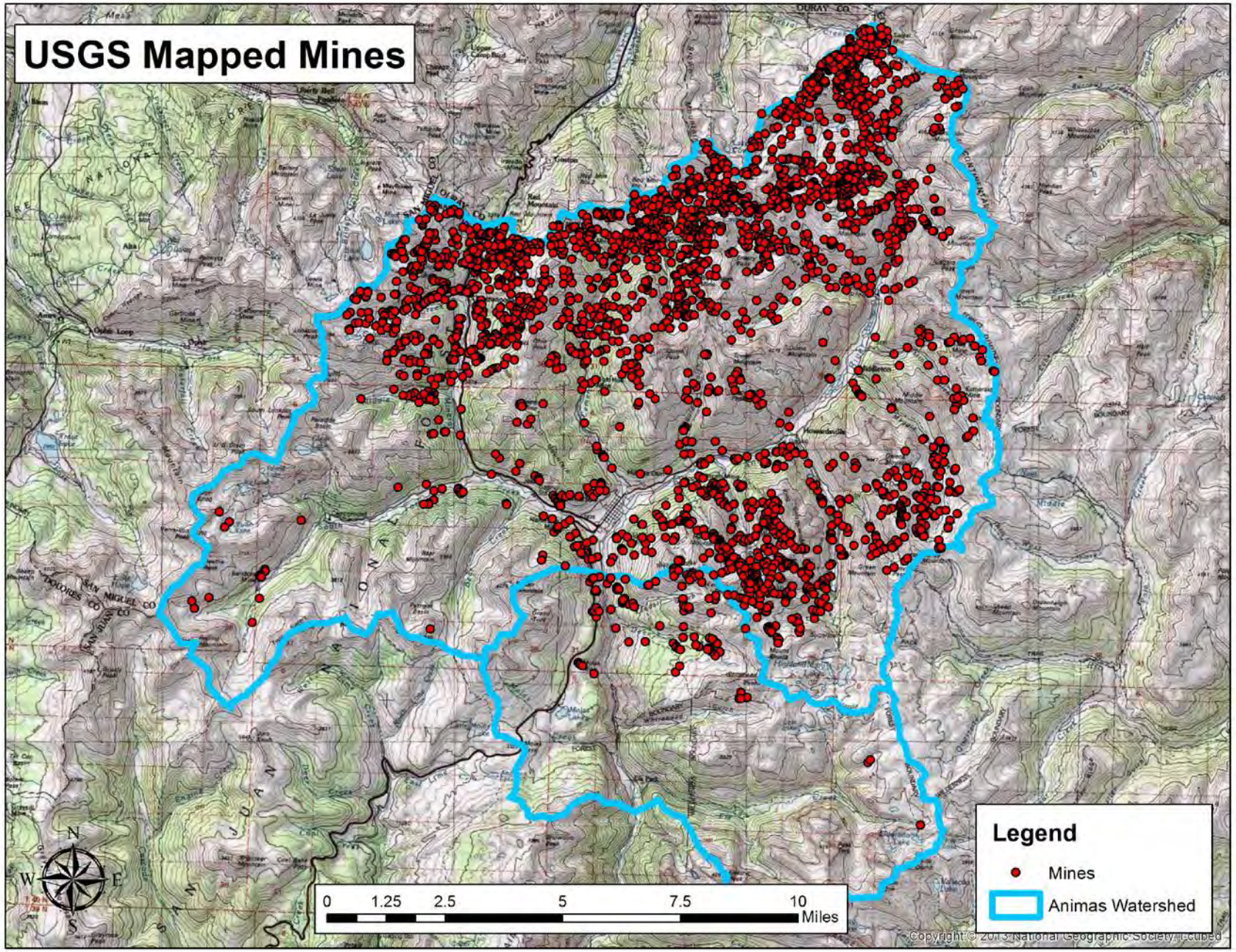
Approximately 500 mines located by USGS in PP 1651

125 + draining mines sampled

56 draining mines sampled in Animas for the 2016 DRAINING MINES STATEWIDE INVENTORY

48 Mines and Mineral Processing Sites Listed on BPMD National Priority List

About a dozen have had unplanned releases worth noting


USGS Mapped Mines
Legend
Mines
Animas Watershed
0 1.25 2.5 5 7.5 10
Miles
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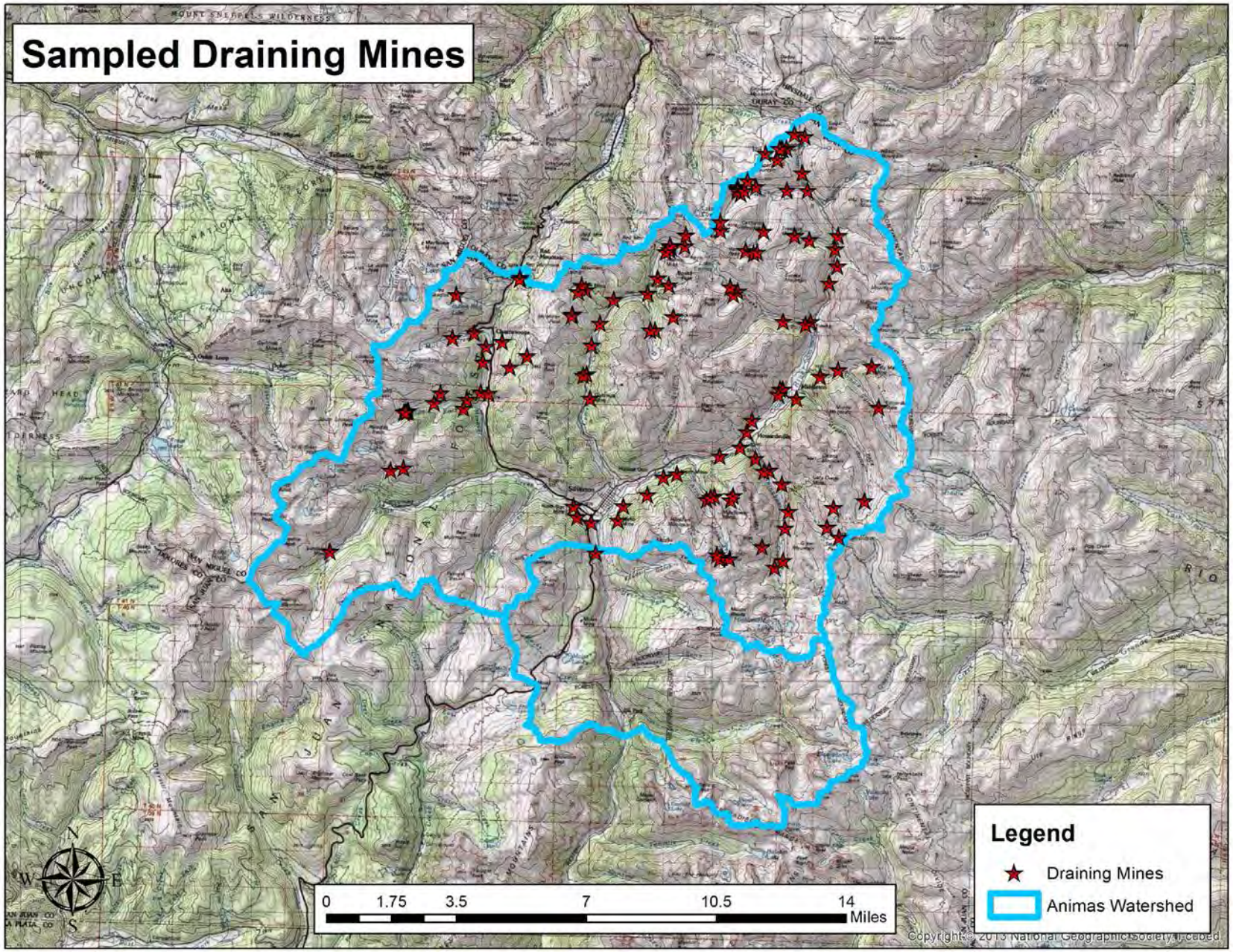
Copyright © 2013 National Geographic Society, i-cubed

Map of kno


Sampled Draining Mines
Legend
Draining Mines
Animas Watershed
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1.75
3.5
7
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Miles
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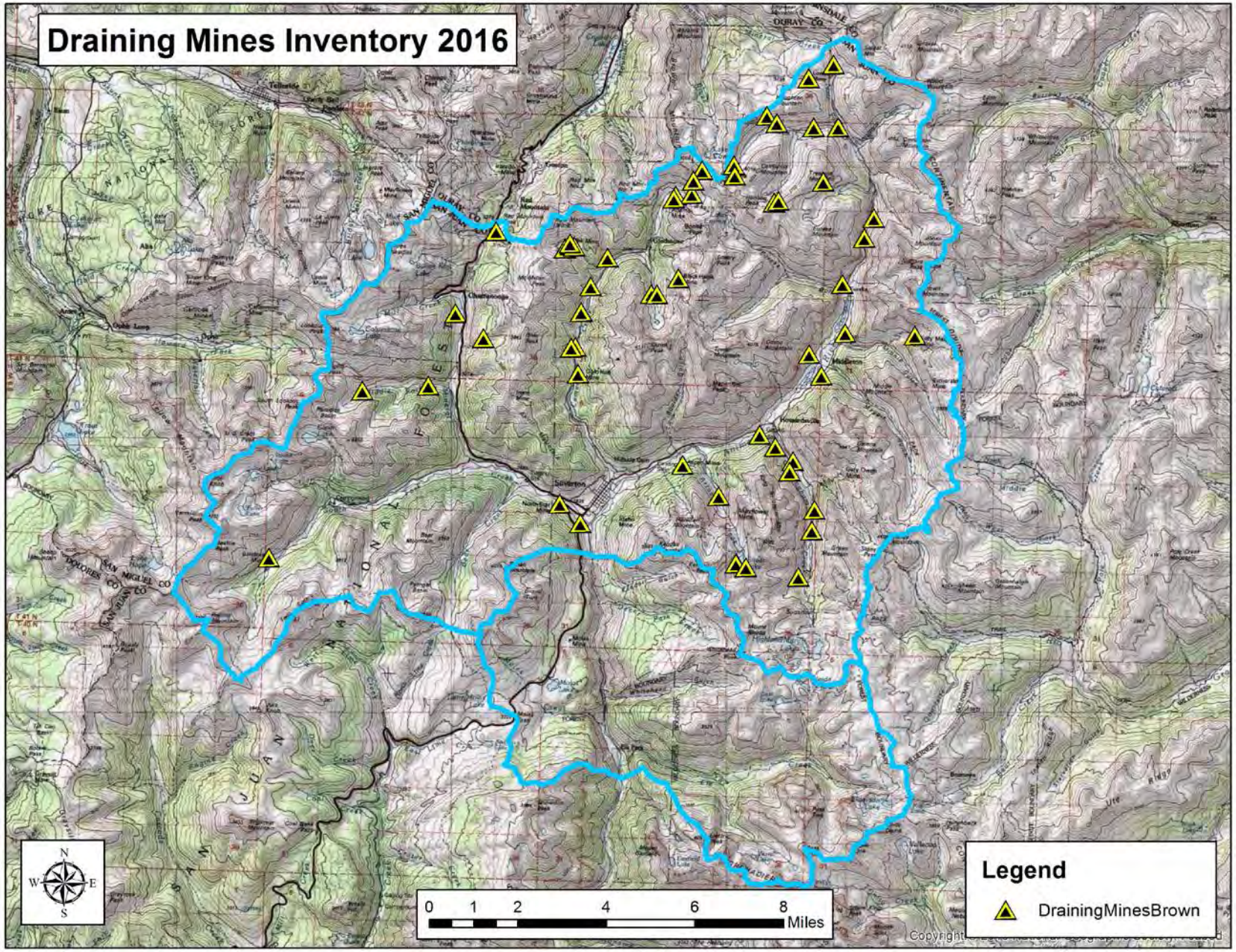
Map of dra


Draining Mines Inventory 2016
Legend
DrainingMinesBrown
0 1 2 4 6 8
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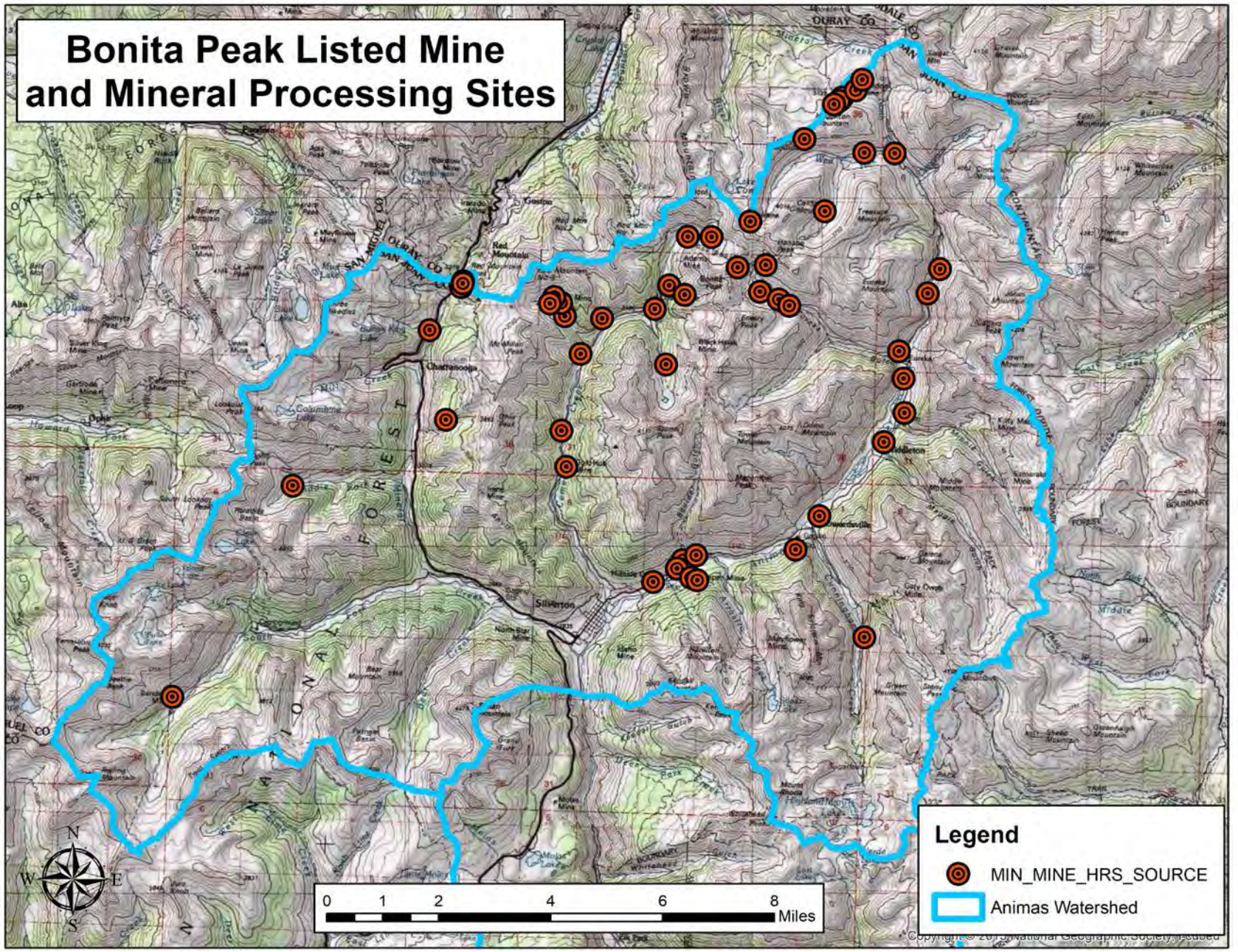
SAN JUAN
Silverton


Bonita Peak Listed Mine
and Mineral Processing Sites
Legend
MIN_MINE_HRS_SOURCE
Animas Watershed
0 1 2 4 6 8
Miles
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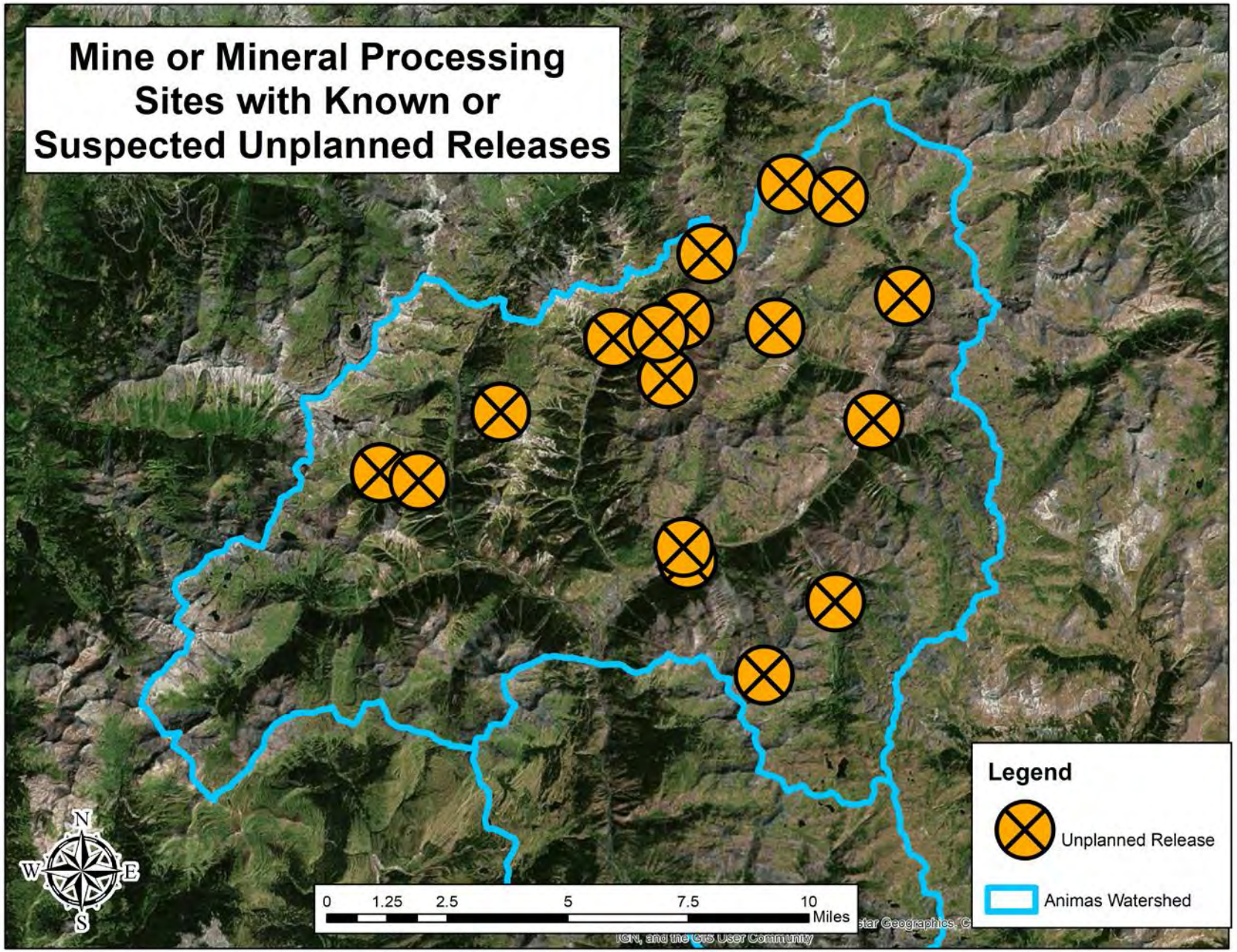
Silverton
Gladstone
Howardsville
Eureka
Chattanooga
Red Mountain
SAN JUAN NATIONAL FOREST


Mine or Mineral Processing Sites with Known or Suspected Unplanned Releases
N
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0
1.25
2.5
5
7.5
10
Miles
Legend
Unplanned Release
Animas Watershed


Silver Hat
Telluride, CO

# Silver Wing BPMD Site

# Silver Wing BPMD Site

# Silver Wing BPMD Site

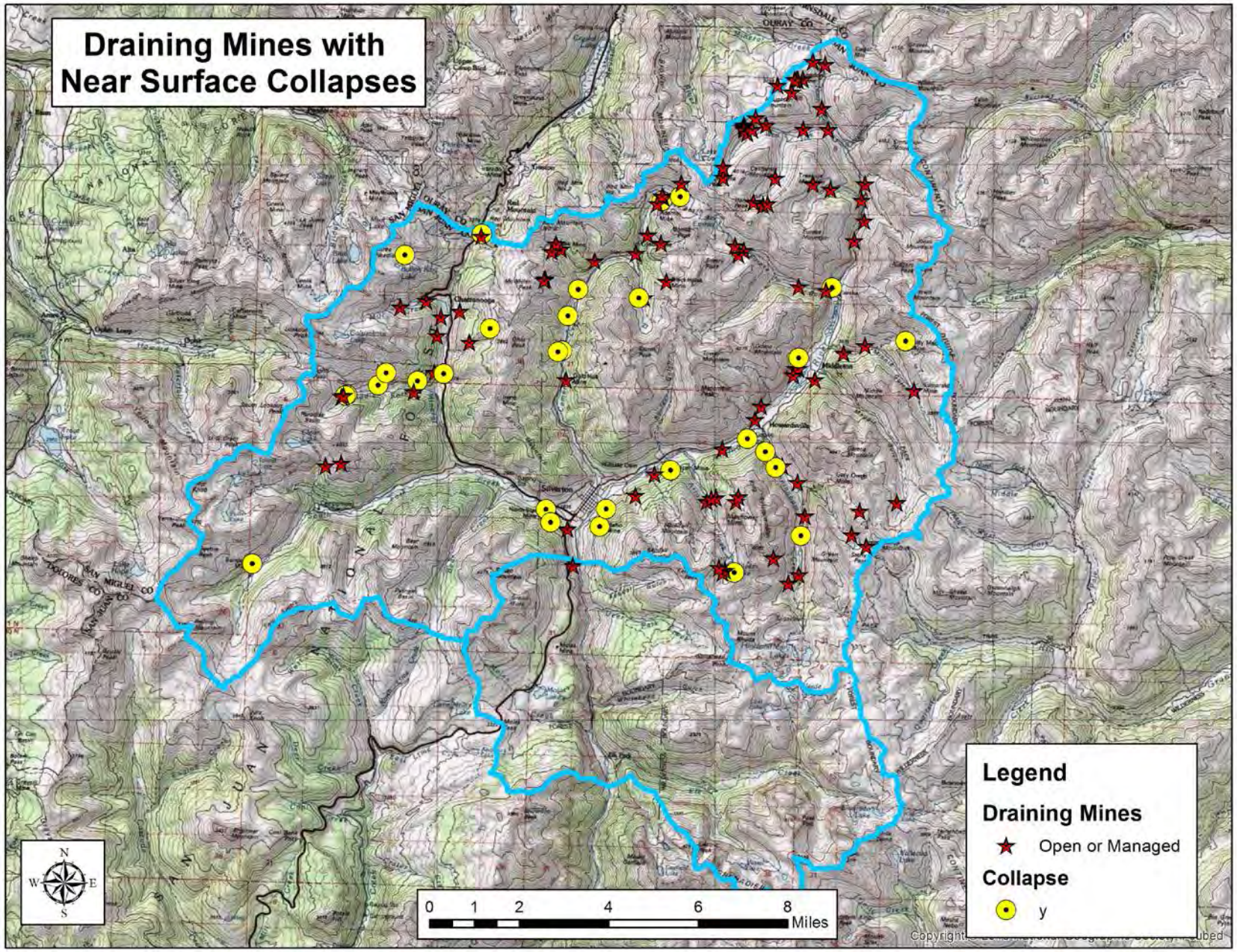
# Natalie Occidental Unplanned Release at Confluence of Animas and Cement Creek 2016

# *Impoundment Modes*

- Near surface collapse
- Collapse inside mine workings
- Sludge Dams
- Ice Dams
- Clogging Pipes
- Ponds
- Snow/Avalanche
- Beaver Dams
- *Combination of factors can occur*

**<u>None of these are bulkheads</u>**

30+


Draining Mines with
Near Surface Collapses
Legend
Draining Mines
Open or Managed
Collapse
y
0 1 2 4 6 8
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# *Near Surface Collapses*

Natural processes, freeze thaw near surface

Rock Quality / Geology near surface

Permeability

Thickness / Extent of collapse (unknown)

Water Quality and amount of precipitates formed

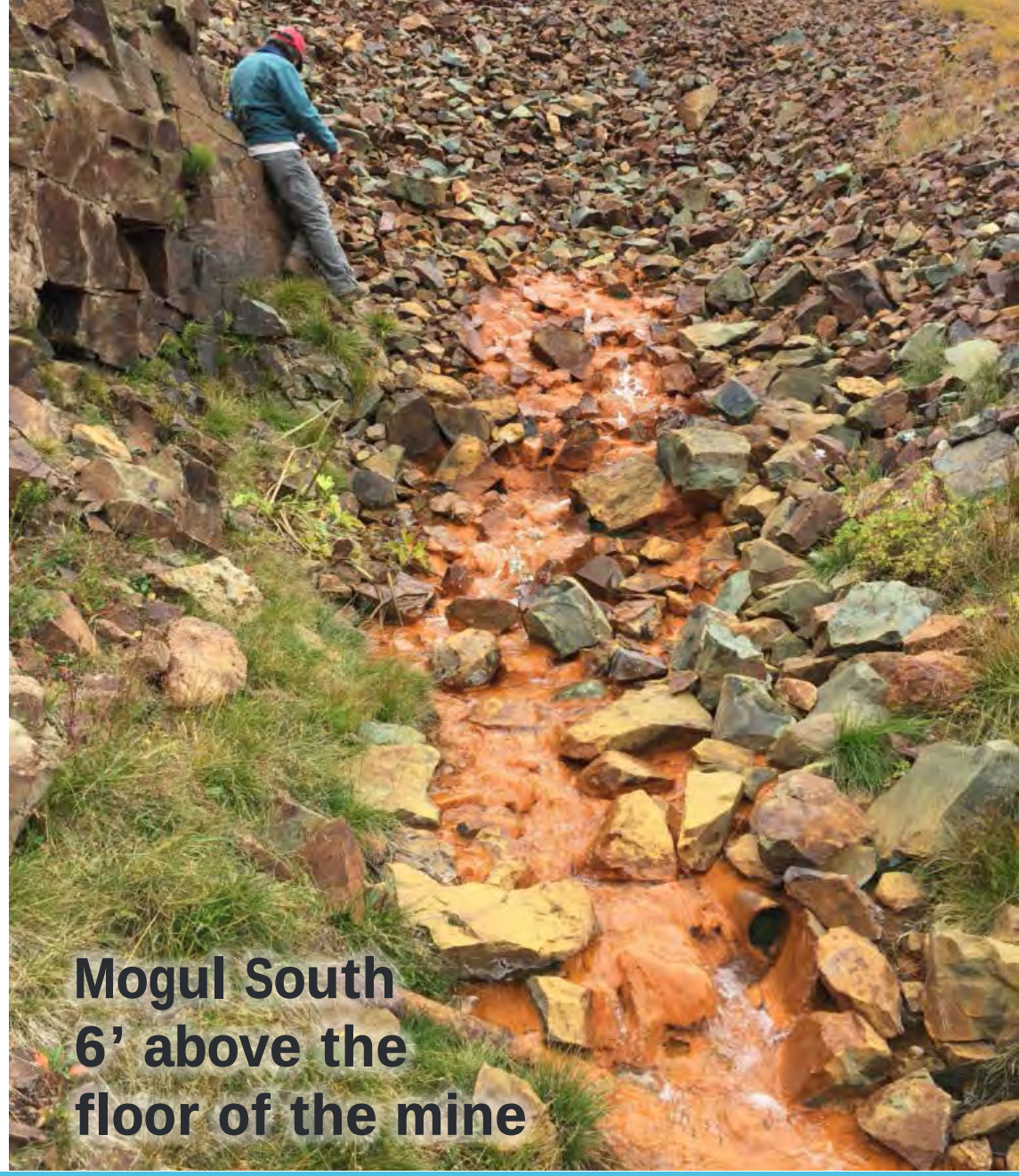
# Permeability



- Can change through time
- Continual clogging of pore space – diminishing permeability

Senator
5’ above
the floor of
the mine


Bandora
8’ above the
floor of the mine


Mogul South
6’ above the
floor of the mine

# *Permeability*

How clogged can the pore spaces become?

How much water can be backed up behind non-engineered, unknown earthen dams?

What could cause failure?

How much time does it take to overwhelm the system?

# *Collapse Inside Mine Workings*

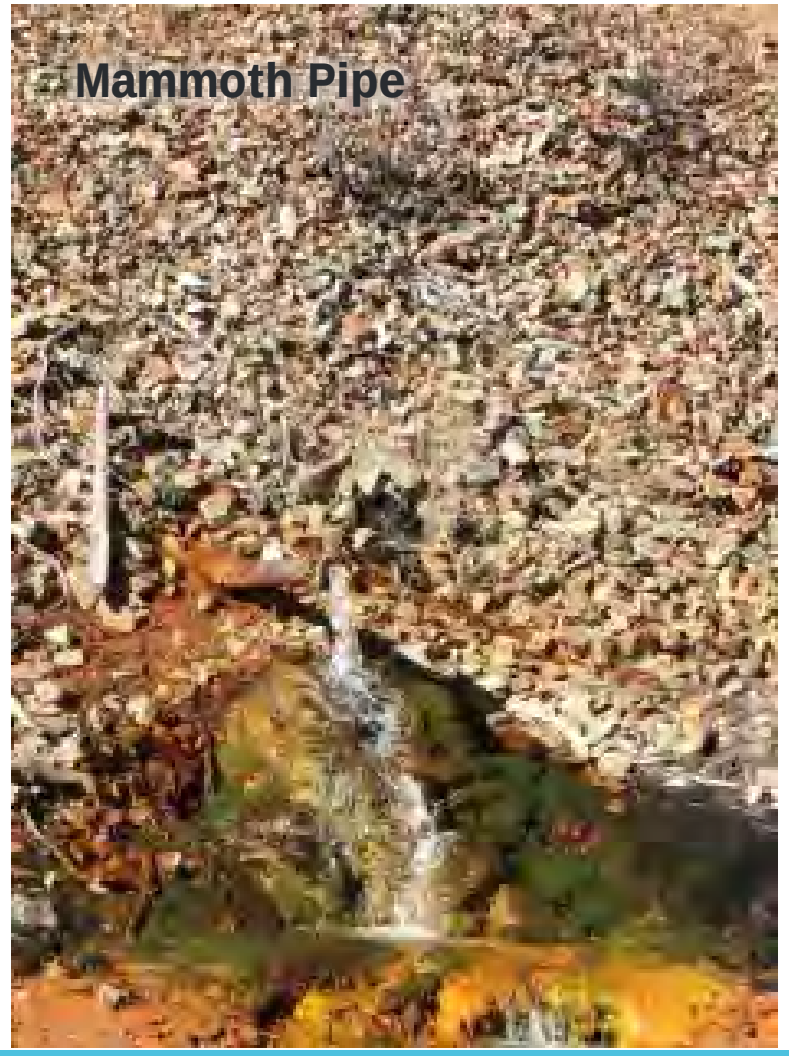

# *Collapse Inside Mine Workings*


**Dinero Tunnel**
**Leadville, CO**

# Ice Dams

# *SLUDGE dams*


# *Clogging Pipes*





Silver Wing

# Snow or Ice


Field Observations
Cement Creek 5/22/2016
Legend
Feature 1
Peak
Sout Fork Cement Creek
Gold King
Source of Discoloration
Red and Bonita
Google earth
© 2016 Google
4000 ft

*Natalie Occidental mine drainage*

*Natalie Occidental after snow bridge collapse at confluence with Animas and Cement Creek*

# Beavers

# *Unplanned Release Causes*

- Equipment operation
- Mining Activity
- Dewatering
- Drilling
- Clogging Pipes
- Failure of near surface collapse
- Failure of underground collapse
- Fresh underground collapses
- Landslides
- Ice dam release
- Sludge dam release
- Beaver dam failure
- Stormwater and high flows destabilization of system
- Avalanche backing water up and releasing

# *Proximity*

Roads

People

Receiving Streams

Environment


- Camping below the portal
- Fish downstream in South Mineral
- Less traveled road


- On a major and important road
- Historic structure holding waste rock back below portal
- No fish in Cement Creek

# *Data gaps to address*

- Mine maps
- Interior mine volume for water volume estimates
- Head Pressure Measurements
- Hydrology
- Conditions underground
- Precipitate accumulation rate
- Precipitate mineralogy
- Pipe clogging rates
- Pond construction and stability
- Landslide, avalanche, flood plain understanding related to sites
- Flow variations at sites
- Proximity to fish populations
- Size of collapses at portals

# *Solutions*

- Provide “managed” drainage path or maintain tunnel to stay open
- Drill into mine workings to monitor head pressure/provide a safe way to pump water out
- Air Curtains (ice dams)
- Institutional Controls
- Institutional controls to prevent equipment operation near portals
- Control water levels with engineering
- Source Controls – prevent water from being impounded
- Active maintenance of mine sites (yearly)?
- Geophysics to determine extent of impounded water
- Analyze flow data from sites to determine concerning changes
- Install remote flow metering at sites
- Humanely manage beavers
- Source Controls


COLORADO

# *Ground control*

Little Dora

# Koehler Ground Control


# Ground control

# *Control water levels*

Red and Bonita Bulkhead
during installation

Koehler Bulkhead

# Source controls

Pride of the West Stope Closure

# *EPA's Goals*

1. Water Quality Improvements

2. Stabilize Source Areas

3. **Minimize Unplanned Releases**

   - Provide data about listed sites to support Goal 3


Thank You!