

# Closure of Remote Historic Underground Mines in Desert Environments

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- **Geotechnical solutions were developed for closure of two historic underground borate mines in the deserts of California**
- **The Old Borate mining district located in the Mojave Desert near Barstow California**
  - **Mined from 1890 to 1907**
- **The Lila C. Mine near Death Valley California**
  - **Mined from 1907 to 1916 and 1920 to 1926**



# Location of the Old Borate and Lila C. Mine Sites



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# Big Borate Canyon



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# Big Borate Canyon

post-1898



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# Haulage Adit



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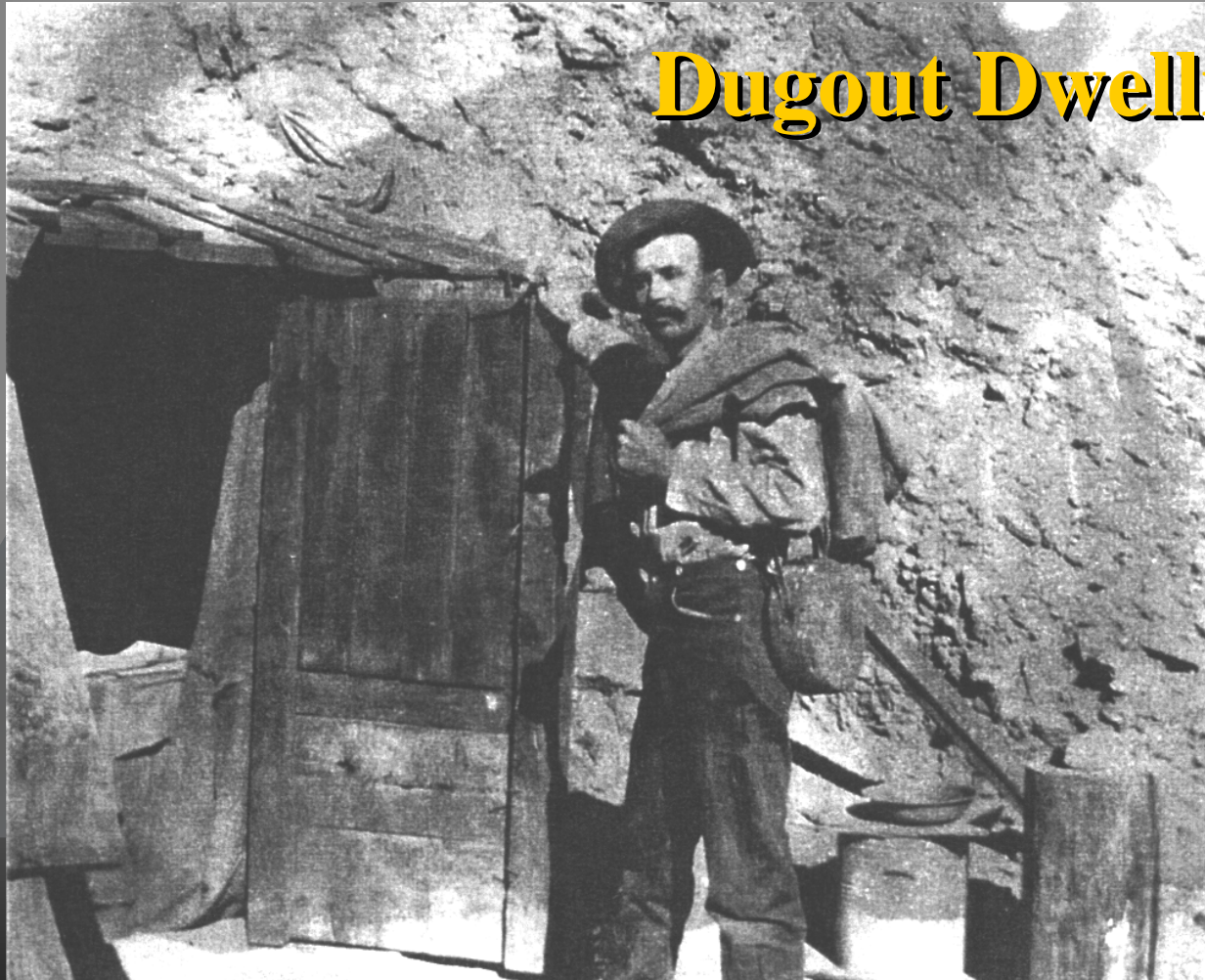


## **Decline Shaft**



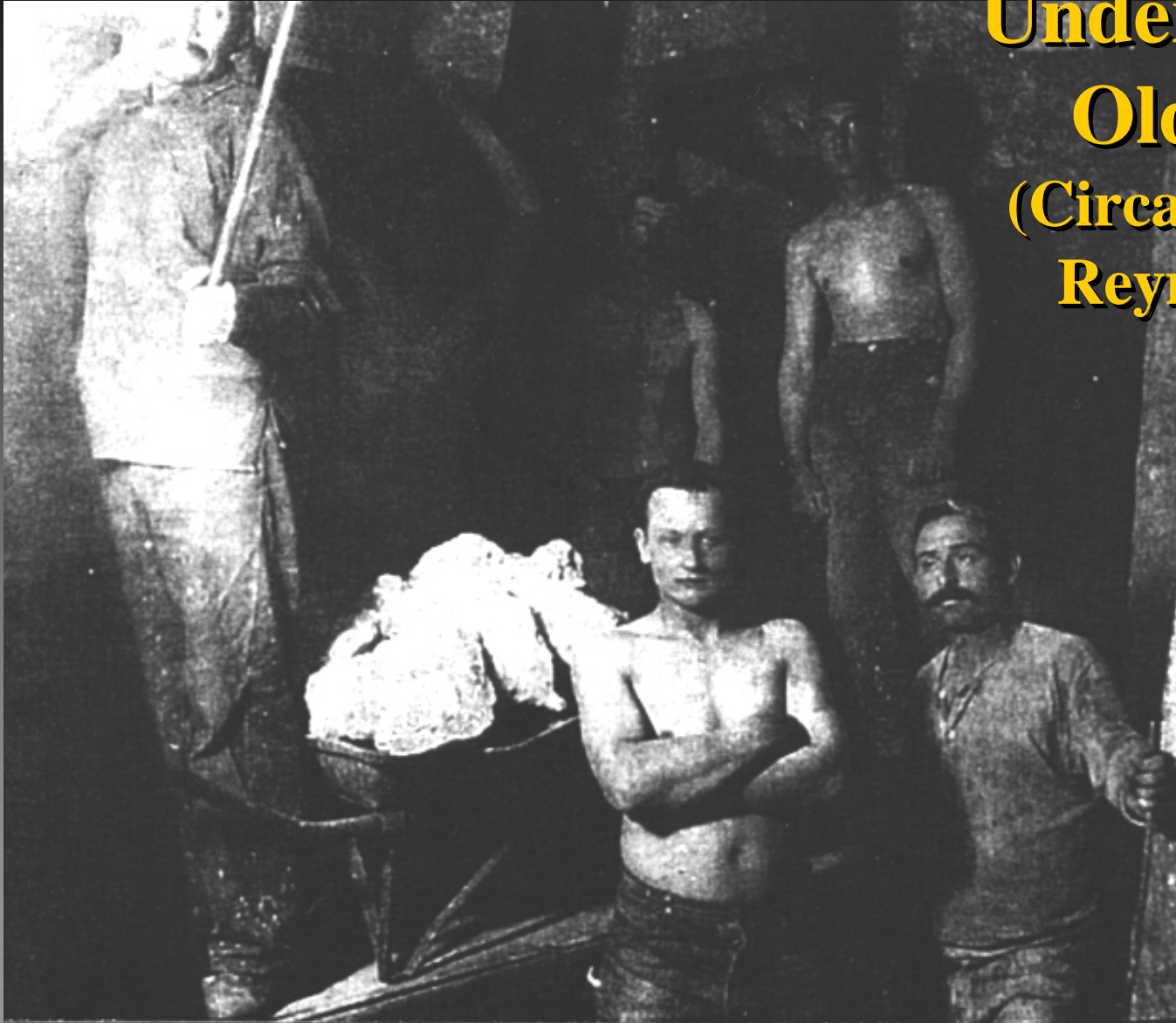
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# Dugout Dwelling





# Underground at Old Borate (Circa 1902—from Reynolds 1999)



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# Closure Criteria

- Prevent public access
- Protect wildlife
- Minimize impact to fragile desert landscape
- Assure environmental compatibility
- Optimize use of native materials



# **Wildlife Protection**

- **Conducted by bat and desert tortoise specialists**
- **Daytime internal examination and night bat surveys with night vision equipment and ultrasonic detectors**
- **No tortoise sign found within mines**
- **Bats or bat sign found in most of the mine openings**
- **Mine openings fenced to allow bat exit but not re-entry**



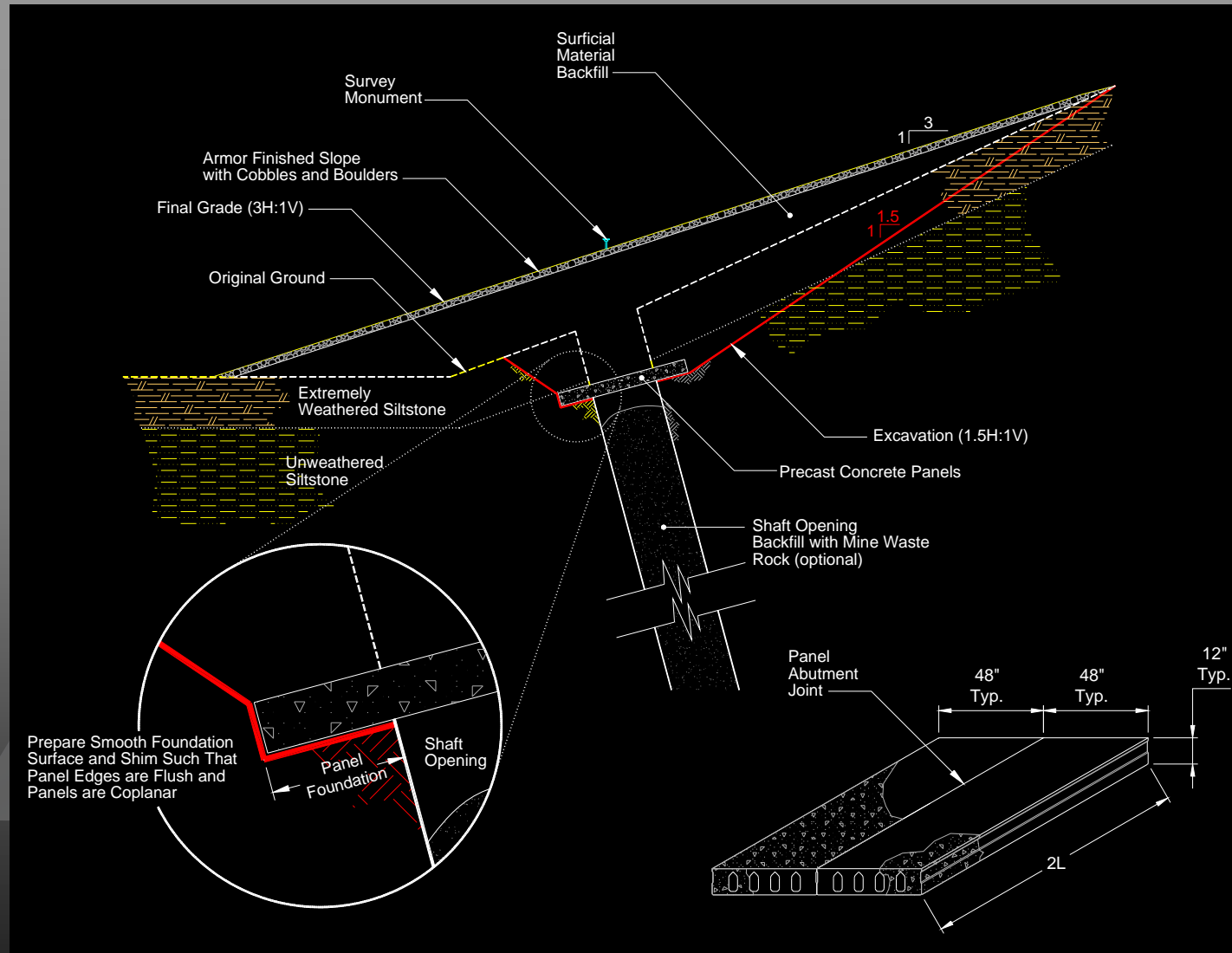


# Pre-Construction Design

- **ADITS**
  - **Collapse and Regrade**
  - **Polyurethane Foam**
- **SHAFTS and STOPES**
  - **Pre-Cast Concrete Panel Caps**



# Pre-cast Concrete Panel Design



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# Field Conditions

- **Strength of weak siltstone and claystone did not increase with depth**
  - **Low bearing capacity**
  - **Foundation could be easily eroded**
  - **Ground caved and grew laterally with excavation**
- **Excavated mine openings were larger than surface expression**
  - **Large spans for pre-cast concrete panels**
  - **Increased number of concrete panels**
  - **Would have required steel beam support for large spans**



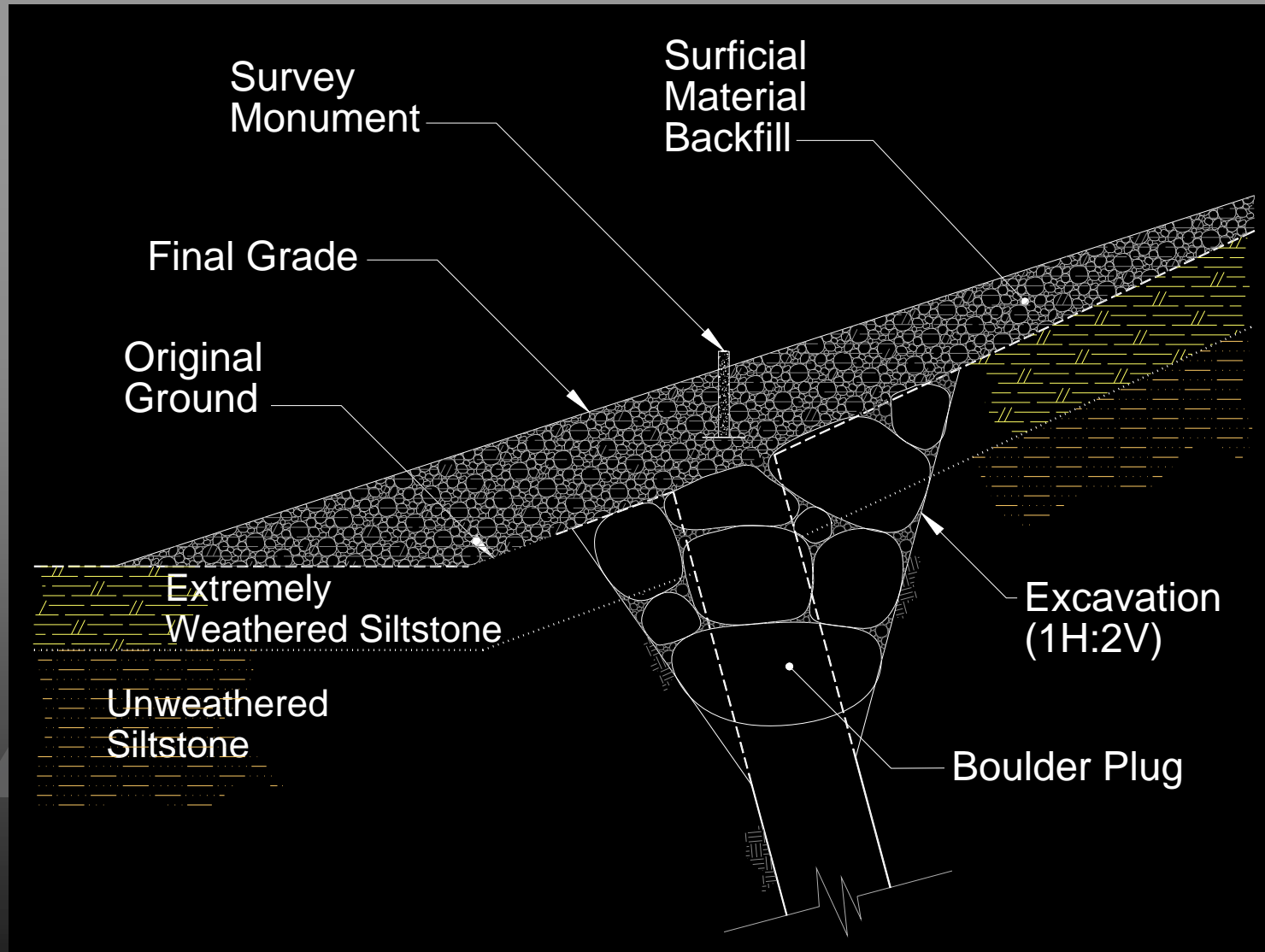


# Final Design

- **SHAFTS and STOPES**
  - **Boulder Plug**
- **ADITS**
  - **Collapse and Regrade with Boulder Plug**
  - **Polyurethane foam**

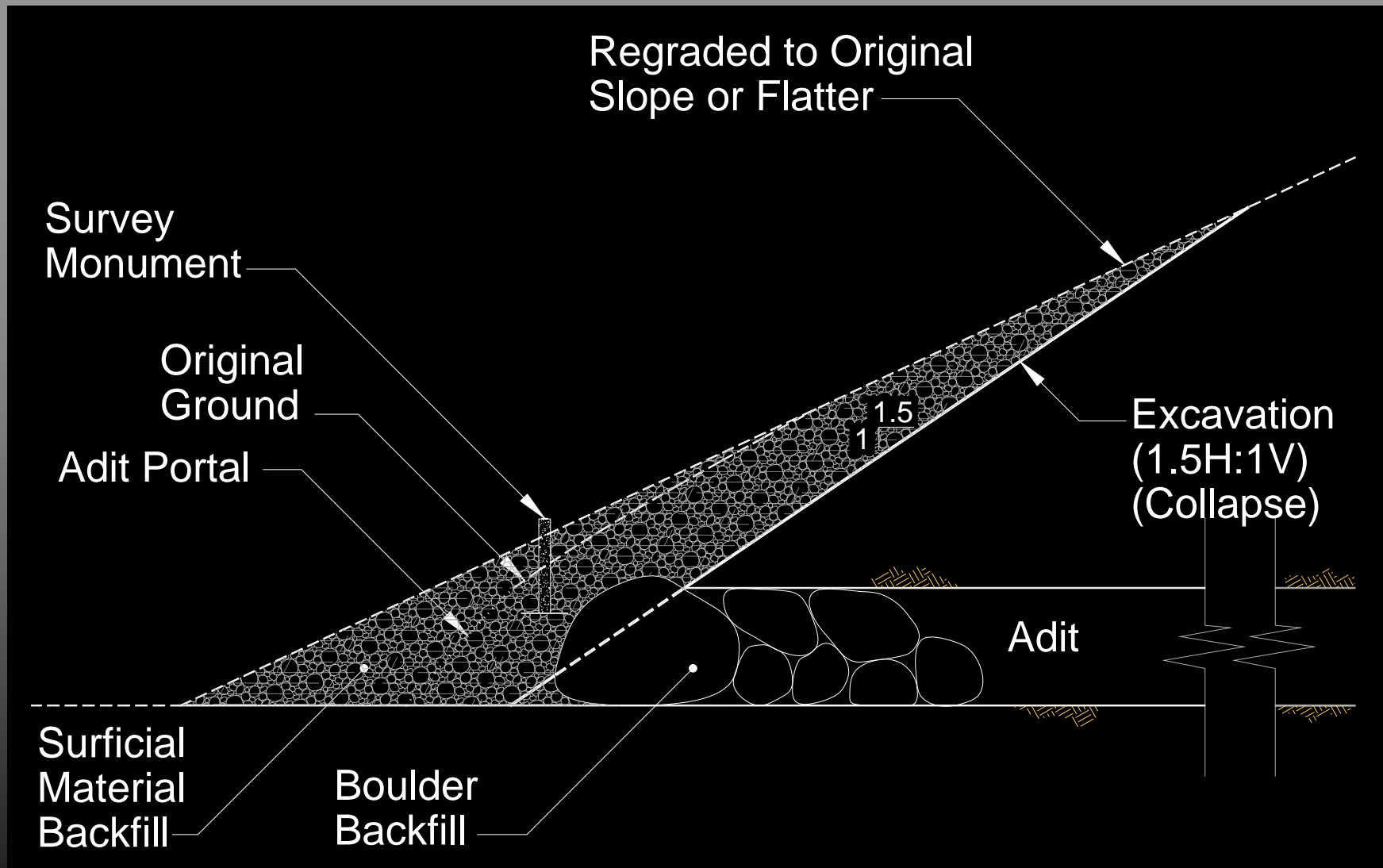


# Components of a Typical Boulder Plug Closure



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# Typical Adit Boulder Plug Closure



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# Excavating a Stope





# Typical Boulder Plug Placement Sequence



**Placing Initial Boulders**

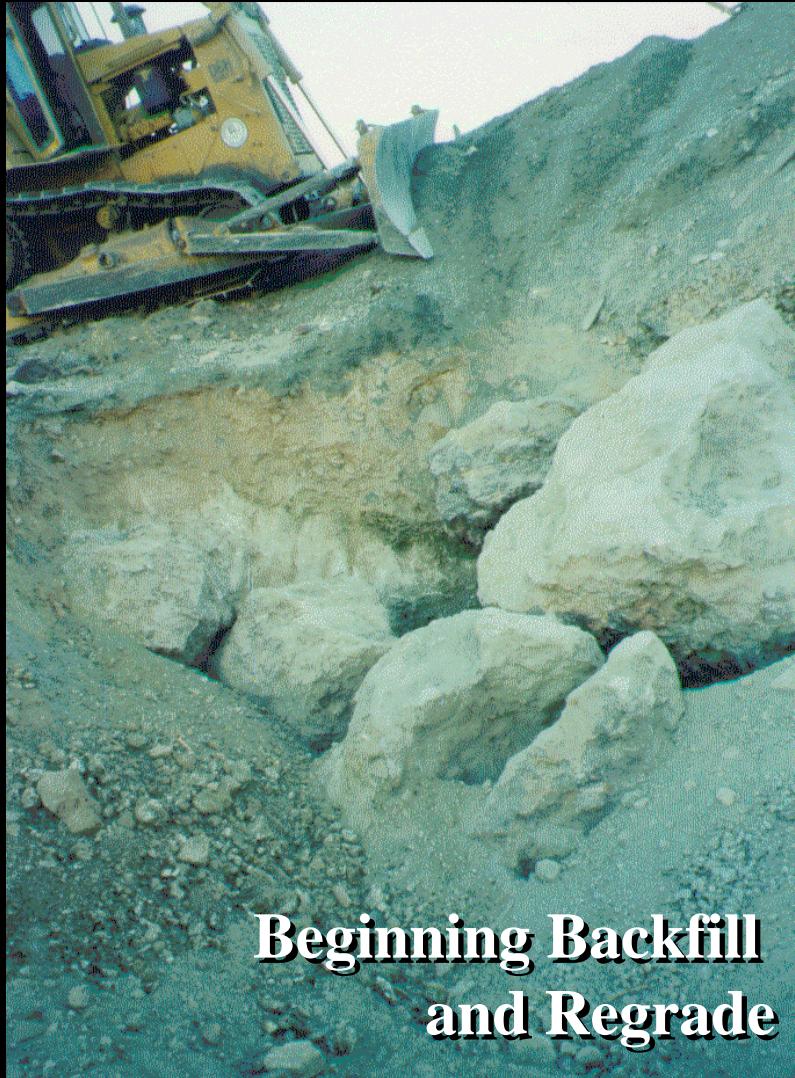


**Completed Boulder Plug**

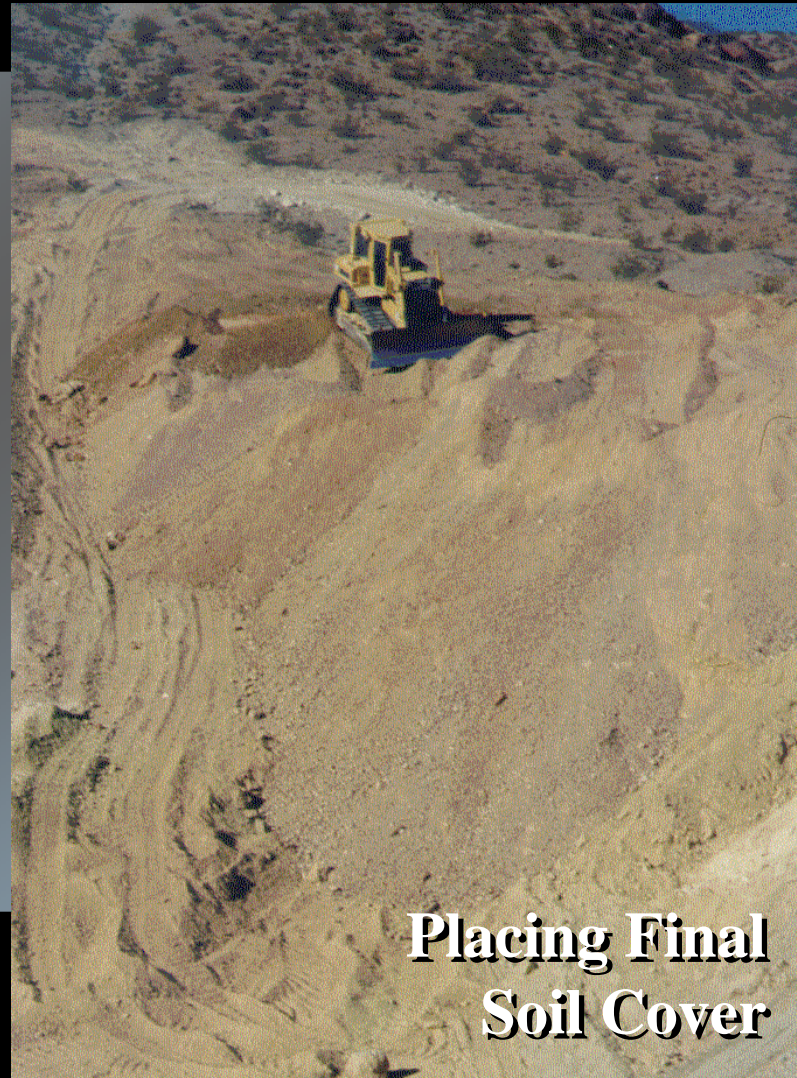




# Typical Boulder Plug Placement Sequence



**Beginning Backfill  
and Regrade**



**Placing Final  
Soil Cover**



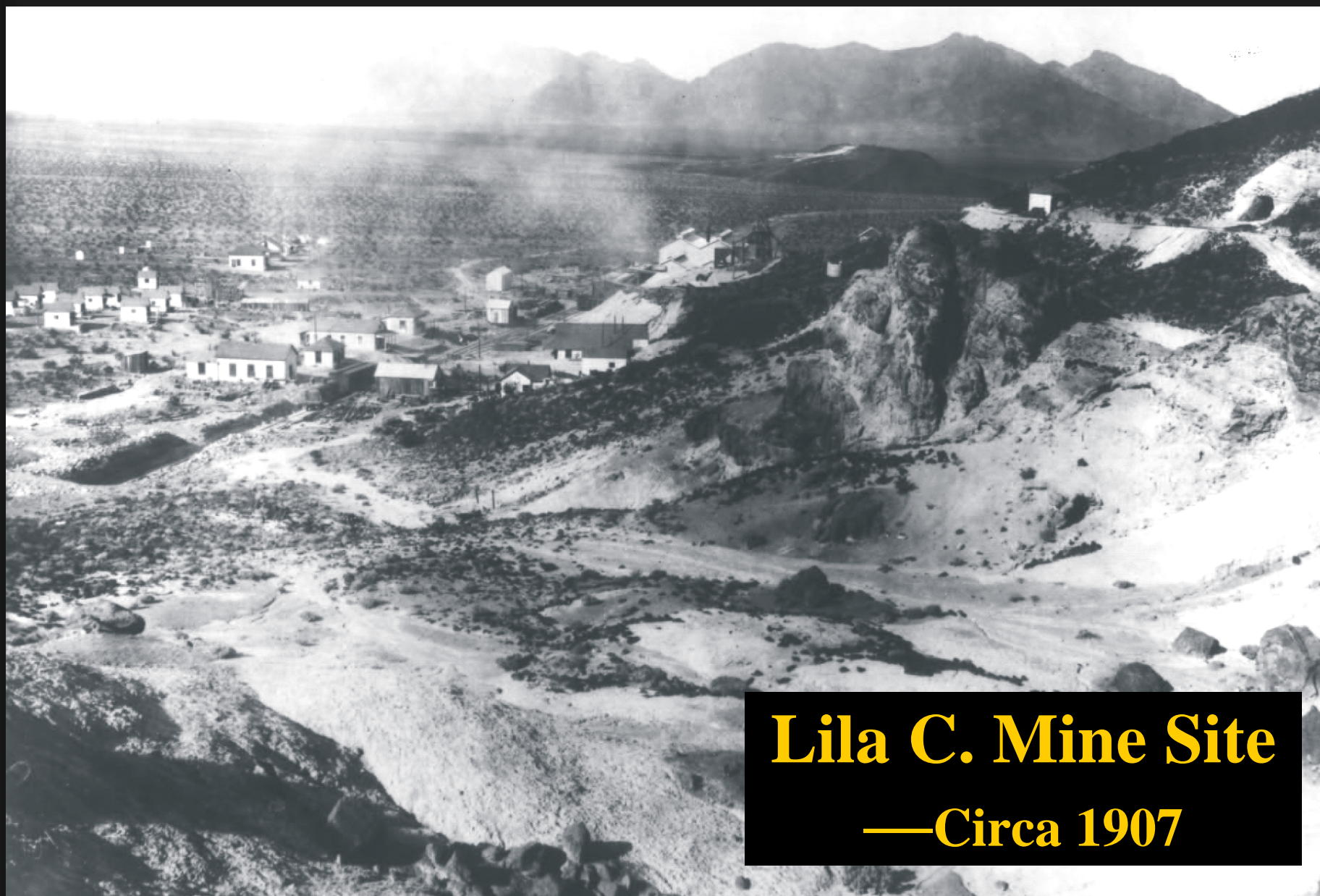
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# Summary of Old Borate Closure

- **120 mine openings closed in 5-week period**
- **Boulder plugs satisfied design criteria**
- **Closure costs were significantly reduced by using native materials**
- **Lower unit costs = more mine openings closed**





**Lila C. Mine Site**  
**—Circa 1907**

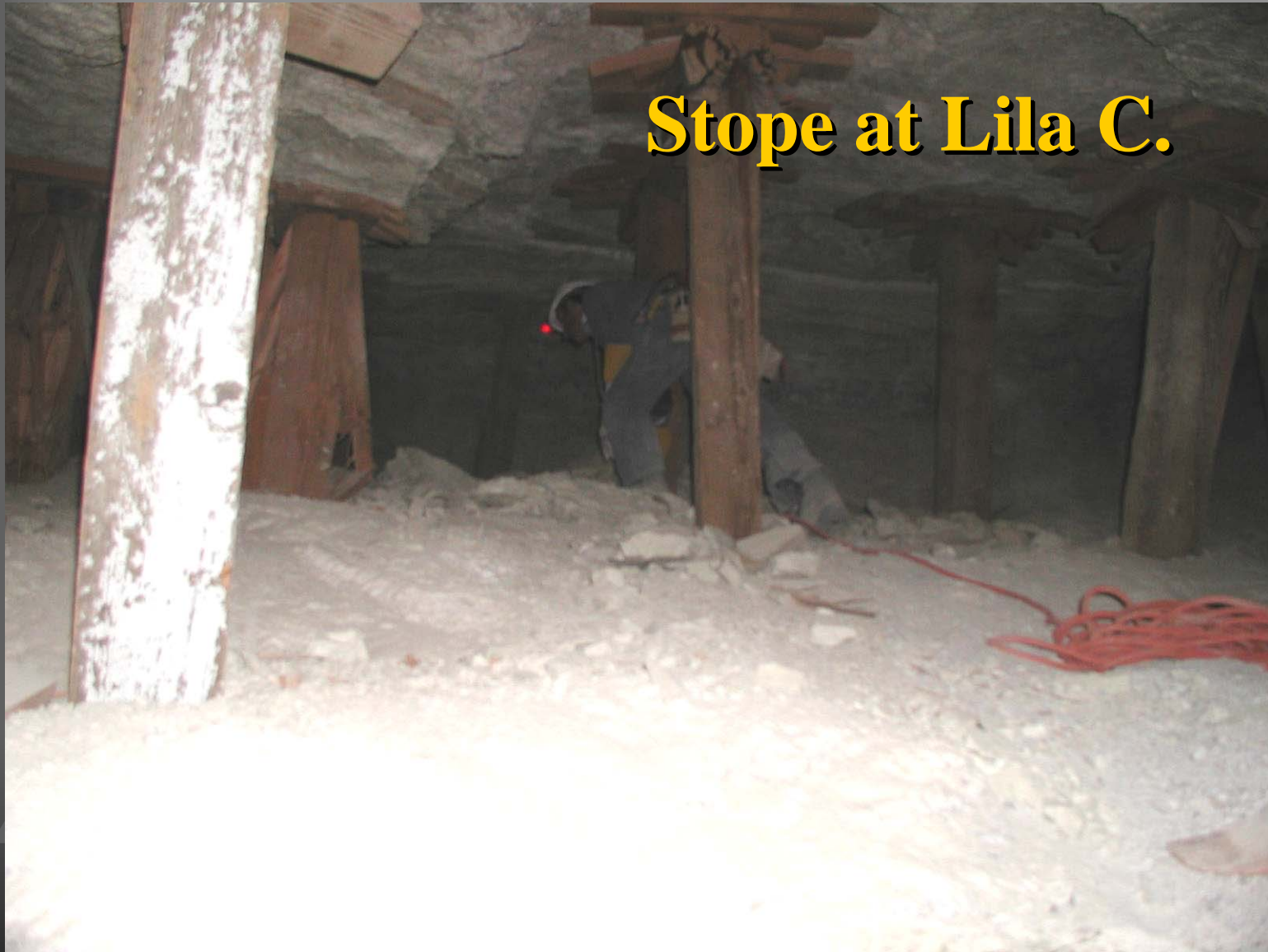
# Main Haulage Level of the Lila C. Mine —Circa 1910



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## Stope at Lila C.



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**Decline shaft at Lila C.**



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# Open Stope at Lila C.



U.S. Borax Lila C. Mine  
July, 2000  
No. 22a-e  
pre-closure

# **Wildlife Protection**

- **Conducted by bat and desert tortoise specialists**
- **No tortoise sign found within mines**
- **Surveys revealed four species of bats in the mines**
- **Two bat “Species of Special Concern” found**
- **Bat accessible designs were included in closure**





# Bat Accessible Closures

- Bat gates and cupolas designed by specialty contractor to protect bat access, preserve ventilation, and maintain temperature
- Underground surveys conducted to optimize bat accessible design





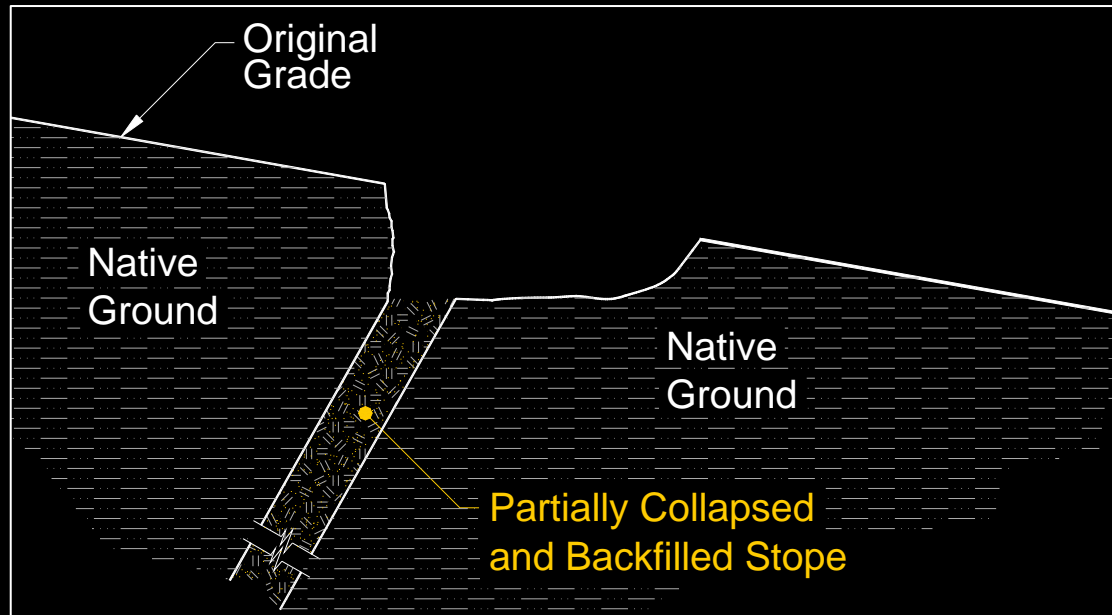
# Closure Design

- **SHAFTS and STOPES**
  - **Rock Mattress – AAI innovation**
- **ADITS**
  - **Collapse and Regrade with Boulder Plug**
  - **Polyurethane foam**

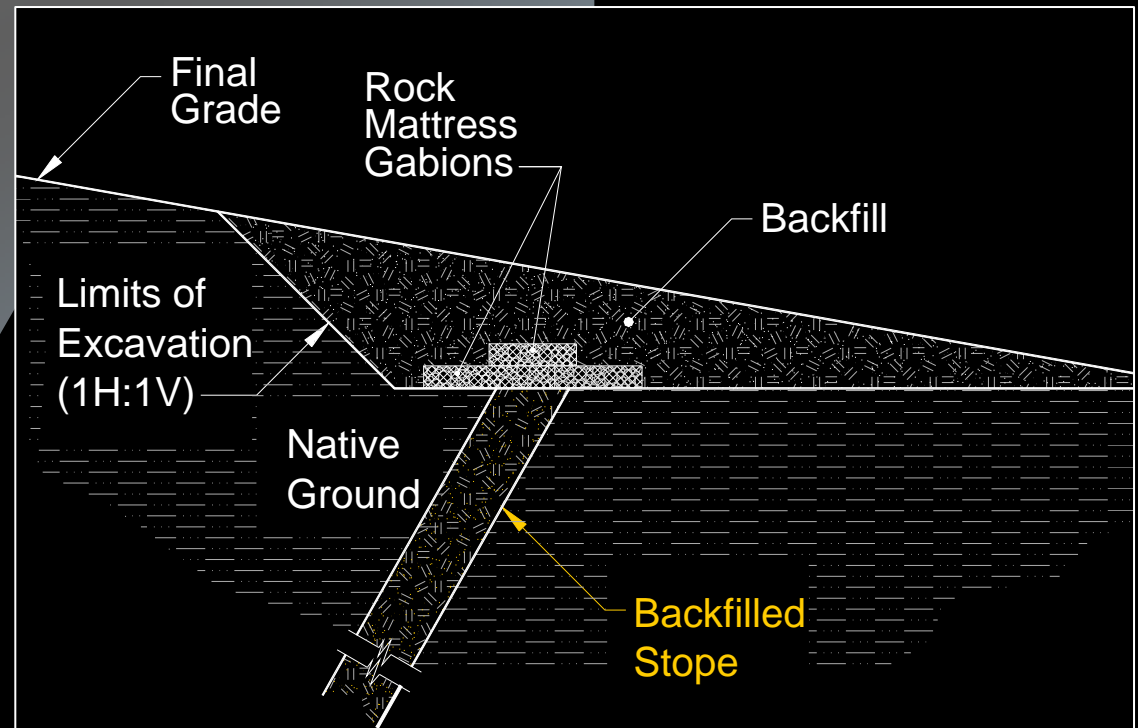


# Lila C. Mine— Typical Profiles

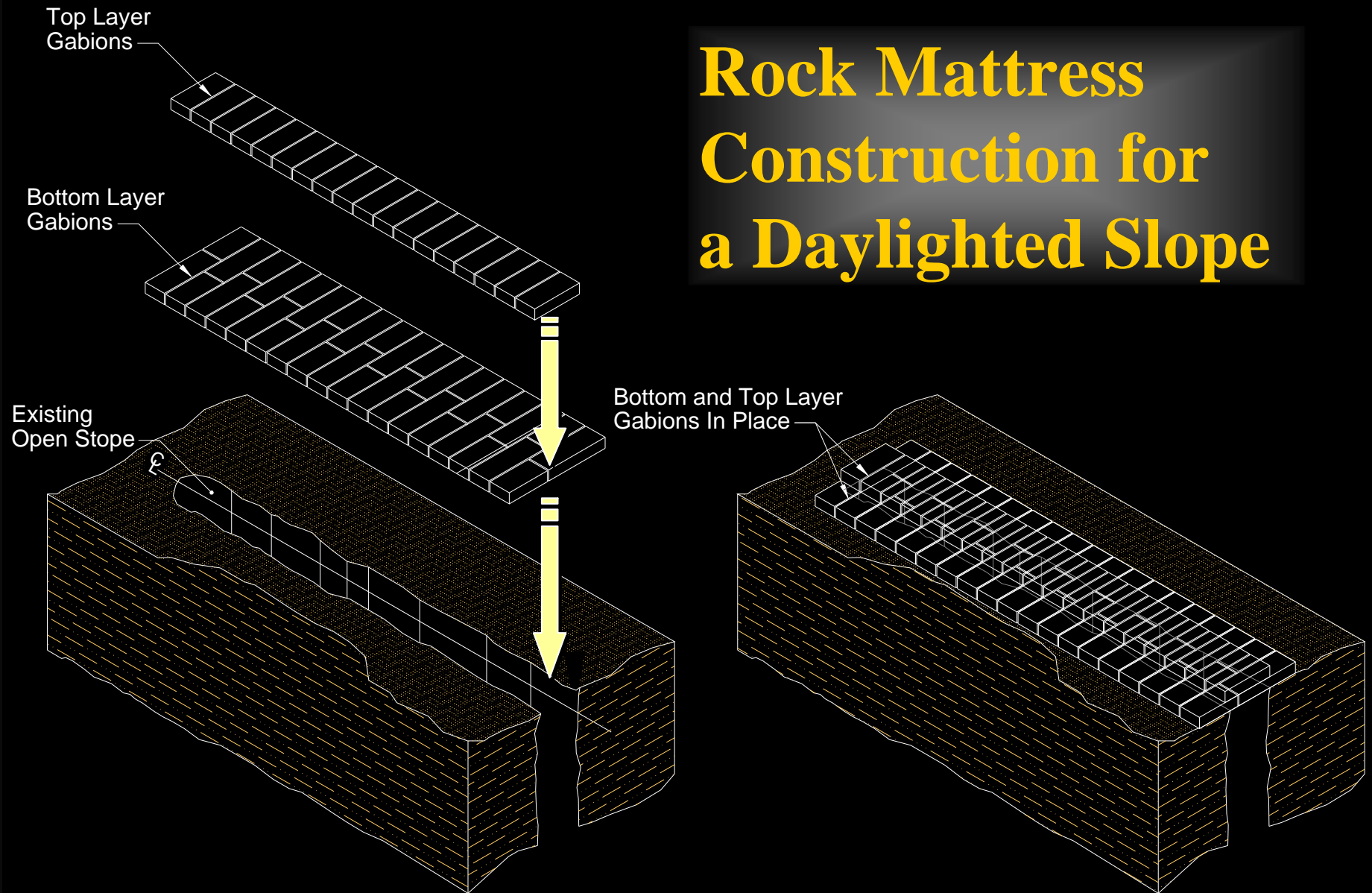
## Pre-closure Daylighted Stope Configuration



## Rock Mattress Excavation and Construction of a Daylighted Stope Closure



# Rock Mattress Construction for a Daylighted Slope



# Attress Construction for a Daylighted Stope



a) Pre-construction



b) Grading Hanging Wall



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# Rock Construction for a Daylighted Stope



c) Wheel Roll Compaction



d) Gabion Construction



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# Rock Construction for a Daylighted Stope



**e) Filling Gabions with Native Rock**



**f) Backfilling Over Gabion Rock Mattress**



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# Rock Construction for a Daylighted Slope



**g) Partially Backfilled  
Rock Mattress**

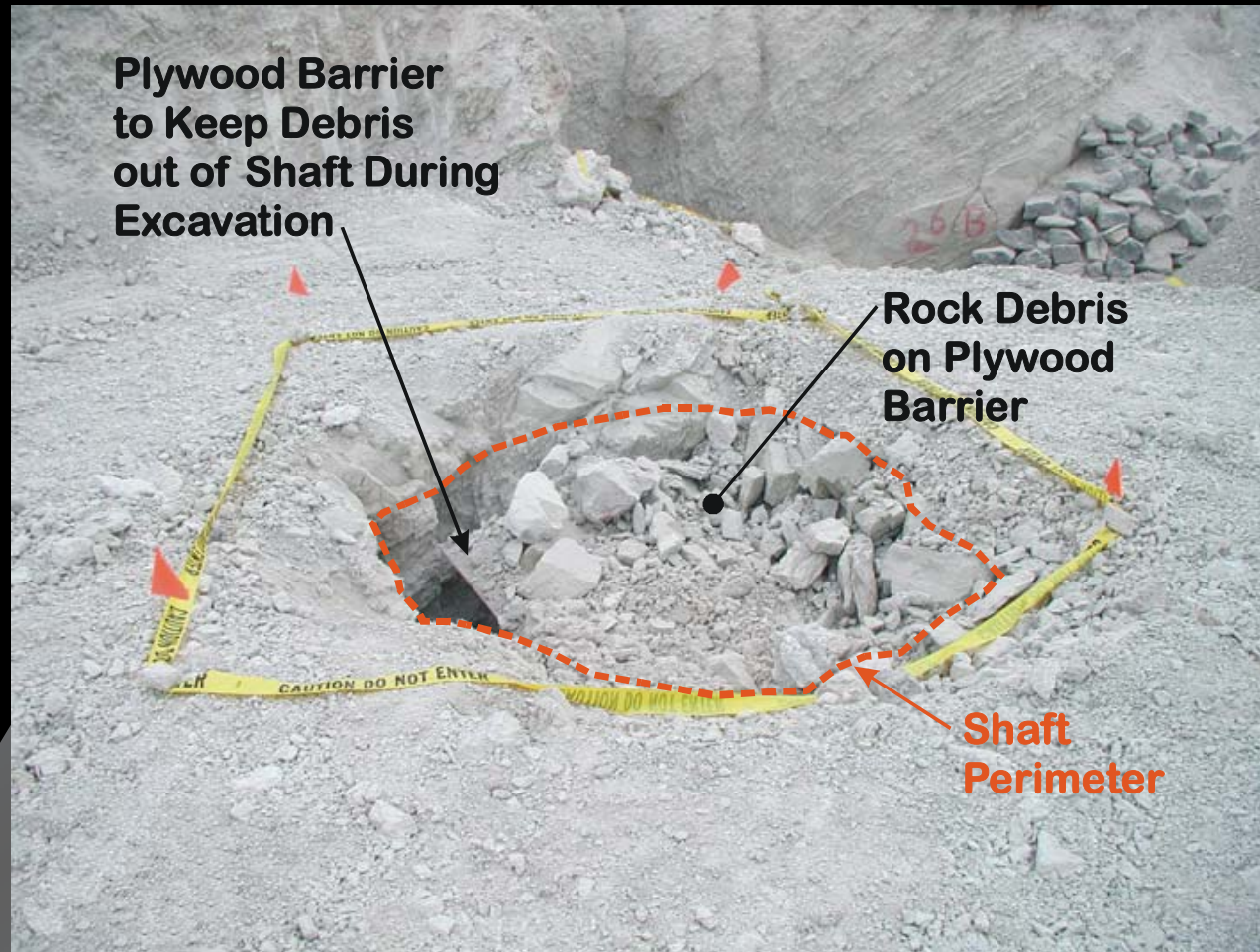
**h) Final Grade and  
Armored Slope**



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# Rock Construction for a Shaft Closure



a) Shaft after Surface Preparation for Rock Mattress

# Rock Construction for a Shaft Closure



**b) First Layer of Gabions of Shaft**



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# Rock Construction for a Shaft Closure



**c) First and Second Layers of Rock-filled Gabions—  
Completed Rock Mattress at Shaft**



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# Rock Construction for a Shaft Closure



d) “Load Test” on a Rock Mattress at Shaft

# Rock Construction for a Shaft Closure



**e) Backfill over Rock Mattress**



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# Typical Foam Seal Construction



**a) Preparing  
Backing Lattice**



**b) Applying  
Foam**

**c) Completed Foam  
Application  
without Backfill**



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# Bat Gate



# Construction and Final Configuration of Bat Cupola

**a) Landing Ring and  
First Course Concrete  
Pipe in Place**



**b) Completed/  
Backfilled  
Shaft Extension  
And Bat Cupola**



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## **Cost Comparison (USD-2000)**



• Gabion Rock Mattress with concrete	\$21,920
• Plastic Grid	\$21,712
• Foam Plug	\$20,890
• Gabion Rock Mattress	\$18,880







**Thank-You**



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