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Managing Water in the West

Risk Analysis for Evaluation of Mine Impounded Water

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Presentation Overview

Overview of Risk Analysis

Consequences of Failure

Potential Failure Modes

Loadings

Common Failure Modes and Uncommon Failure Modes

Lessons Learned

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Mine Impounded Water Includes:

Tailings Dams and Waste Impoundments

Water Storage Dams

Process Ponds

Sediment Control Ponds

Pipelines and Storage Tanks

Pit Lakes

Flooded Underground Workings

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Overview of Risk Analysis

Risk is defined as:

Probability of Failure times the Consequences of Failure

$$R = P_f \times C_f$$

Consequences of Dam Failure

Water Storage Dam Failures:

1963 Vajont Dam, Italy – 2,600 lives lost

1975 Banqiao & Shimantan Dams, China - 171,000
(government decided to build smaller spillways to save money)

1979 Machhu-II Dam, India – 10,000 lives lost

1976 Teton Dam, Idaho, USA – 11 lives lost

Consequences of Mine Impounded Water Failure

1965 El Cobre Tailings Dams, Chile – 200 lives lost
1966 Mir Tailings Dam, Bulgaria – 488 lives lost
1970 Mufulira Tailings, Zambia – 89 lives lost
1972 Buffalo Creek, WV, USA – 125 lives lost
1985 Stava Tailings Dam, Italy – 268 lives lost
1994 Merriespruit Tail. Dam, S. Africa – 17 lives lost
2015 Smarco Tailings Dam, Brazil – 19 lives lost
Pit Lakes – 0 fatalities

Underground Mines – 1 known fatality

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Consequences of Failure

Different Failure Modes can have different consequences depending on:

Location of failure, speed of failure, volume released, velocity of flood wave, downstream population at risk, warning time, and evacuation

Damage proportional to depth and velocity of flood wave, life loss reduced by efficient evacuation

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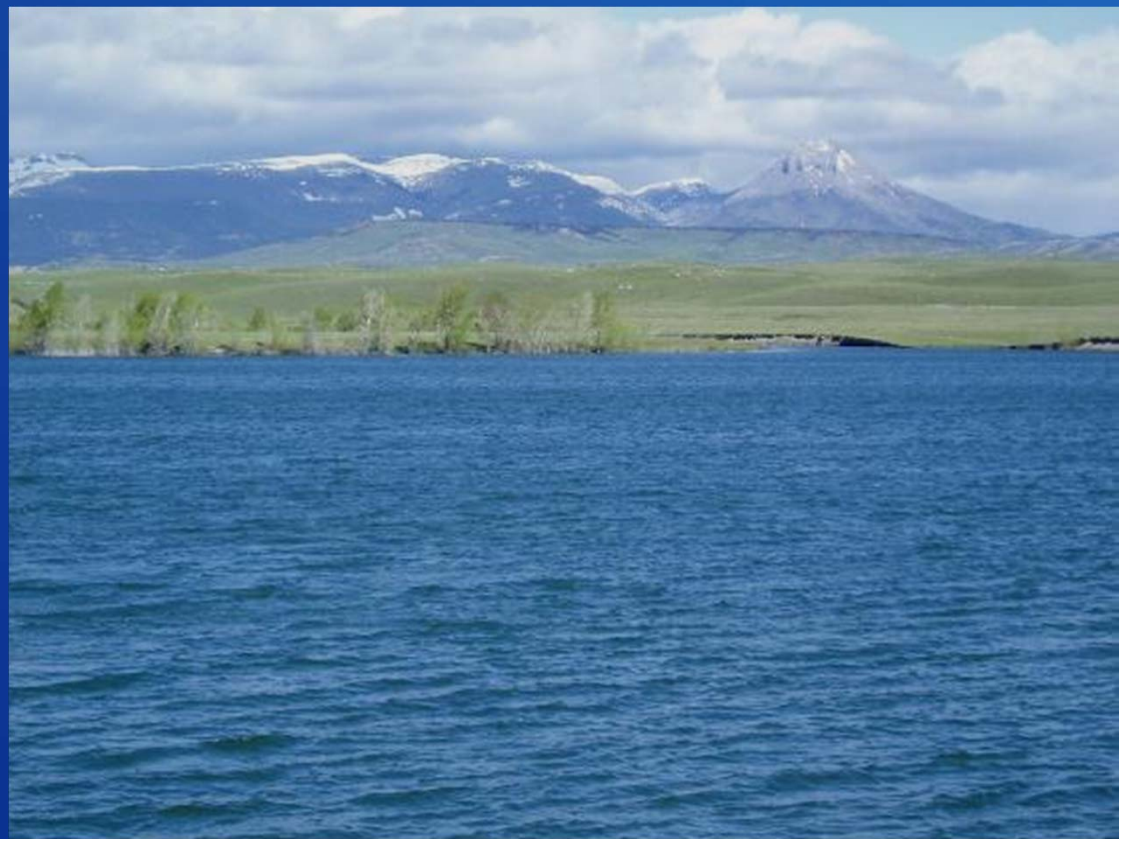
Potential Failure Modes

Are Related to Loadings:

- Seepage Erosion
- Earthquakes
- Floods
- Operation Error
- Others



Loadings

Wind – Wave erosion / overtopping

Reservoir Landslides / Dam Slope Failures

Foundation Failure / Settlement

Avalanche, Fire, Desiccation Cracking

Accidents, Sabotage, Vandalism

Design Errors, Construction Errors

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How to Evaluate a Site?

Inventory the site and review records

Brainstorm potential failure modes
(write detailed descriptions of the process with sketches)

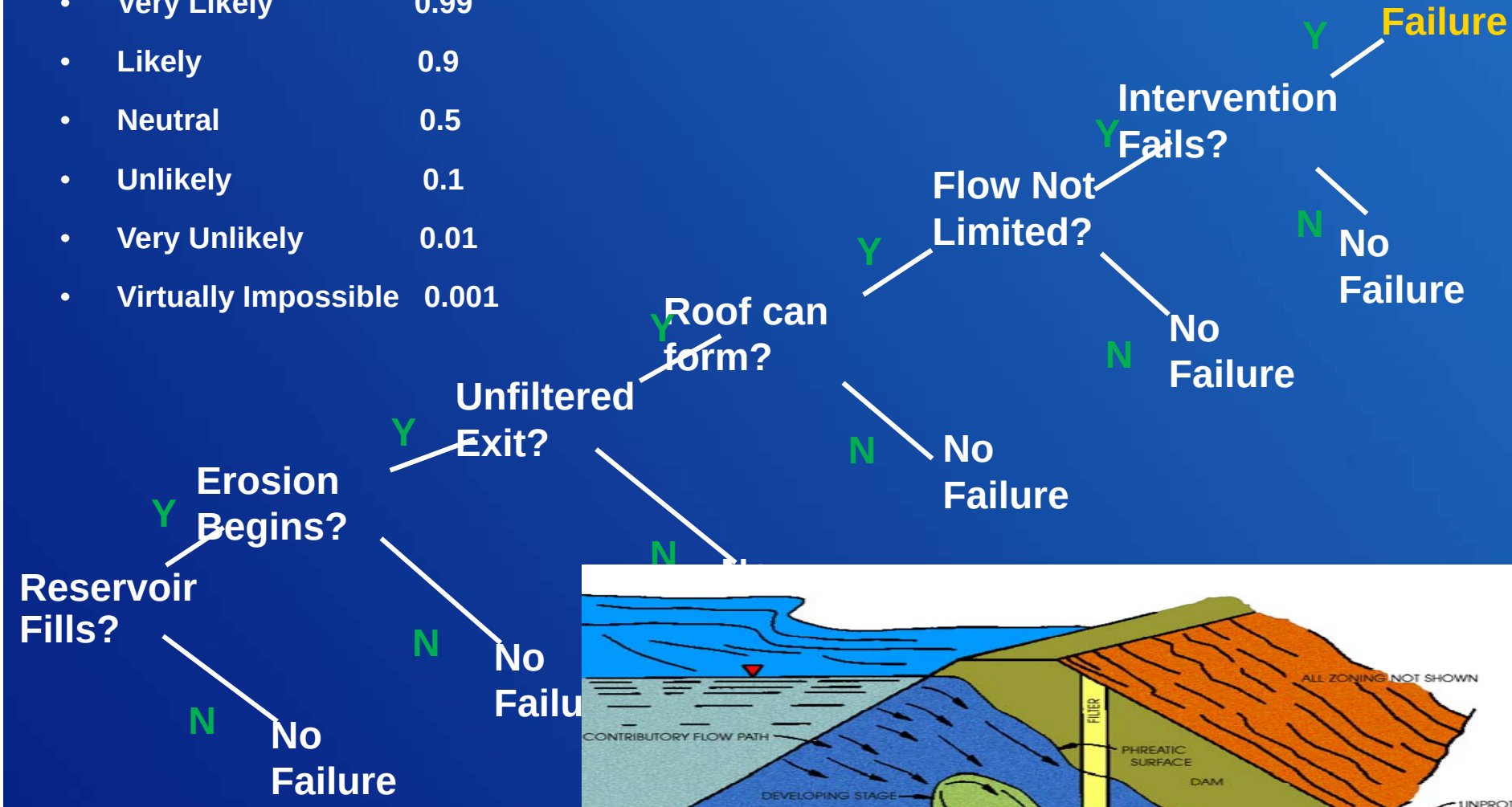
Evaluate the potential for failure and consequences

Get independent peer review

Make decisions based on risk

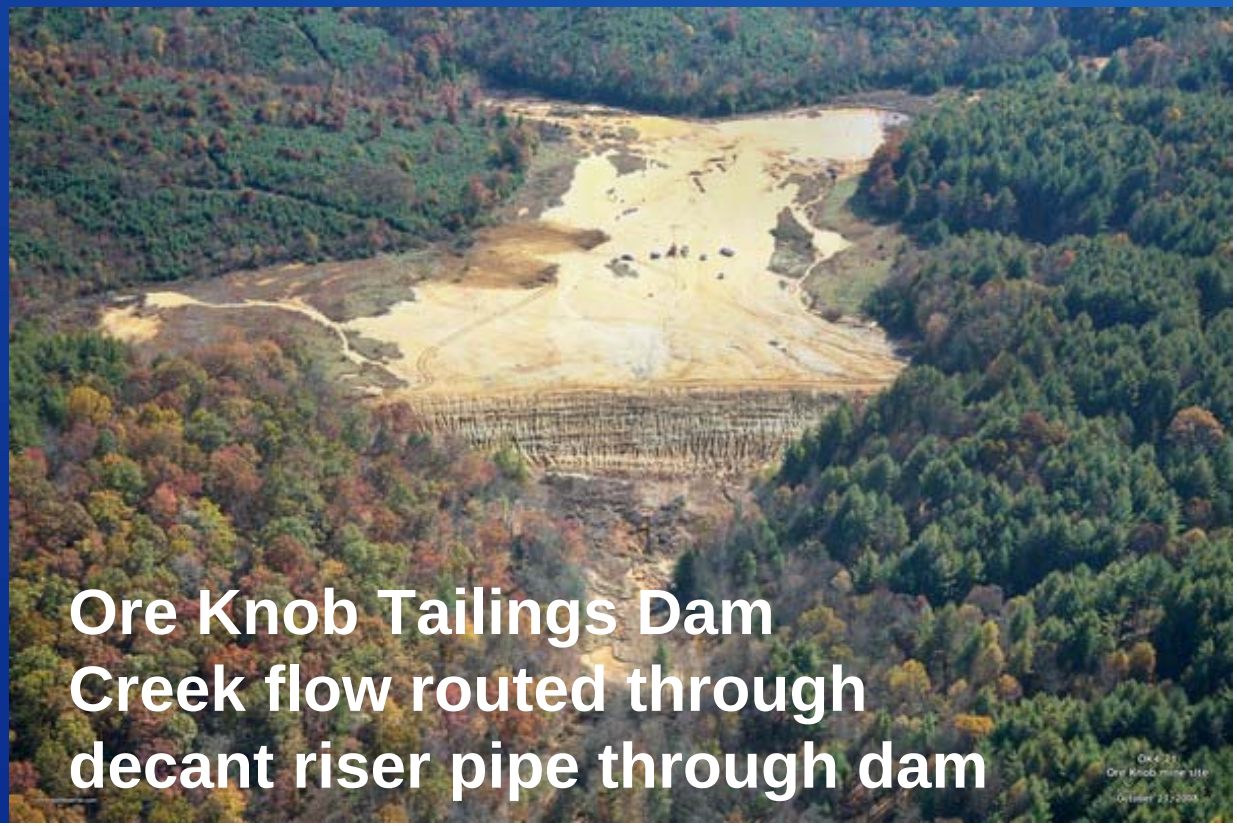
Event Tree for Internal Erosion

- Virtually Certain 0.999
- Very Likely 0.99
- Likely 0.9
- Neutral 0.5
- Unlikely 0.1
- Very Unlikely 0.01
- Virtually Impossible 0.001



Common Tailings Dam Failure Modes

- Foundation / Slope Instability
- Seepage Induced Internal Erosion
- Overfilling and Other Operational Errors
- Embankment Erosion by Ruptured Pipeline Flows
- Flood Overtopping
- Seismic Instability



Ore Knob Tailings Dam
Creek flow routed through
decant riser pipe through dam

Learn From Past Failure Case Histories

Reservoir Landslide: Ignored warnings that reservoir could saturate steep mountainside and lead to slope instability

Vajont Dam, Italy

268 lives lost

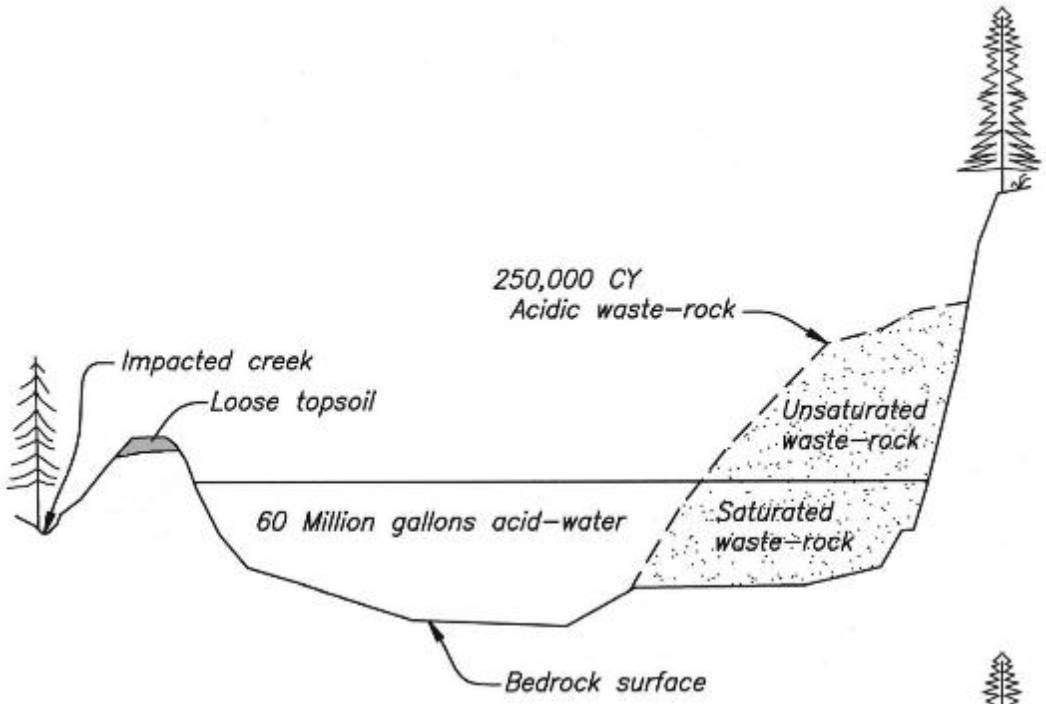
Uncommon Tailings Dam Failure Modes

Avalanche

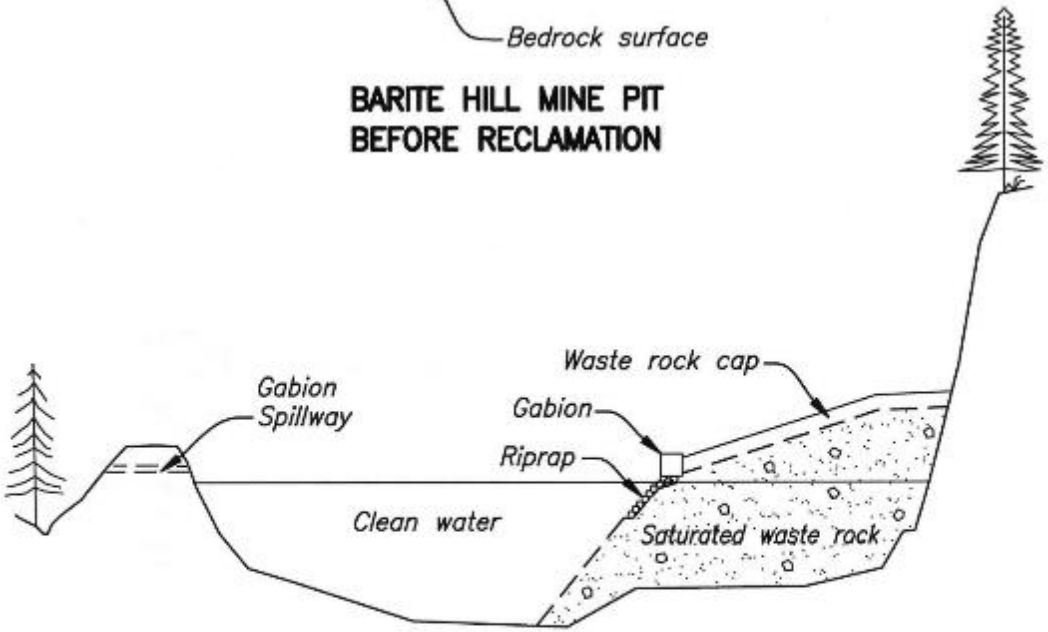
Incorrect Stability Analysis

Pit Lakes can Fail

Barite Hill Pit



BARITE HILL MINE PIT
BEFORE RECLAMATION



BARITE HILL MINE PIT
AFTER RECLAMATION

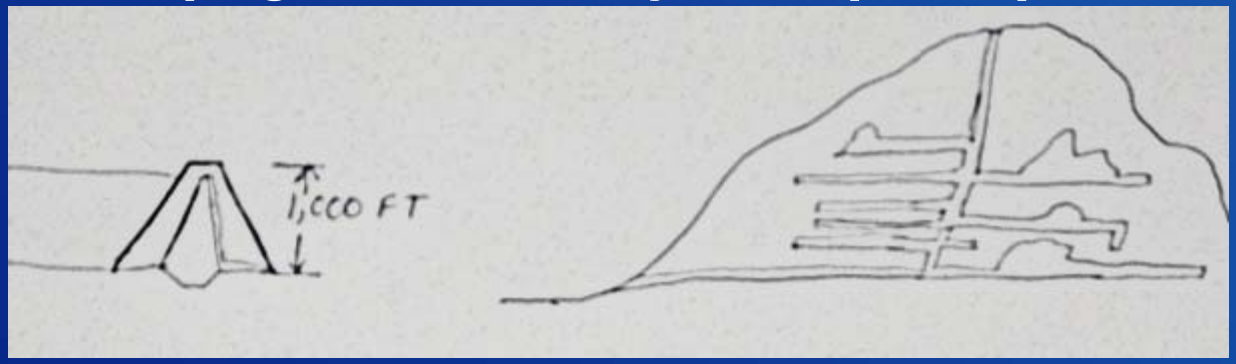
Flooded Underground Mines

Can act like a dam, concerns:

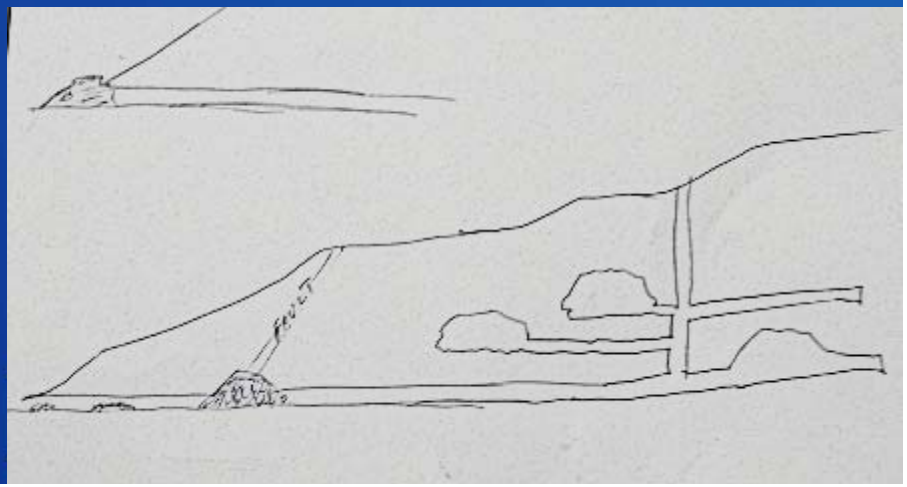
Large volume of workings at higher elevation than portal

Draining adits with declining seepage

Seepage blocked by collapsed portal



Old underground mines are decaying infrastructure that in many cases are not being maintained.



Flooded Underground Mines

A small collapse can impound a large amount of water
Evaluation requires understanding the mine pool
Do not drill near the blockage, it could trigger a failure

Foundation Preparation & Inspection

Foundations Filters and Drains

Monitoring - Evaluate and Act on Unusual Performance

Obvious Evidence

Subtle Evidence

Design Failures – Reliance on Assumptions for Critical Data

Kingston Flyash Impoundment

Lessons Learned

Failures occur in response to Loadings (seepage is always at work)

Consider current and future conditions (big floods will occur in the desert)

Useful insight comes from the study of failure histories

Critical thinking is essential, every site is unique

Extra efforts are justified where the potential consequences of failure are high

Conclusions

The most experienced people are needed for critical aspects of site investigation, design and construction

Use independent external review boards to evaluate and concur on project details

A senior designer should participate in site investigation, construction startup, perform key foundation inspections, and observe initial filter and drain construction

Do not assume critical aspects of design, get the facts from site investigation and construction testing

Regular inspection and monitoring are essential requirements for safe operations

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Questions ?