

Fontenelle Dam, Ririe Dam, and Teton Dam

An Examination of Organizational Culture on
Decision-Making

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What We're Going to Talk About

- Fontenelle Dam Incident
- Teton Dam Design and Construction
- Ririe Dam Design and Construction*
- Teton Dam Performance
- Ririe Dam Performance*
- Pull it all together



Big Dams Don't Fail

Typical thought circa 1970's



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Teton Dam

Ririe Dam

Fontenelle Dam

Yellowstone NP

Boise

Ogden

Salt Lake City

Provo

Fort Collins

Rocky Mountain NP

Fontenelle Dam, WY



Fontenelle Geology

- Bedding plane joints
- Near vertical joints
- Near vertical relief joints
- Deep open joints perpendicular to dam axis
- Not well suited to place embankment material on



Fontenelle Construction – 1961



Fontenelle Foundation



Fontenelle Incident 1 – May 1965



Figure 75: P154-428-1458 Seepage emerging from shale formation along east side of spillway chute. 5/21/65

Fontenelle Incident 2 – July 1965



Photo FO-65-9 -- Fontenelle Dam. Seedskaadee Project, Wyoming, USBR July 28, 1965 -- Slide in the gravel backfill adjacent to the left spillway chute retaining wall. Seepage exits are in the center of the photograph.

Fontenelle Incident 3 – September 1965



How do you treat geologists?



Fontenelle Incident

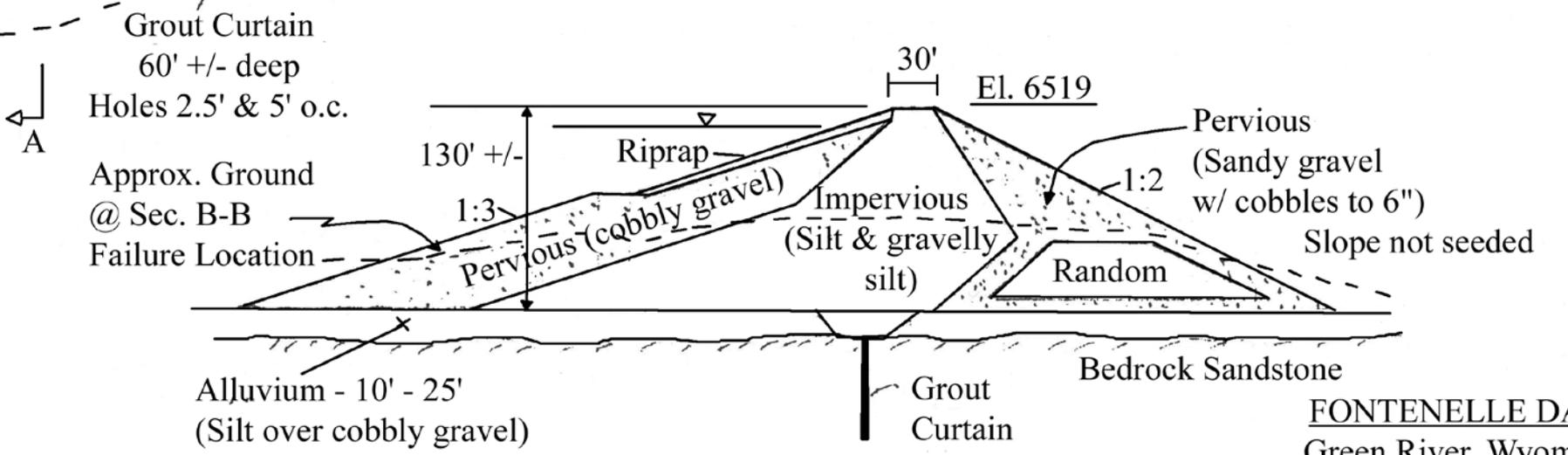
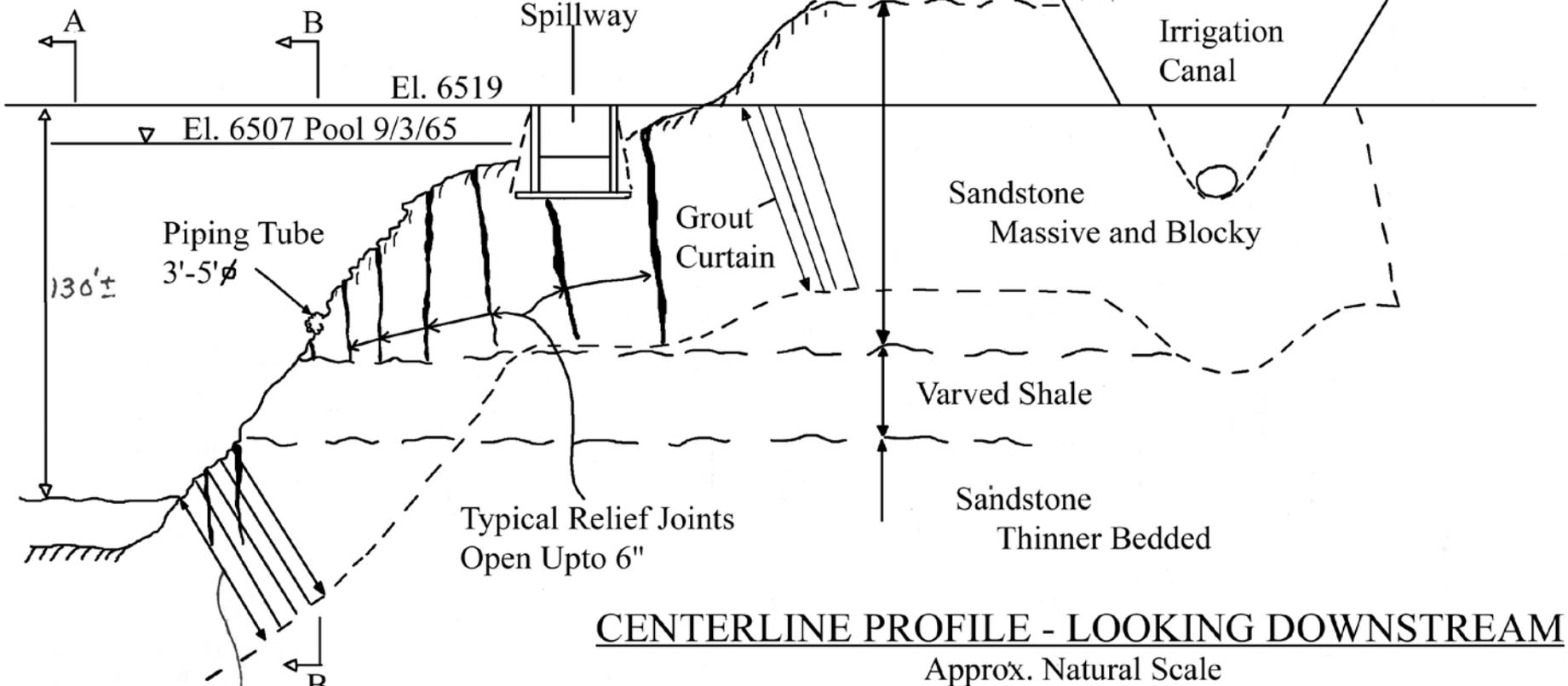


Fontenelle Incident



Fontenelle Incident





FONTENELLE DAM
Green River, Wyoming

11-19-65

Reclamation Response to Incident

- Reclamation designers and managers had heard of the Fontenelle incident
- Details of the incident were not distributed throughout the organization
- Consideration was not given to designers about protecting the core from foundation erosion



Reclamation Response to Incident

“Although failure and its accompanying damage were avoided, this situation is considered sufficiently serious to warrant a thorough appraisal to the end that repetitions need not occur. We believe that this event should be considered along with the circumstances related to the occurrences at Malpasset, Vaiont, and Baldwin Hill in our efforts to improve the design and construction practices for dams.”

ICOLD, 1967

Bernie Bellport

Chief Engineer, Reclamation



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Corps Site Visit

- 11/29/65 Report on Inspection of Seepage Performance - Fontenelle Dam by Kenneth S. Lane, Chief of Engineering, Missouri River Division, Corps of Engineers
- Sent to Reclamation Chief Engineer



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Lane's Observations

- Essentially this is a case of **pipng through the earth embankment at its contact with the rock abutment**. It is felt seepage entered through the open relief joints in the rock and doubtless eroded soil into these open joints. Most probably the seepage jumped the grout curtain (and its 3 to 4 ft. wide concrete grout slab) by passing through looser pockets in the embankment. As the piping tube enlarged, this would attract additional seepage, accelerating erosion to cause the very severe situation shown by the enclosed ENR photo.
- Both Mr. Walker and the writer had some suspicions on the possibility of cracking in the embankment as a result of **differential settlement at this steep rock abutment** – somewhat from Corps experience at Wister and East Branch dams where cracking occurred from differential settlement and was enlarged by piping. However, it was understood that men crawled into the piping tube at Fontenelle and found no evidence of cracking in the embankment. Furthermore, the gravel to silt mixture would be less prone to cracking due to its well graded nature. In the last analysis, whether or not embankment cracking also occurred is a rather academic questions, since at best it was probably not more than an additional contributing factor to the main cause of piping at the earth-rock contact as discussed above.



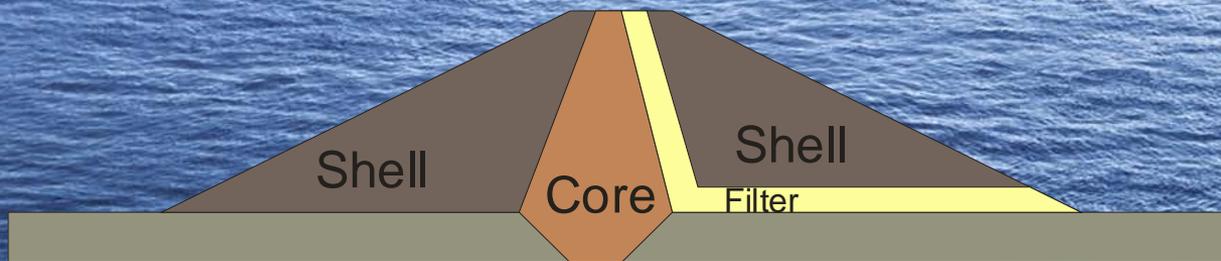
Lane's Lessons Learned

- This emphasizes the policy that **designers inspecting** earthwork and foundation conditions at key times during construction is a must.
- **Fractured abutment rock** deserves very **conservative treatment**, including consolidation grouting for near full width of the core plus a conservative grout curtain (deeper than 60-foot curtain installed initially at Fontenelle).
- An irregular rock surface should be smoothed out and all overhangs removed in order to facilitate compaction of the embankment at the rock contact.
- Locating a concrete spillway close to an abutment edge is not desirable. At Fontenelle it prevented smoothing the rock surface by pre-splitting.

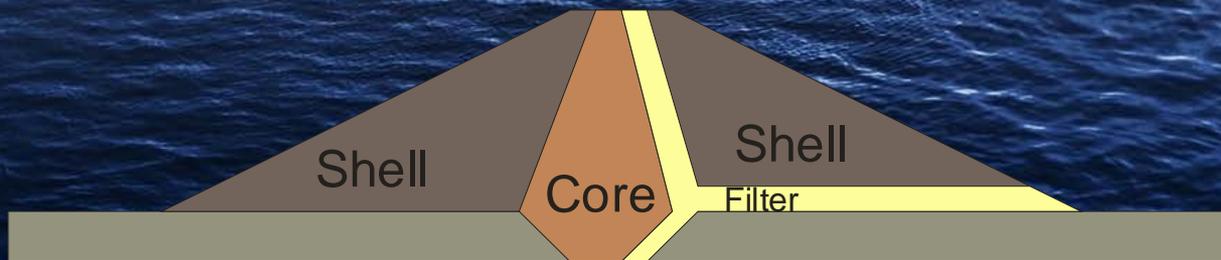


Corps Response to Incident

Before Fontenelle



After Fontenelle



Internal and External Review

- Reclamation
 - Designed and reviewed internal to each design team
 - Reviewed by Section Head
 - No cross-pollination
 - No external review
- Corps
 - Designed at district level
 - Reviewed by division
 - Reviewed by headquarters
 - Engaged consultant reviews when necessary



Reclamation Design Atmosphere

- Training of designers was limited
- Very little on-site time by designers
- Poor interactions of designers with geology
- **Very limited interaction with field personnel**
- **It was the era of Standard Designs**
- Construction offices had a poor interaction with designers
- Field offices had a real resentment of the Denver Office (Some Basis for This)
- Designers went to dam sites and said nothing about a job



Reclamation Design Atmosphere

- Communications Were Very Slow
- Telephones and Faxes were the fastest communication
- Denver would write a letter for most problems – leaving the construction office to resolve most issues
- It is hard to describe problems on the phone
- Inclination must have been not to call Denver Office
- Bulk of designers came out of the depression era
- They lived through WWII
- **They tried to cut every corner on cost in their dam designs**



A view looking upstream at the Fremont Dam Site



Teton Dam Geology

- Right and left abutments consisted of a Rhyolite welded ash flow Tuff
- It was covered by slopewash and alluvial deposits in the stream valley
- It has prominent jointing intersecting at high and low angles
- **Many joints were open**, some were filled with various materials
- A basalt flow was in the lower left abutment
- **Highly fractured and permeable, with some very large fissures**





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Teton Dam Design and Construction Strategy

- Designs were completed in the late 60's
- Left abutment test grouting program completed in 1969
- Major grout losses lead to a decision to use a 70-foot deep key trench as a more cost effective measure to reduce seepage
- This is a first in USBR design history
- Standard homogeneous-zoned-embankment design
- Contract was in one phase, not many opportunities for changes during construction
- Depended on grout curtain to force seepage away from embankment



Teton Dam Foundation Preparation

- No dental concrete
- Minimal foundation shaping
- Slush grout added*
- Slush grout discontinued around El. 5100/5200
- No blanket (consolidation) grouting
- Special compaction at foundation contact
- No treatment of foundation downstream of the bottom of the cutoff trench



Teton Dam Right Abutment Section

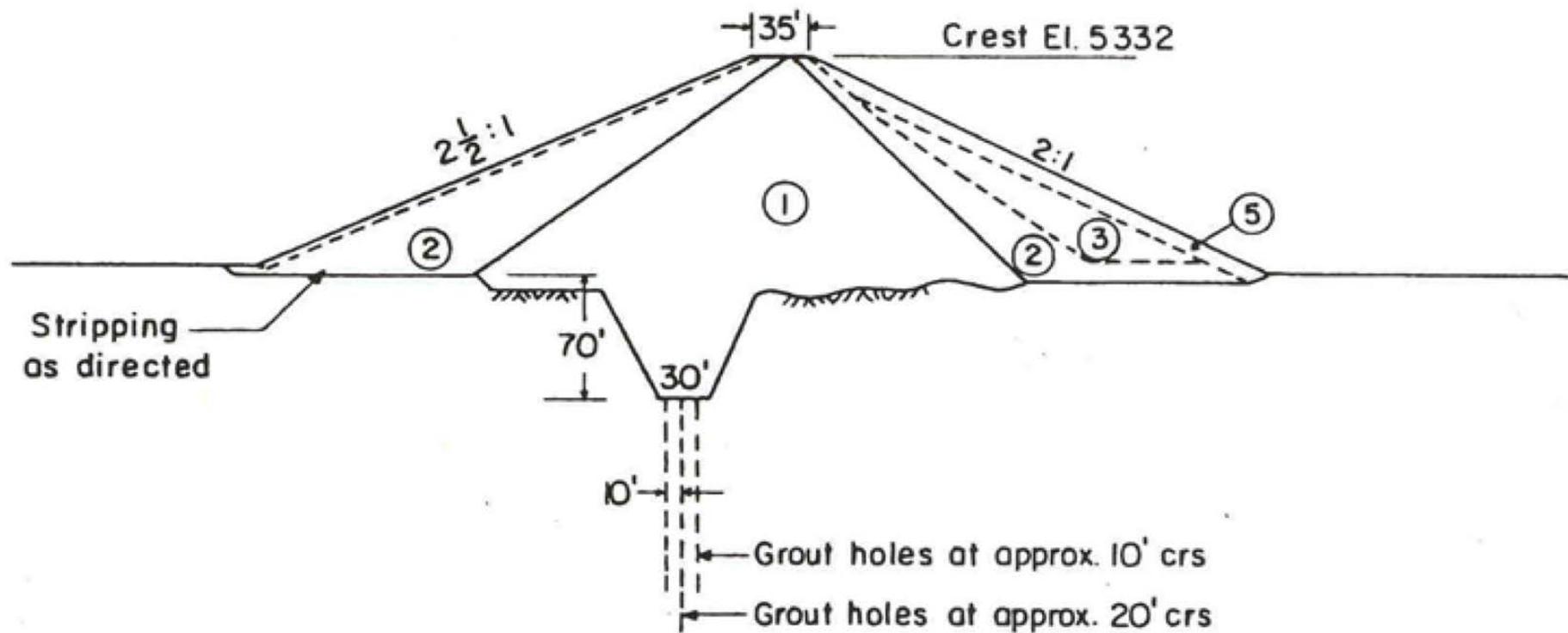


Fig.3. Typical cross-section over abutment sections founded on jointed rhyolite.

Ririe Dam Design and Construction Strategy

- Designs were completed in the late 60's
- Construction was split into two phases:
 - First phase consisted of excavation of the abutment, foundation outlet works and outlet works tower foundation
 - Second phase finished the project
- **During excavation, concerns were raised**
- Designs were modified based on conditions:
 - Added a wide filter and drain downstream
 - Expanded foundation treatment
 - Extended filter zones to cover portions of the foundation
 - Delayed construction by 1 year, cost \$4M

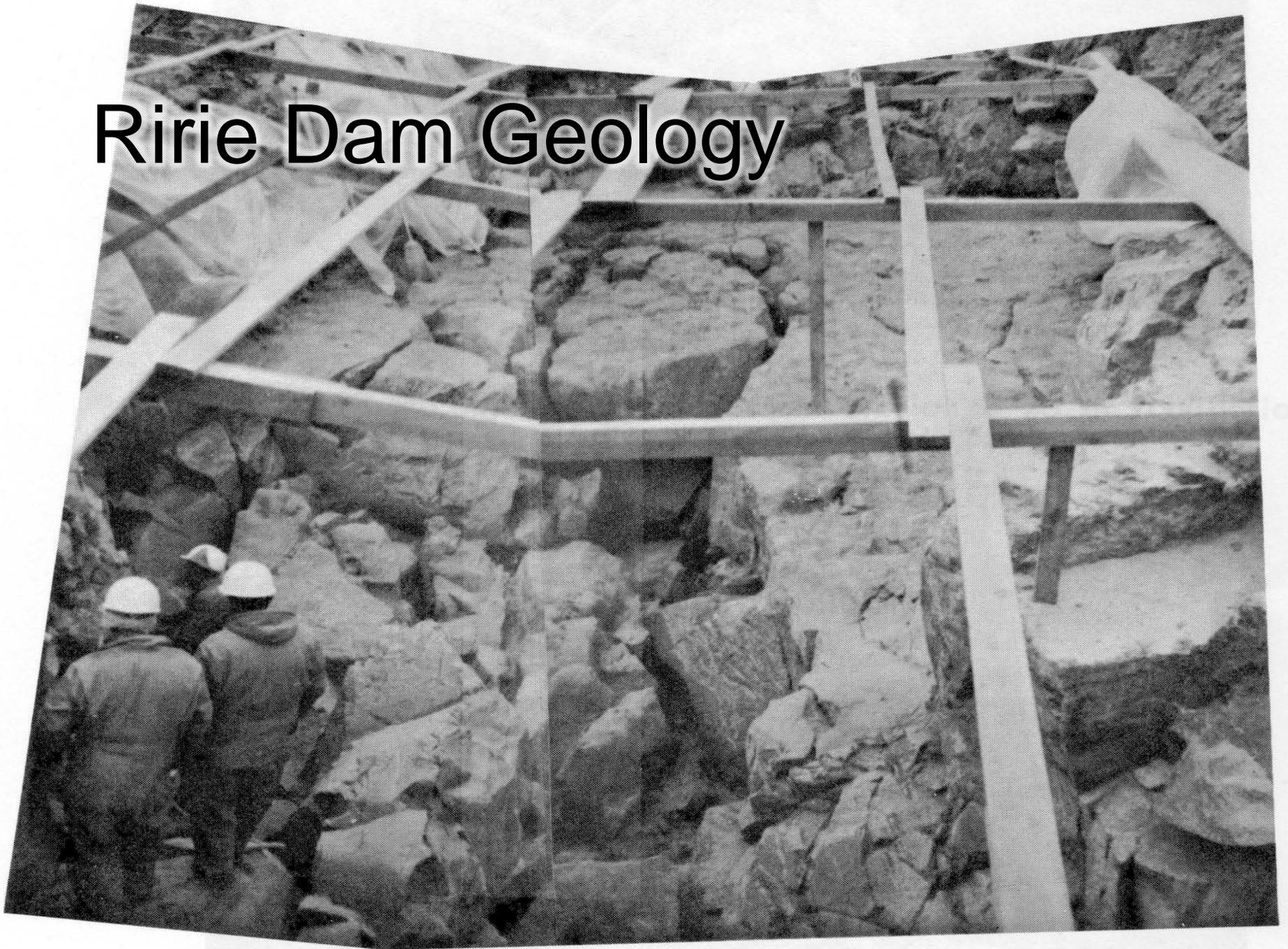


Ririe Dam Design Considerations

- State-of-the-art Foundation Treatment
- Embankment contained multiple lines of defense
- **Extensive foundation treatment**
- Wide filters upstream and downstream
- Chimney drain, rock drains collect seepage and control pressures
- Minimal seepage observed
- Cutoff to rock wide
- Rock fill zones, shallow slopes (large flow-through capacity)



Ririe Dam Geology



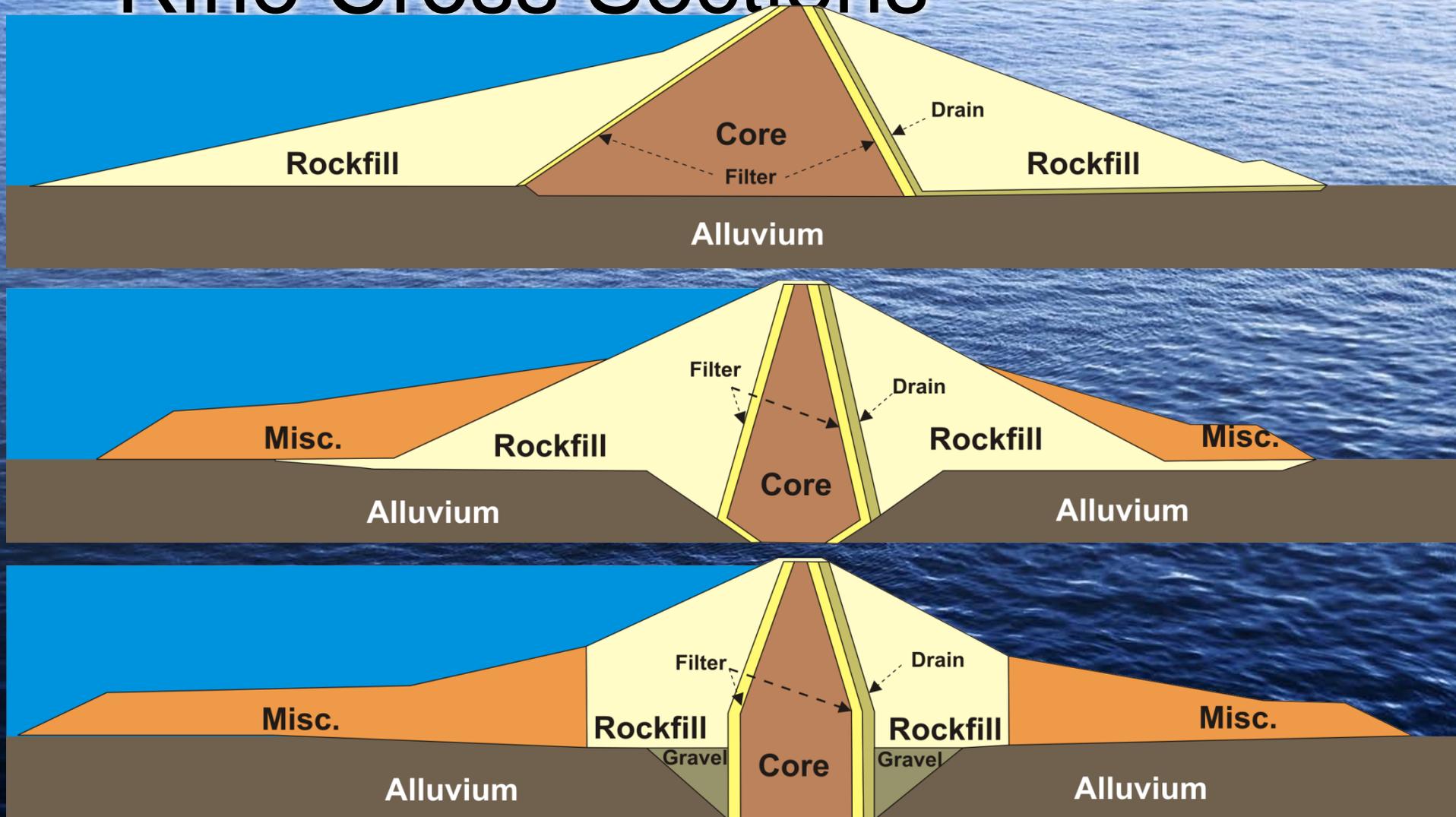
Ririe Abutment



Ririe Geology



Ririe Cross Sections



Similarities

Teton

- Completed 1976
- 280 feet tall
- 3,200 foot crest length
- 288,250 acre-foot reservoir
- Non-Plastic Core
- Highly Fractured Volcanic Foundation
- Actual Consequences – 11

Ririe

- Completed 1976
- 253 feet tall
- 1,070 foot crest length
- 90,500 acre-foot reservoir
- Non-Plastic Core
- Fractured Volcanic Foundation
- Estimated Consequences – 10 to 20



Fall 1973





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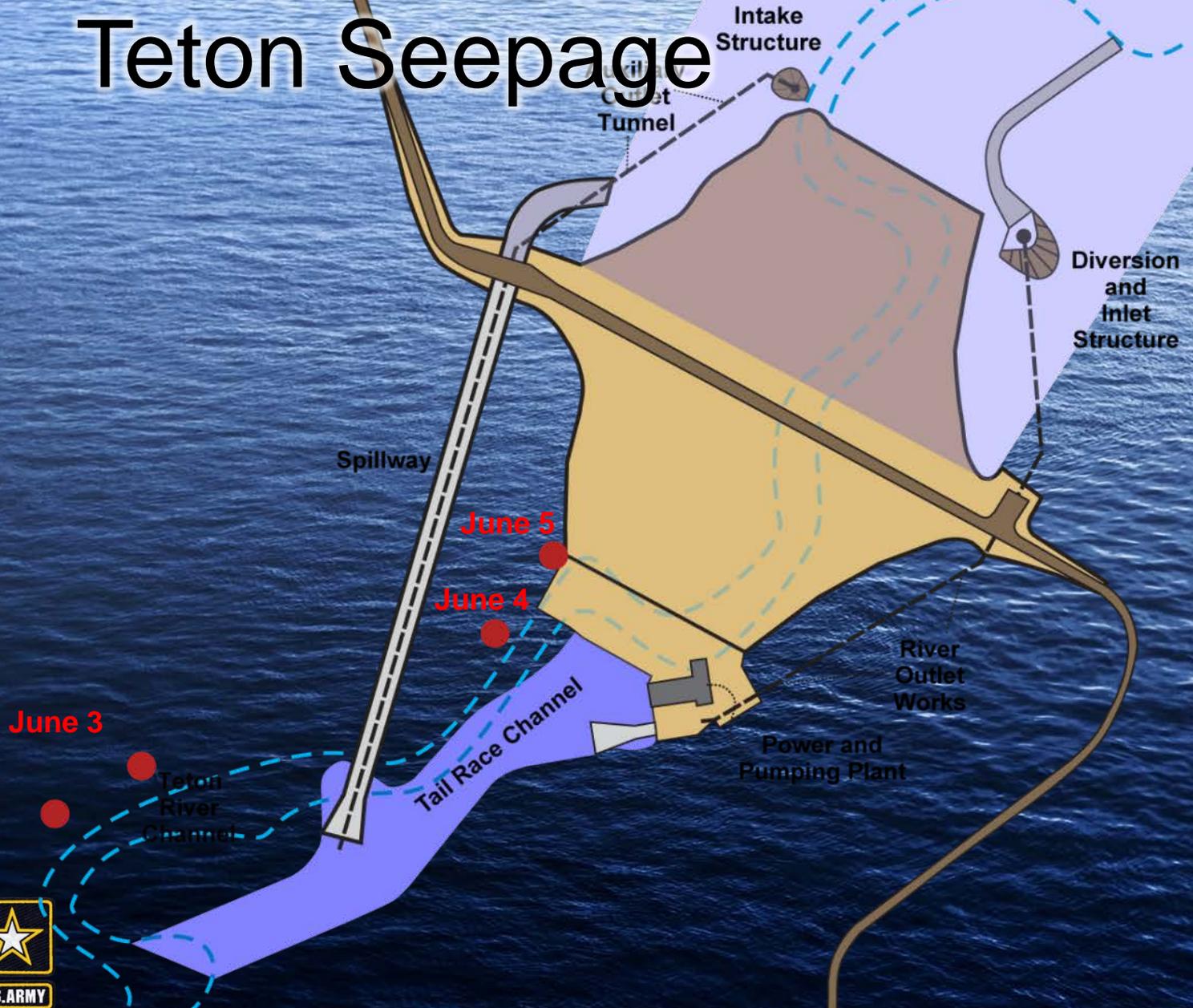


Design Changes During Construction

- Apparently in response to the foundation conditions at the site, Denver designers prepared a memorandum recommending a shotcrete treatment of the downstream face of the cutoff trench.
- According to staff present at the time, the document was never signed or transmitted
- Evidently, the Project Construction Engineer did not want to do this because it would have slowed the job and opened possible claims
- The Construction Liaison in Denver convinced the Head of Earth Dams section to acquiesce
- As part of the acquiescence, the field evidently said they would put extra effort into “special compaction”



Teton Seepage





Ririe Dam



Ririe Dam Today



Independent Review Panel

- Wallace L. Chadwick (Chairman)
- Arthur Casagrande
- Howard A. Coombs
- Munson W. Dowd
- E. Montford Fucik
- R. Keith Higginson
- Thomas M. Leps
- Ralph B. Peck
- H. Bolton Seed
- Robert B. Jansen



Independent Review Panel Major Conclusions

- “...caused **not because of some unforeseeable fatal combination existed**, but because (1) the many combinations of unfavorable circumstances inherent in the situation were not visualized, and because (2) adequate defenses against these circumstances were not included in the design.”
- The zone 2 fill, flanking the zone 1 was intended to act as a drainage blanket and chimney drain...”much of the zone 2 material may have been nearly as impervious at the zone 1 material.”
- The steep sides of the 70-foot-deep keyways promoted initiation of erosion
- Wind-deposited non-plastic to slightly plastic clayey silts were too erodible to place on such a foundation.



Interior Review Group

- F. William Eikenberry (Chairman)
- Neil F. Bogner
- Floyd P. Lacy, Jr.
- Robert L. Schuster
- Homer B. Willis



Interior Review Group

“Design notes, developed early in the design process, identify and report a variety of potential design problems and possible design alternatives. However, there **are no records, documents, or reports that show: (1) the logical resolution** of each of the identified design problems, (2) why a particular design alternative was considered satisfactory and selected in preference to others, and (3) why an identified design problem was subsequently judged important or not important and omitted from, or included for, further consideration.”

The fundamental cause of failure may be regarded as a **combination of geological factors and design decisions** that taken together permitted failure to develop



Most of the
Recommended
Changes were made
by 1980



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Fontenelle Lessons Learned

Not Applied at Teton

- Conservative foundation treatment
- Dental Concrete
- Slush Grouting
- Foundation Shaping
- Designed embankment-foundation contact
- Adjust to site conditions
- Document critical decisions

Applied at Ririe

- Conservative foundation treatment
- Dental Concrete
- Slush Grouting
- Foundation Shaping
- Designed embankment-foundation contact
- Adjust to site conditions
- Document critical decisions



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Conclusions – Decision-Making

- During the design and construction of Teton Dam, important decisions made at very low levels
 - “Surface grouting stopped at El. 5200. Neither the designers nor the liaison engineer were aware of the decision to stop surface grouting until after the failure of Teton Dam. According to field personnel, the field geologists also played no part in the decision to stop surface grouting.”
- Documenting decisions is a critical step to ensure safety decisions are given proper consideration
- At the time Teton failed, once decisions were made (at the time specifications were prepared) it was almost impossible to change



Conclusions - Responsibility

- There was a lack of organizational responsibility related to design decisions at all levels of the organization
- There was a lack of personal responsibility on the part of the designers, design managers, and construction forces
- During the construction of Teton, everyone assumed that someone else understood and had taken care of any problems
- As individuals, learning from past mistakes can serve to greatly reduce the likelihood of repeating them

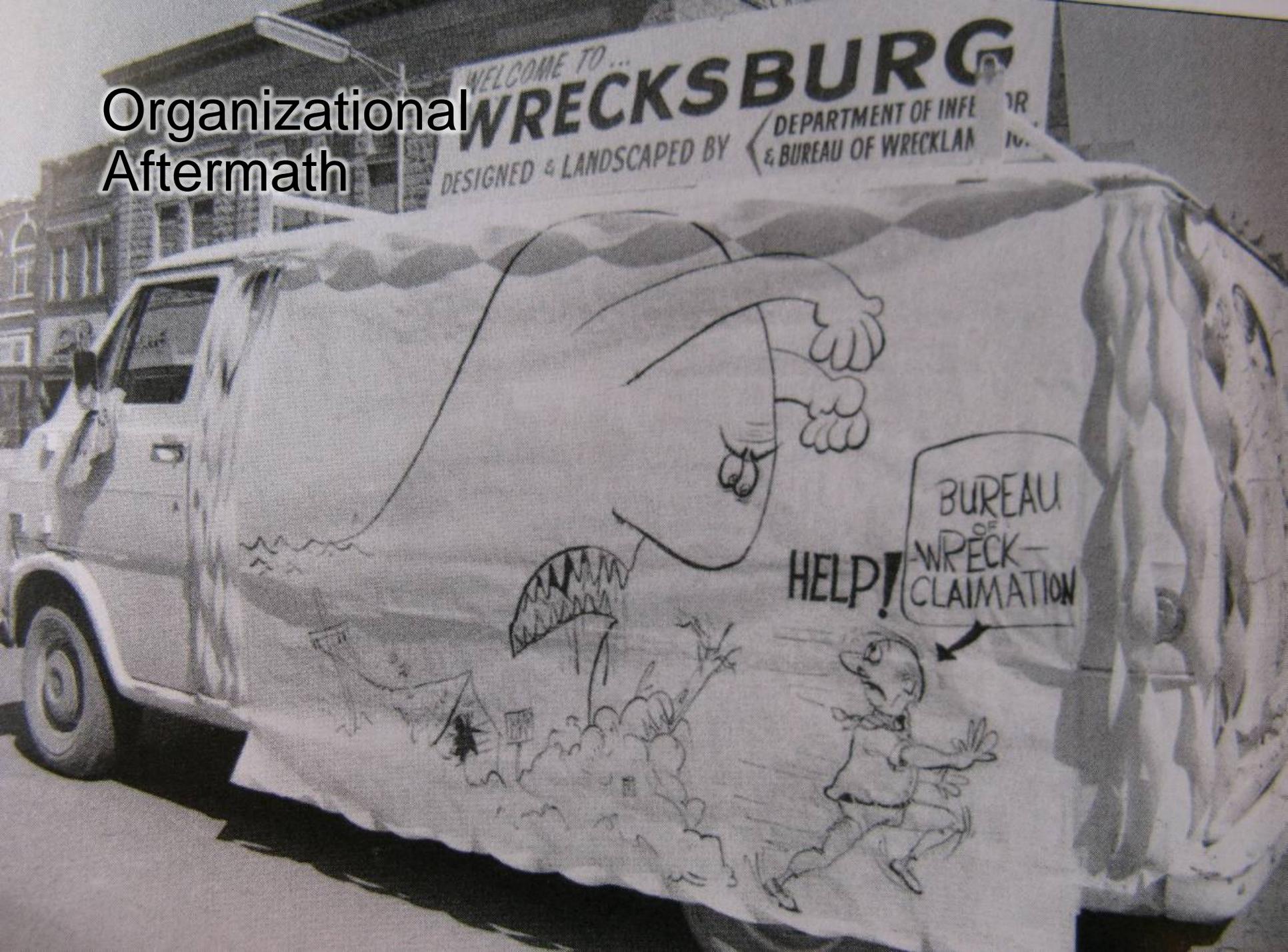


Conclusions - Hubris

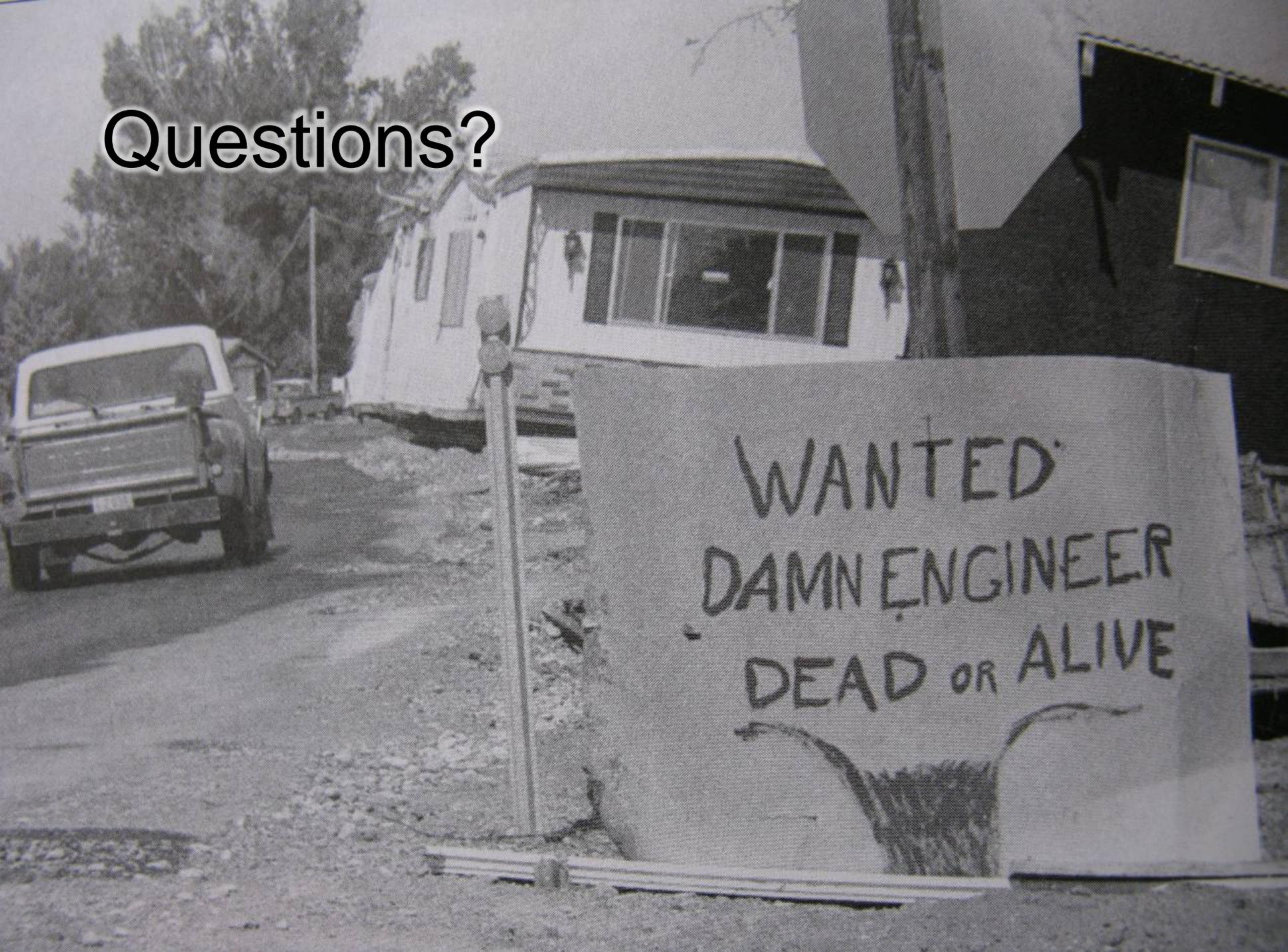
- Use more than one line of defense against seepage.
- Flaws can occur in man-made structures.
- External review of designs and decisions is a key step to evaluate the safety of a structure
- Hubris engineering is detrimental.
- Critique problem or controversial conditions.



Organizational Aftermath



Questions?



WANTED
DAMN ENGINEER
DEAD OR ALIVE