U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD
PANEL ON STRUCTURAL GEOLOGY & GEOENGINEERING

SUBJECT: OVERALL STRATEGY TO SEAL EXPLORATORY BOREHOLES

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Conclusions

Significance

- Significant boreholes are within and close to the edge of the repository
- Deep boreholes are potentially more important than shallow boreholes

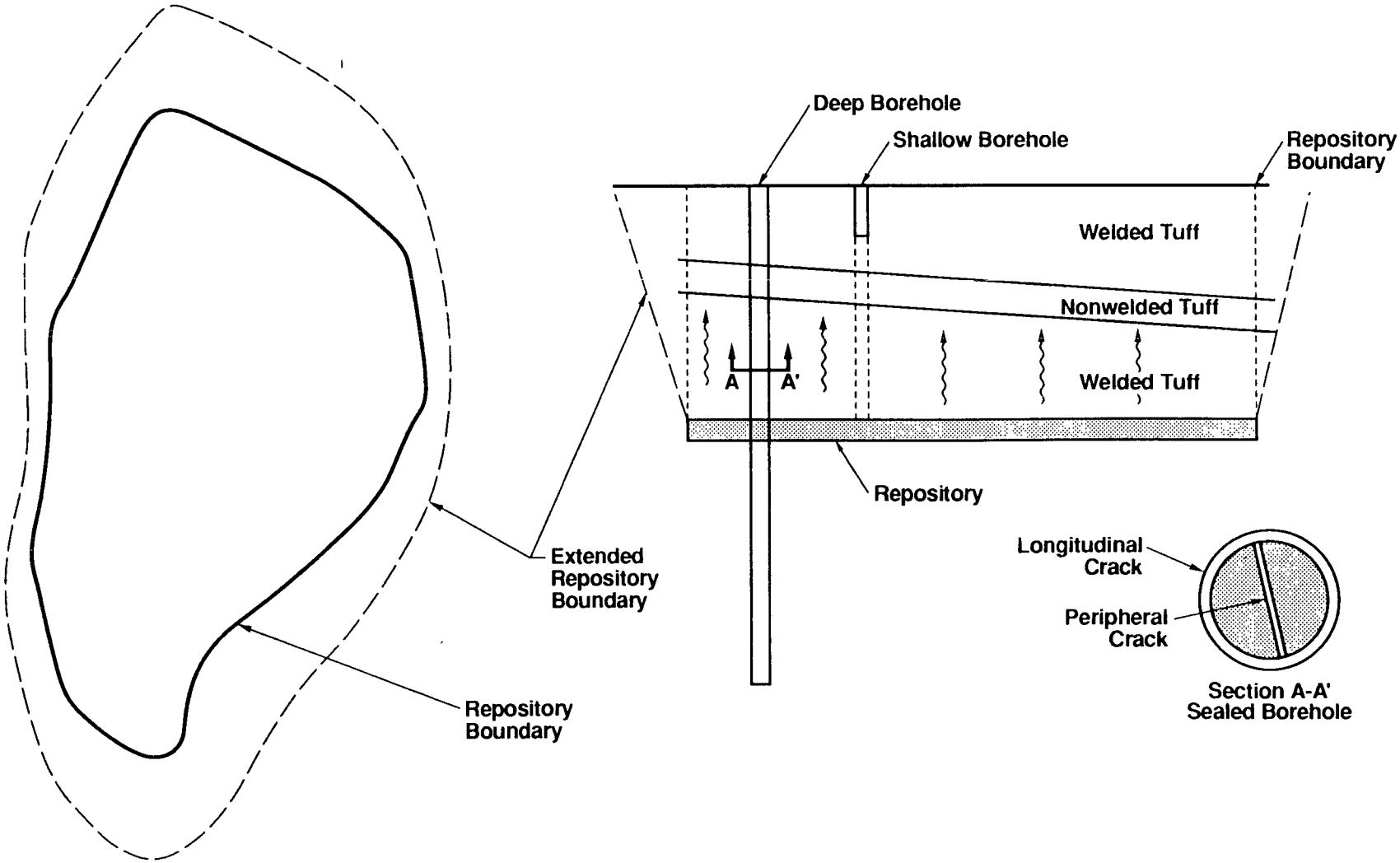
When to Seal

- Seal deep and significant boreholes within the repository boundary concurrent with or before waste emplacement

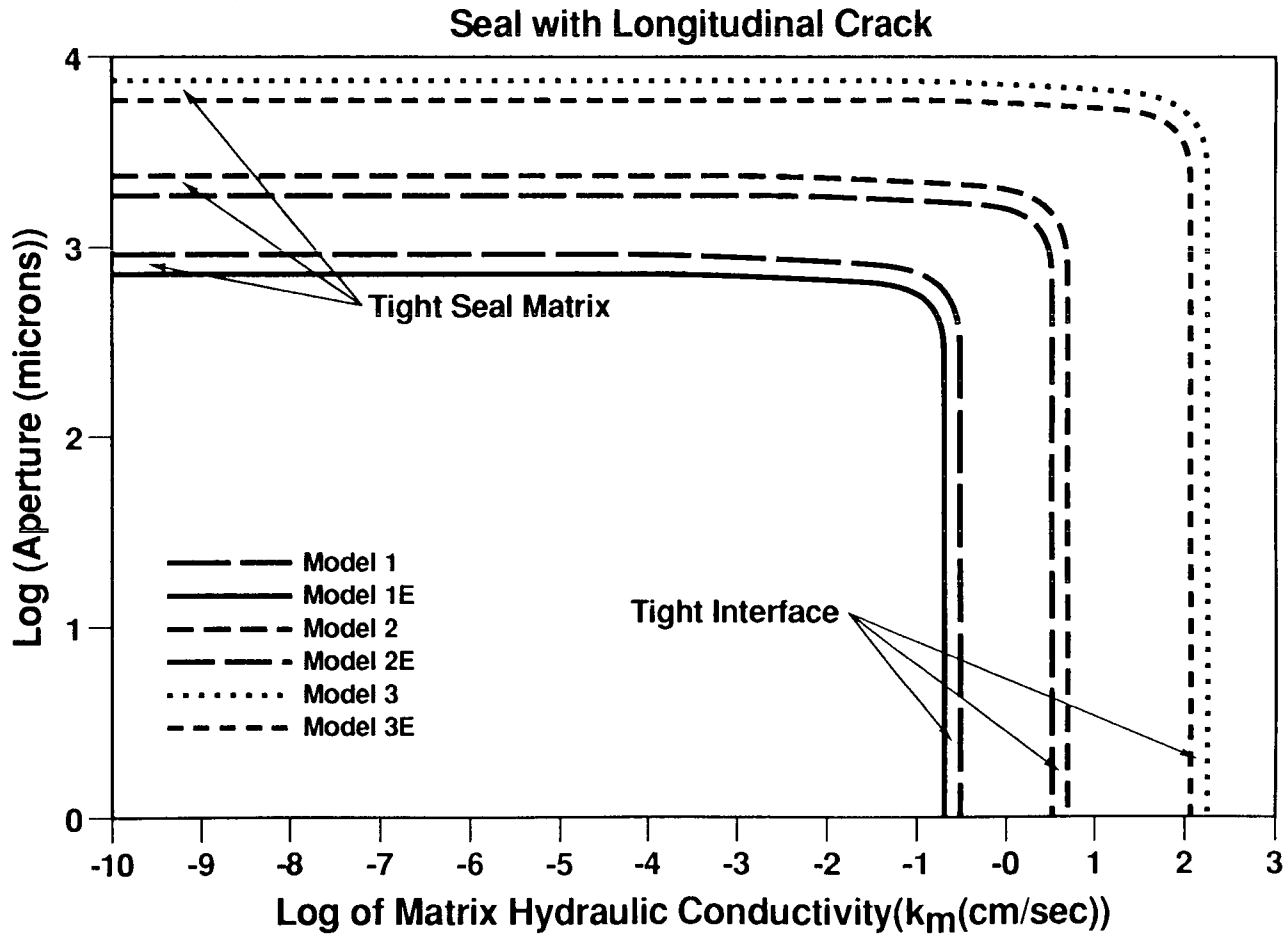
How to Seal

- Use low pressure squeezing to develop compressive stress at interface zone
- Increase length of plug up to 10m to resist static, dynamic, and thermal loads
- Lower the temperature of grout by reducing the heat of hydration and pre chilling materials

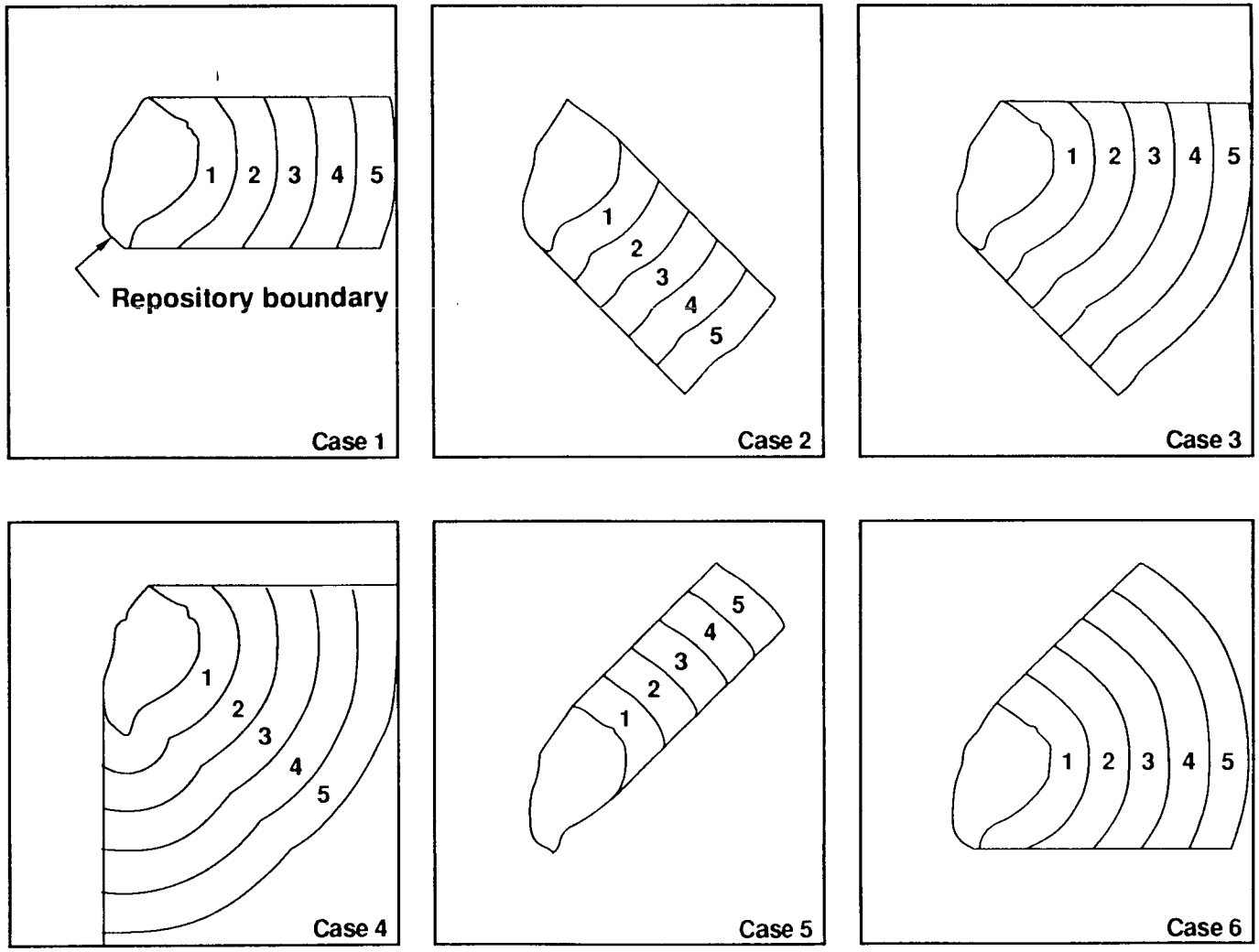
Airflow Model and Extended Boundary



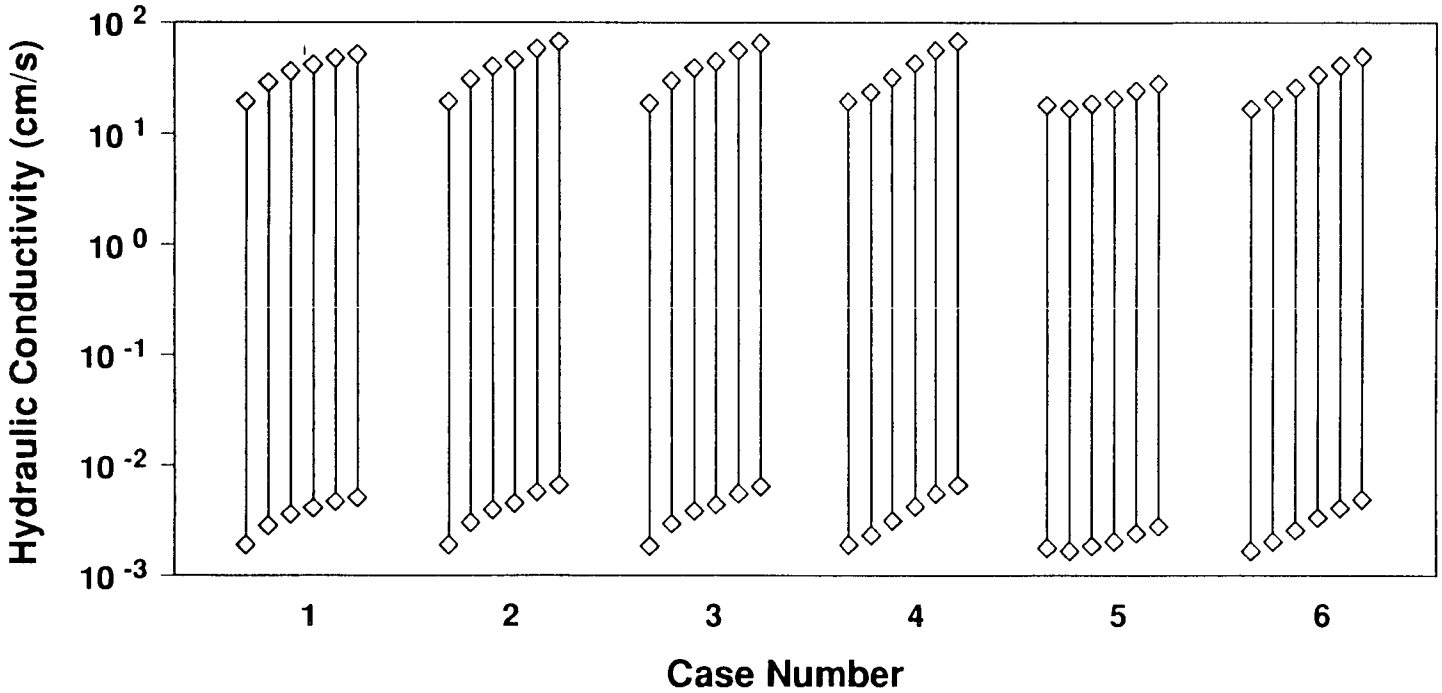
Preliminary Design Requirements for Seals Above the Repository Horizon Aperture vs. Seal Conductivity



Scenarios - Borehole Seal Below Repository



Preliminary Design Requirements for Seals in Calico Hills Member



LEGEND

Bulk Rock Hydraulic Conductivity
10^{-4} cm/s (Upper Points) 10^{-8} cm/s (Lower Points)

First Range for Case - Repository area Only
Second Range for Case - Area 1 km out
Third Range for Case - Area 2 km out
Fourth Range for Case - Area 4 km out
Fifth Range for Case - Area 4 km out
Sixth Range for Case - Area 5 km out

Where to Seal

- Place seals away from high temperature zones near the repository
- Place primary seals (cementitious seals) where hole conditions are good or excellent
  - Paintbrush tuff nonwelded to partially welded zones
  - Upper part of Topopah Spring Member
  - Calico Hills vitric and zeolitic zones

Where to Seal *continued*

- Place granular materials in selected fracture areas where perching is possible (to dissipate porewater pressure) and in high temperature areas
- Place combination of clay and granular materials in highly fractured tuff below the Paintbrush tuff and the repository

Considerations in Selecting Seal Materials

- Use a rigid cementitious seal where structural performance is desired
- Avoid placement of cementitious seals in high temperature environments
- Enhance stability of cementitious seals
  - Minimize leachable phases, portlandite $Ca(OH)_2$ and reactive alkalis, NaOH, KOH by adding excess reactive silica (silica flour, and slag)
  - Reducing ettringite formation by selecting a cement with a low sulfate content
- Use earthen materials (clay and crushed rock) as initial seal in highly fractured areas

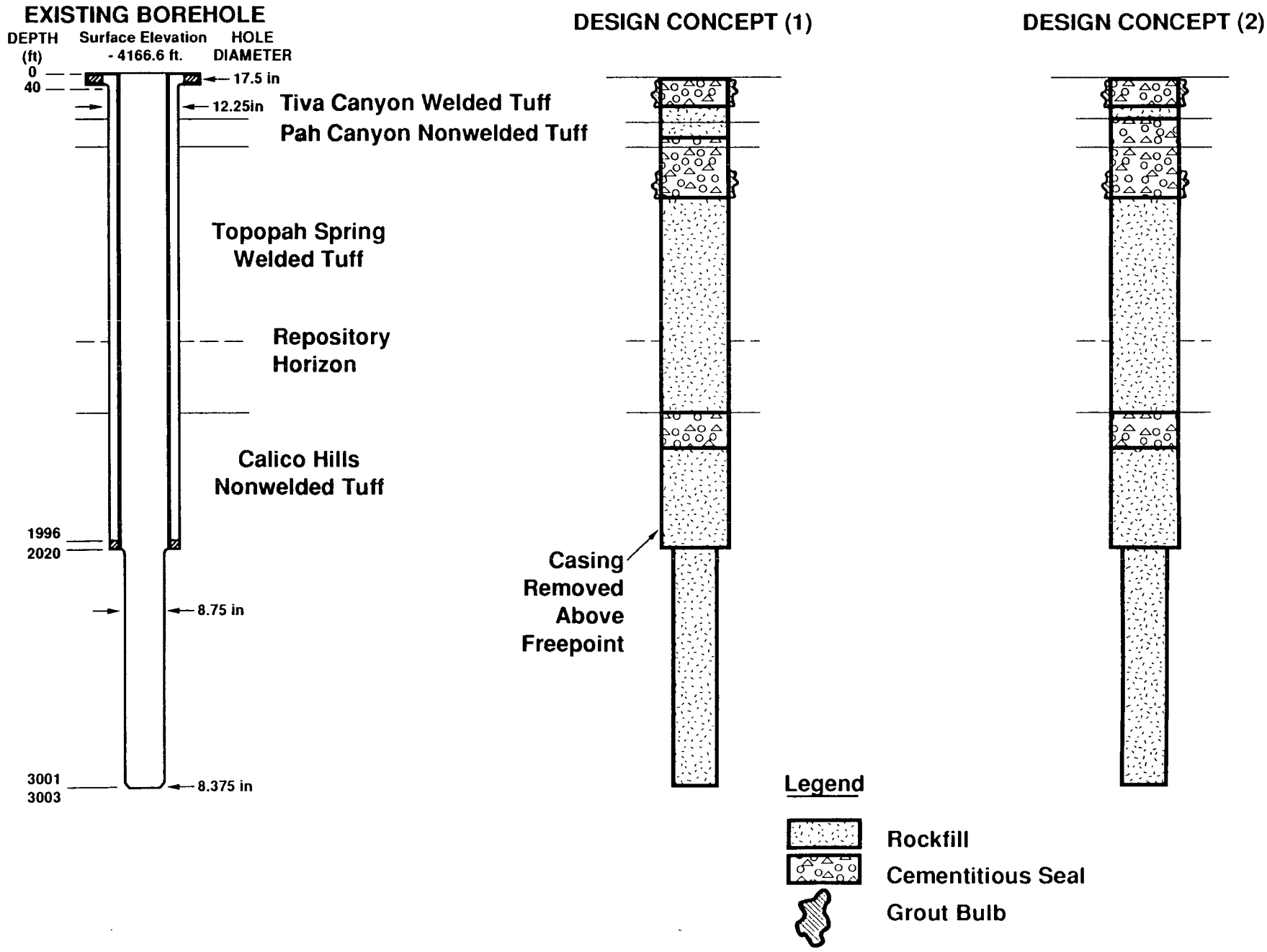
Considerations in Placing Portland - Based Grout Above Swelling Clay

- Grout can increase pH and calcium concentrations of ground water
- Calcium can cause decrease in swelling pressure of Na - K swelling clay
- Elevated pH can destabilize swelling clay
- Possible solutions:
  - Avoid placing grout above clay
  - Use a grout formulation that will not release calcium
  - Use a grout formulation that will not cause an increase in pH
  - Use a calcic form of clay
  - Process the sodic form of clay into a calcic form

Overall Conclusions to Sealing Exploratory Boreholes

- Existing holes can be sealed using existing technologies
- Several individual boreholes have conditions which are problematic
- A general sealing plan needs to be developed for exploratory boreholes
- A detailed sealing plan should be prepared for each borehole
- Inspection/assessment of each well should be conducted prior to implementation of sealing procedures

Conceptual Design of Exploratory Borehole Seals



Recommendations to Sealing Exploratory Boreholes

- Sealing concerns should be taken into account before drilling the proposed boreholes
  - Maintain detailed construction documentation
  - Select drilling methods, if possible, that will reduce wall cake build - up
  - Select drilling methods, if possible, that will result in better well condition
  - Minimize risk of losing drilling tools and "junk" in the borehole, e.g. develop a protocol for tool inspection, make routine field inspections intermittent with downhole operations
  - Utilize materials that are relatively easy to remove through fishing or milling
  - Limit number of exploratory boreholes