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

NUCLEAR WASTE TECHNICAL REVIEW BOARD
PANEL ON STRUCTURAL GEOLOGY & GEOENGINEERING

SUBJECT: SEALING CONCEPTS AND DESIGN APPROACH

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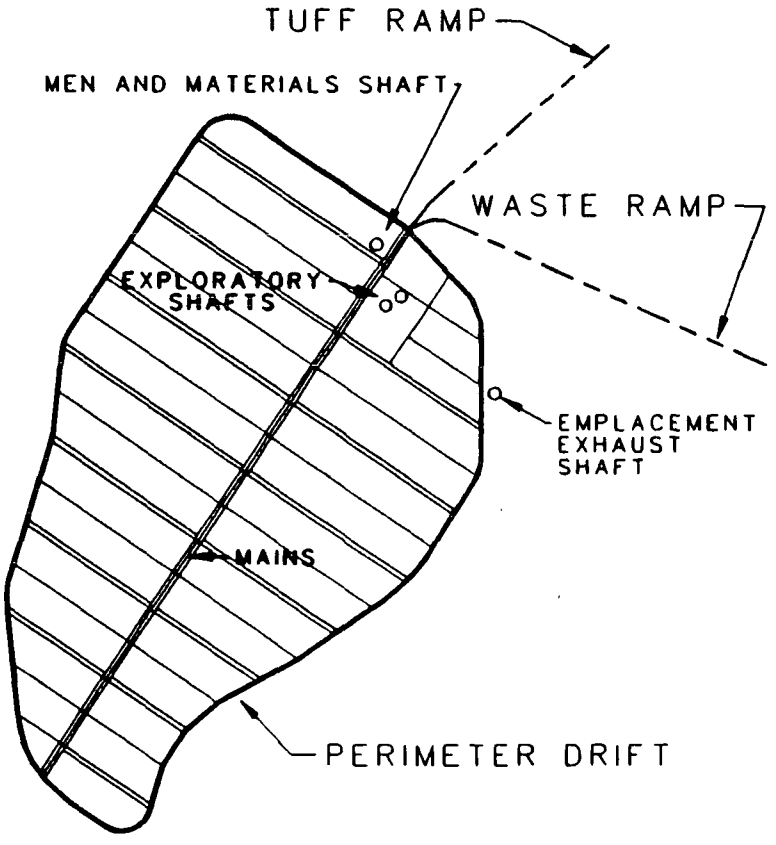
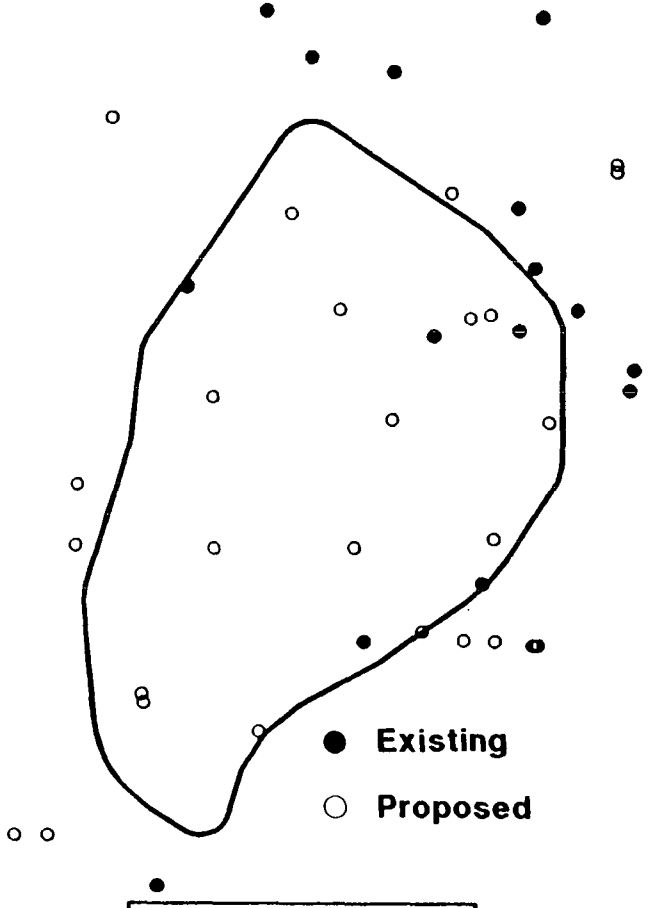
Sealing Is Part of the Permanent Closure of the Underground Facility, Shafts, Ramps, and Boreholes



REPOSITORY DESIGN



BOREHOLES

Objectives for the Sealing Program

- Meet regulatory performance requirements by
  - Reducing water inflow via accesses
  - Diverting water from waste packages
  - Controlling release of gaseous radionuclides
  - Preserving structural integrity of host media
  - Limiting human intrusion

Reference: SAND83-1778, Sealing Concepts Report
DOE/RW-0199, Site Characterization Plan

Hydrogeology Categories of Tuffaceous Units at Yucca Mountain

- Densely welded, low-porosity, but highly fractured units with high hydraulic conductivity
- Nonwelded, porous, zeolitized, but relatively nonfractured units with low hydraulic conductivity
- Nonwelded, porous, vitric, but relatively nonfractured units with high hydraulic conductivity

Hydrogeologic Assumptions Used for the Sealing Concepts

- Repository located above the water table in the unsaturated zone
  - Predominantly vertical downward gradient is driving mechanism for groundwater flow
  - Lateral flow possible at material contrast interfaces
  - Flow in discrete fault and fracture zones is a potential flow mechanism
  - Vertical flow is expected to dominate and lateral flow is expected to be minimal at the storage horizon

Hydrological Experience From Rainier Mesa (NTS)

- G-Tunnel
  - 1 water-producing fault zone
  - ~0.01 GPM
  - 2 order-of-magnitude variation in K_S in 5 m
- E-Tunnel
  - Only free water in open fractures--mostly fault zones
  - Initial discharge (usually ~20 GPM) decreased rapidly
  - ~50% of 110 faults yielded 98% of free water
  - Poor hydraulic connection between fractures
  - Draining perched water
  - Saturated matrix retains water

Reference: SAND84-1895, Technical Basis Report

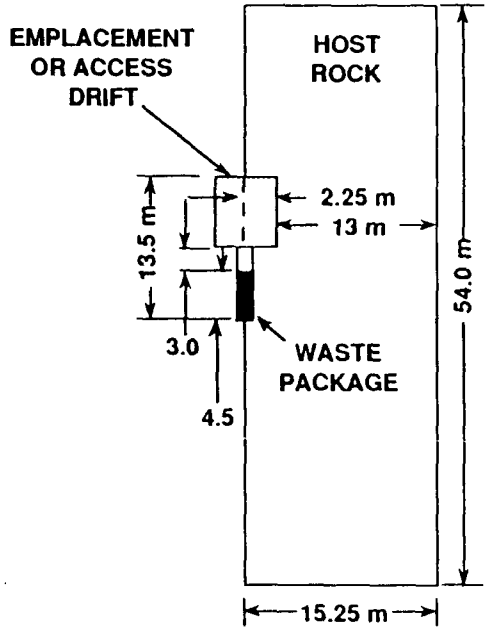
Hydrologic Analyses

Drift Analyses

Objective: Determine if backfill can enhance performance

Approach: Backfill--sand and clay
Rock conductivity--varied

4 analyses

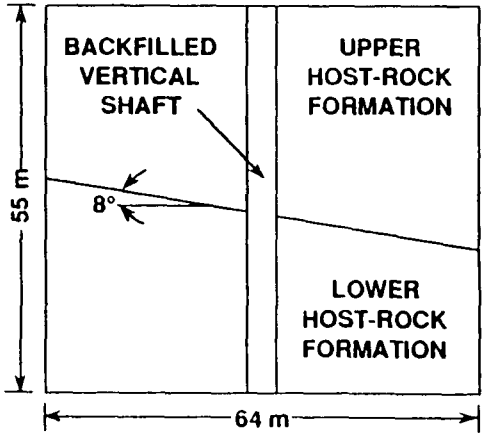


Shaft Analyses

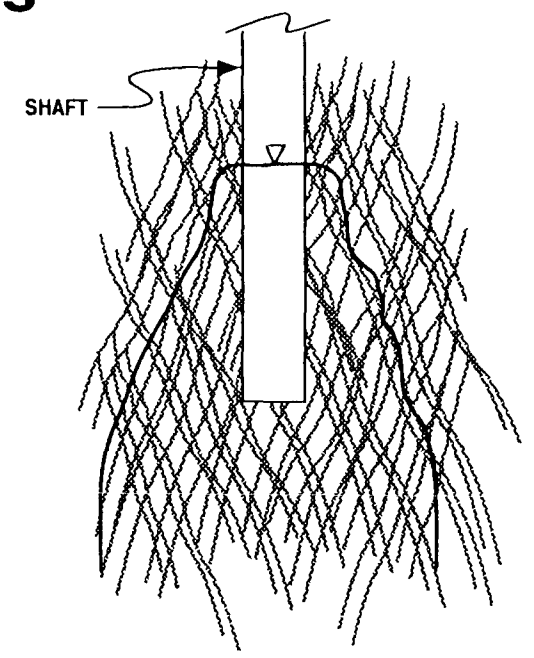
Objective: Determine influence of material contrast

Approach: Backfill--sand and clay
Rock--welded, nonwelded
Rock properties--varied

5 analyses



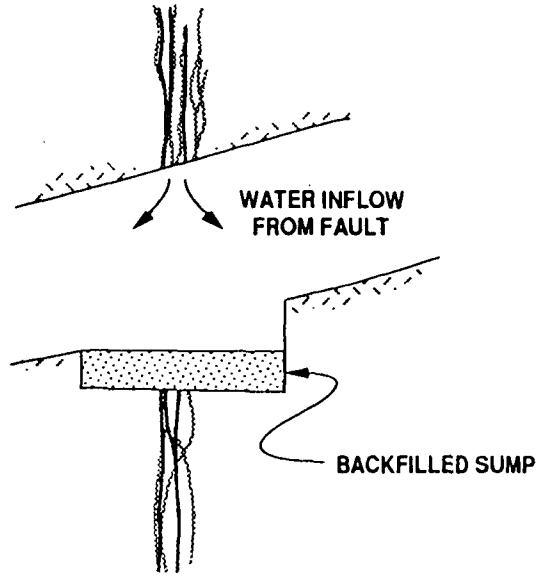
Hydrologic Analyses



Shaft Drainage Analyses

Objective: Determine if water entering shaft can be drained in sump

Approach: Analytical approach
Rock conductivity--varied
Shaft diameter--varied



Drift Drainage Analyses

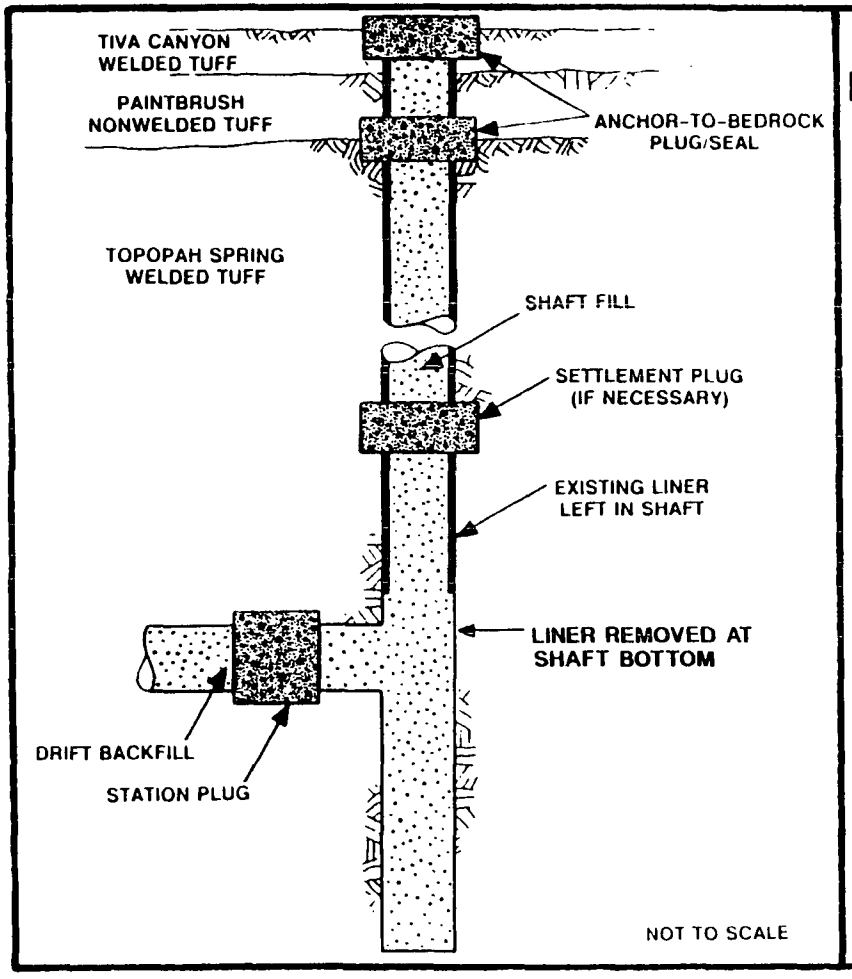
Objective: Determine size of sump to drain water entering drift from fault

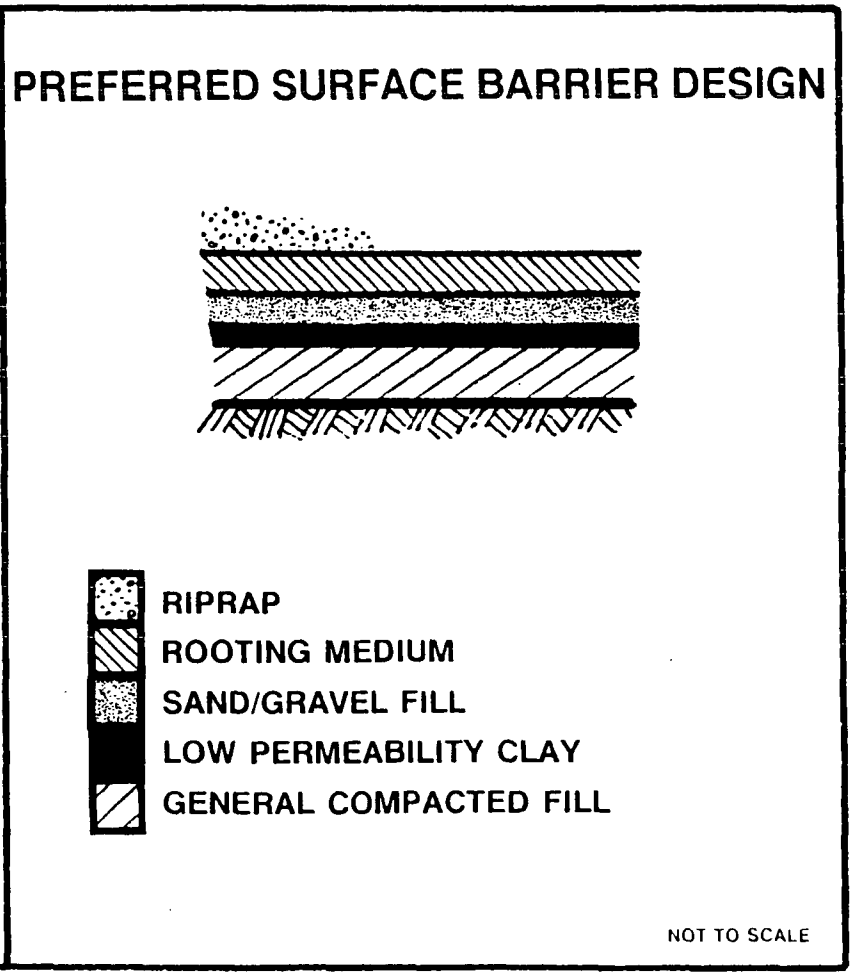
Approach: Parallel plate analogy assumed
unit gradient
5, 16 μm fractures

Results From Hydrologic Analyses

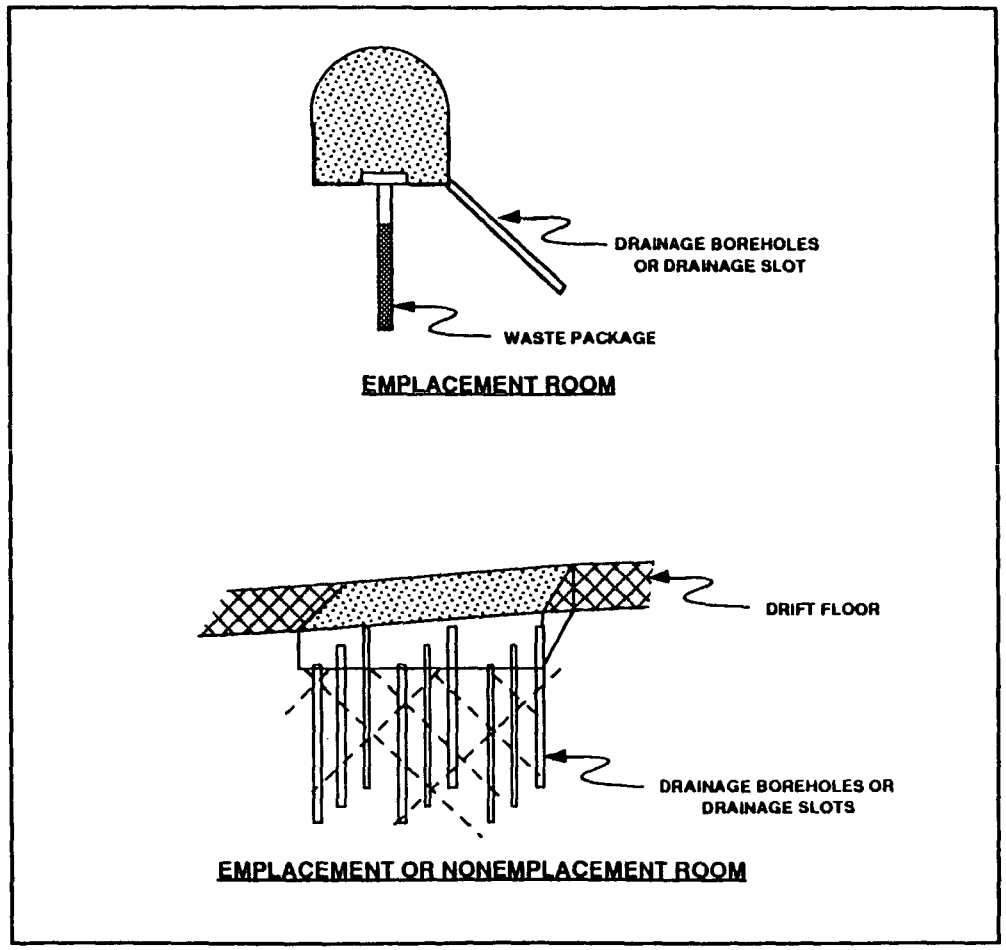
- From a hydrologic viewpoint, backfilling the repository and shafts is not essential (matrix flow only)
- If backfill is needed for other reasons, coarse materials are better because of their capacity to drain and act as capillary barriers
- Greater flows into drifts may occur when saturation in surrounding host rock formation is high (98-99%)
- Anticipated drift inflow can be effectively drained through drift floor

Shaft Sealing Concept





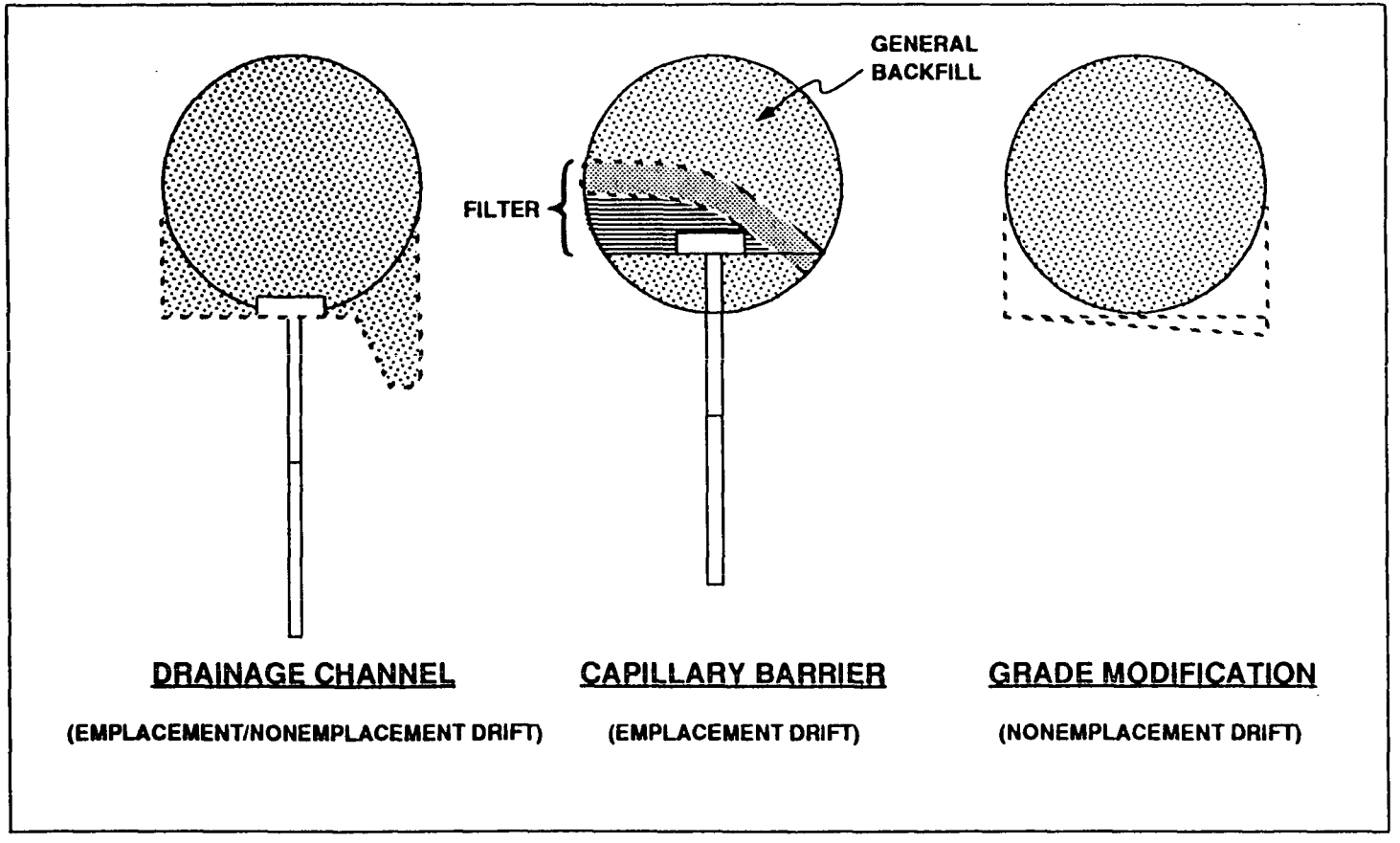
Drainage Enhancement Concepts



Benefits

- Simple way of controlling small drift inflow
- Increase drainage and storage capacity of floor

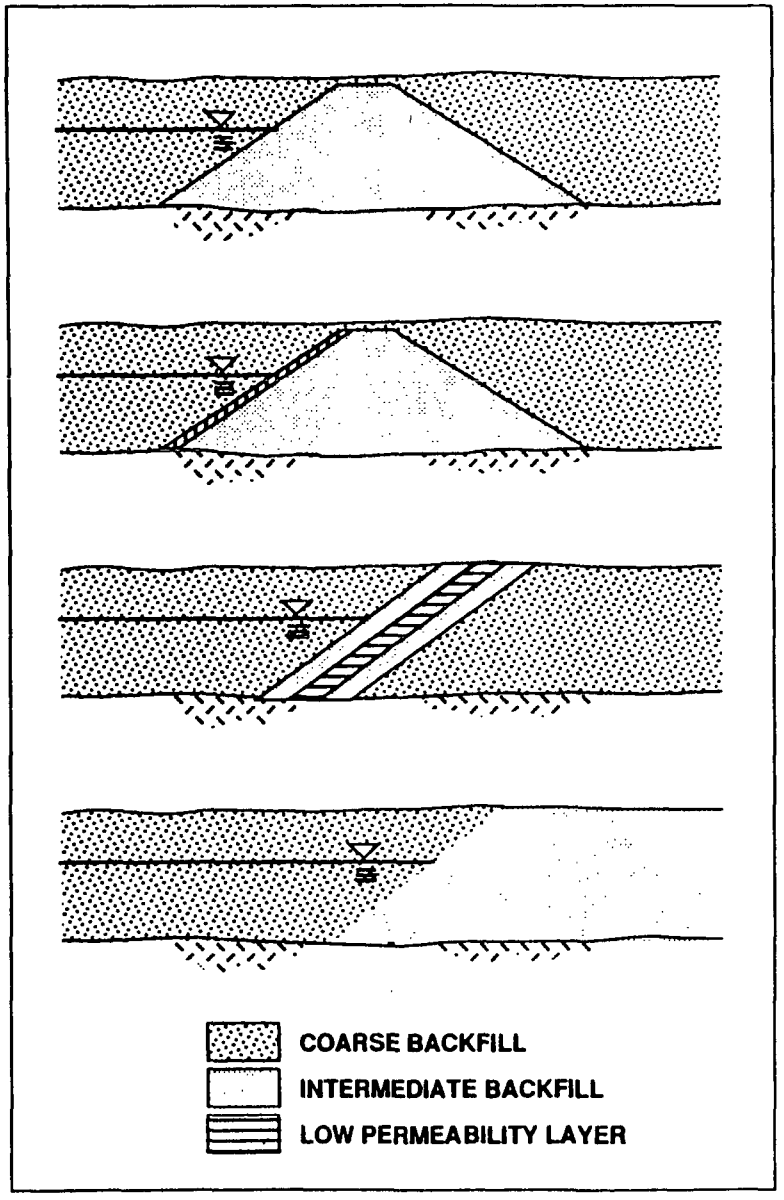
Water Control Concepts



Benefits

- Diversion of water to nonemplacement drifts
- Diversion of water from waste packages

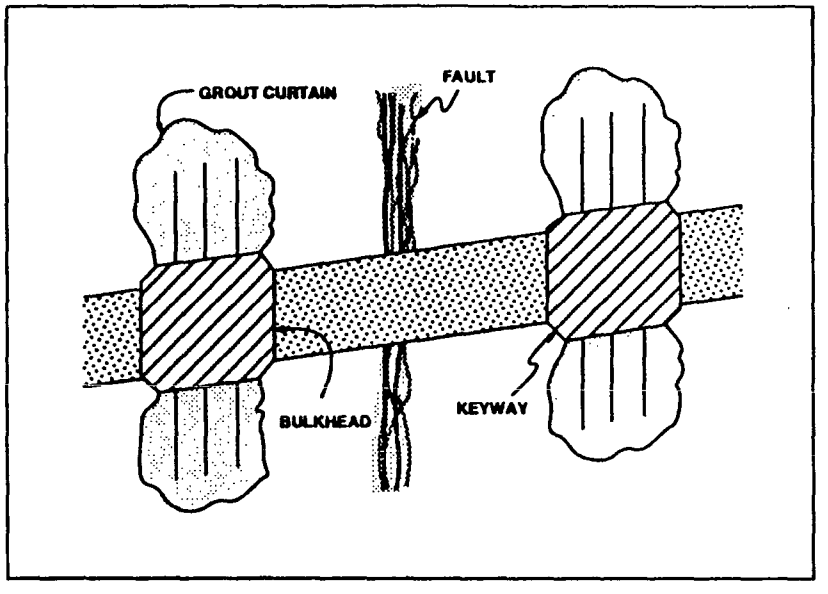
Single Embankment Concepts



Benefits

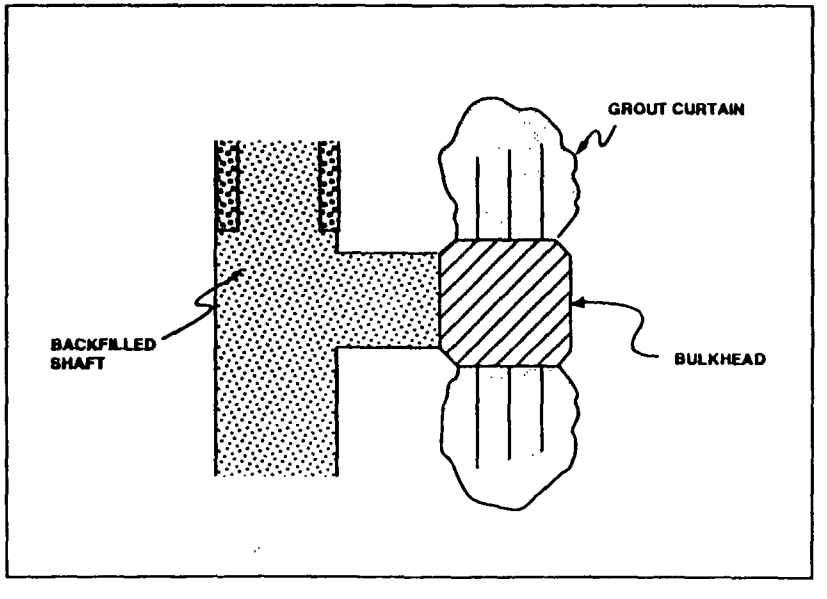
- Option 1
  - Retain larger amounts of water
  - Increase drainage and storage capacity of floor
  - Can be emplaced in predefined areas
- Option 2
  - Same as Option 1
  - Reduced extent of phreatic surface
- Option 3
  - Same a Option 2
  - Filter design more stable
  - Ease of construction
  - Optional keyway and grout curtain
- Option 4
  - Same as Option 3
  - Simple and effective

Bulkheads



Benefits

- Isolate large amounts of water from waste
- Preserve integrity of host media



Benefits

- Reduce potential volume of water entering from shafts to repository
- Preserve integrity of host media

Approach Used in the Sealing Program

- Maintain an integrated program
  - Site characterization
  - Repository design maturation
  - Seal component performance
    - Refinement of requirements
    - Testing program (laboratory, field)

Focus: Reduce uncertainties related to sealing

UNCERTAINTIES

SITE

- Hydrologic
  - Dominant flow mechanisms
  - Variability in properties
  - Flux
  - Location, frequency, quantity, and nature of flow
- Rock properties
  - Mechanical, thermal, and geochemical
- Future conditions

DESIGN

- Construction method
- Grades and dimensions of drifts
- Number and interconnection of drifts
- Thermal loads

SEAL COMPONENT

- Required performance
- Actual performance
- Longevity of seal component
- Emplacement concerns

Approach in Current Design Phase

SITE

- Select a broad range of site properties in analyses
- Estimate anticipated and unanticipated conditions

DESIGN

- Develop constraints for repository system
- Provide focus for seal location and size

SEAL COMPONENT

- Propose alternative seal designs
- Select conservative design requirements
- Establish general design requirements
  - Lower temperature areas
  - Selective use of man-made materials

Constraints on Repository System

Water Control Strategies

- Control drift grade
- Provide selected water storage and drainage areas
- Ensure reliability of drainage areas (base of shafts and selected drift floors)
- Control and monitor water usage

Design Control Strategy

- Place shaft collars above floodplain
- No grout emplacement in seal locations during construction phase
- Limit excavation damage
- Control grades to divert water away from waste packages
- Stand-off distance between exploratory boreholes and drifts
- Design liners for easy removal

Seal Component Uncertainties

PERFORMANCE

- Hydrologic performance of seal component in situ
- Drainage capacity of rock
  - Geochemical alteration of flow through fractures
  - Thermal effects on fractures
  - Fines migration

EMPLACEMENT

- Liner removal
- Keyway excavation
- Grout emplacement
- Shrinkage and temperature effects due to placement procedures
- Fines creation
- Placement of seal component