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

NUCLEAR WASTE TECHNICAL REVIEW BOARD
PANEL ON STRUCTURAL GEOLOGY & GEOENGINEERING

SUBJECT: OVERALL APPROACH AND PERFORMANCE CALCULATIONS

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Basis for Strategy

Criteria	10 CFR 60.134 Boreholes should not be preferential pathways for release of radionuclides
Assumptions	Tie performance to rock properties
Design Goal	Flow through boreholes should be < 1% of total flow through rock

Approach to Develop Strategy

Define borehole system
- Location, number and quality

Define environment
- Rock properties, in situ stress and temperature

Establish significance of boreholes

Air	Water
• Dispersion	• Flooded drift
• Conductance	• Proximity of borehole to flood plain

Perform design calculations
- How
- When
- Where

Review available technology

Formulate strategy

Existing Boreholes

	Depth	Diameter
UZ	57' to 1887'	48 - 36" to 3.94 at depth
WT	1100' to 2100'	15" to 8.75" at depth
H	4000' to 6000'	48" - 36" to 8.75" at depth
G	2444' to 6006' (one at 551')	23" to 2.98" at depth
A	500' to 2500'	17.5" to 2.98" at depth
B	4002'	36" to 8.5" at depth
C	3000'	48" - 36" to 9.875" at depth
P	5923'	30" to 6.125" at depth
UZN	typically < 50' 20' to 120'	6.0" at depth
RF	60' to 306'	9.875" to 3.94" at depth
Seismic Holes	typically 200'	6.25" at depth

Drilled with air foam, bentonite mud, polymer mud and air

Existing And Proposed Boreholes

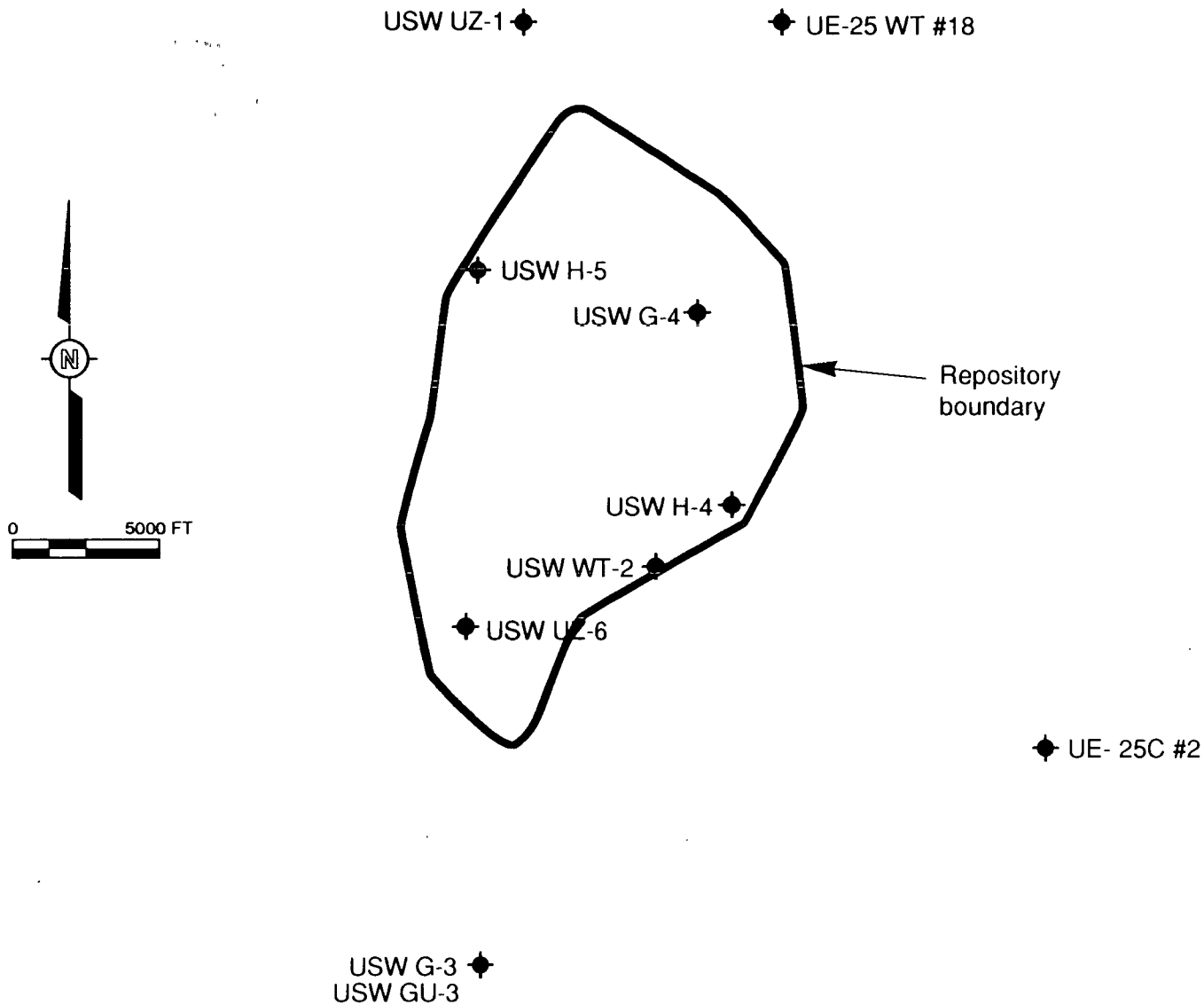
CATEGORY OF BOREHOLE	Existing			Proposed			
	Within Repository Boundary	Within Extended Boundary	Outside Repository Boundary	Within Repository Boundary	Within Extended Boundary	Outside Repository Boundary	Outside Repository Boundary
UZ	3	-	5	7	4	7	26
UZN	28	8	37	3	8	15	99
WT	1	-	15	-	-	5	21
A	1	3	1	-	-	-	5
C	-	-	3	-	-	-	3
H	2	2	1	-	-	1	6
G	1	1	4	-	-	2	8
P	-	-	1	-	-	-	1
B	-	-	1	-	-	-	1
RF	-	-	12	-	-	2	14
SEISMIC	-	1	42	-	-	-	43
SD(1)	-	-	-	5	7	-	12
FM (2)	-	-	-	-	-	2	2
LPRS (3)	-	-	-	30	80	30	140
VSP (4)	-	-	-	1	1	-	2
MPBH (5)	-	-	-	2	-	-	2
Total By Location	36	15	122	48	100	64	385

Footnotes
(1) SD=Systematic Drilling Program Boreholes
(2)FM=Fortymile Wash Recharge Boreholes
(3)LPRS=Large Plot Rainfall Simulation Boreholes
(4)VSP=Vertical Seismic Profile Boreholes
(5)MBPH=Multiple Purpose Borehole

General Borehole Conditions

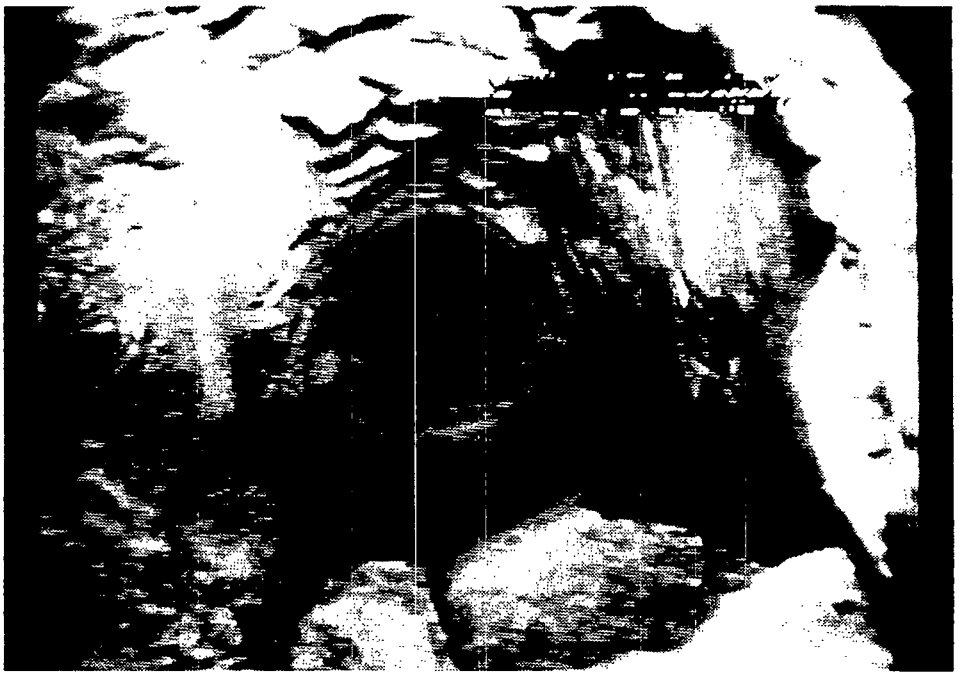
- Presence of PVC tubing, screen, casing
- Eroded zone and sloughing holes
- Lost circulation
- Uncemented steel casing in deep and shallow holes
- Steel casing grouted at surface
- Perforated cemented casing and uncemented casing
- Steel casing grouted at bottom or at selected areas along casing
- Cement on wall

Review of Selected Boreholes

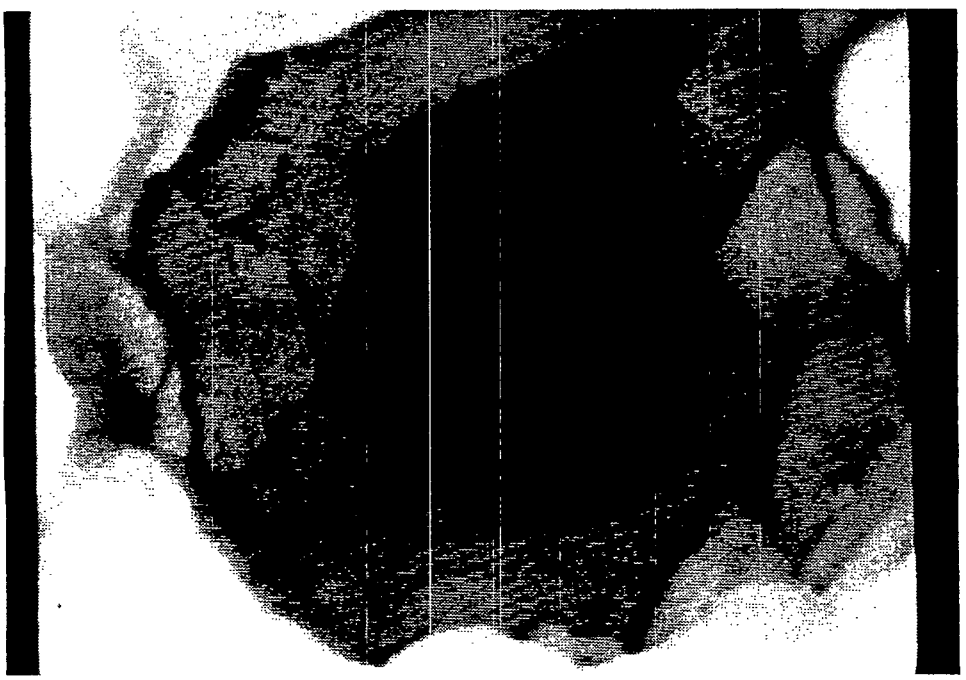


Hole Conditions

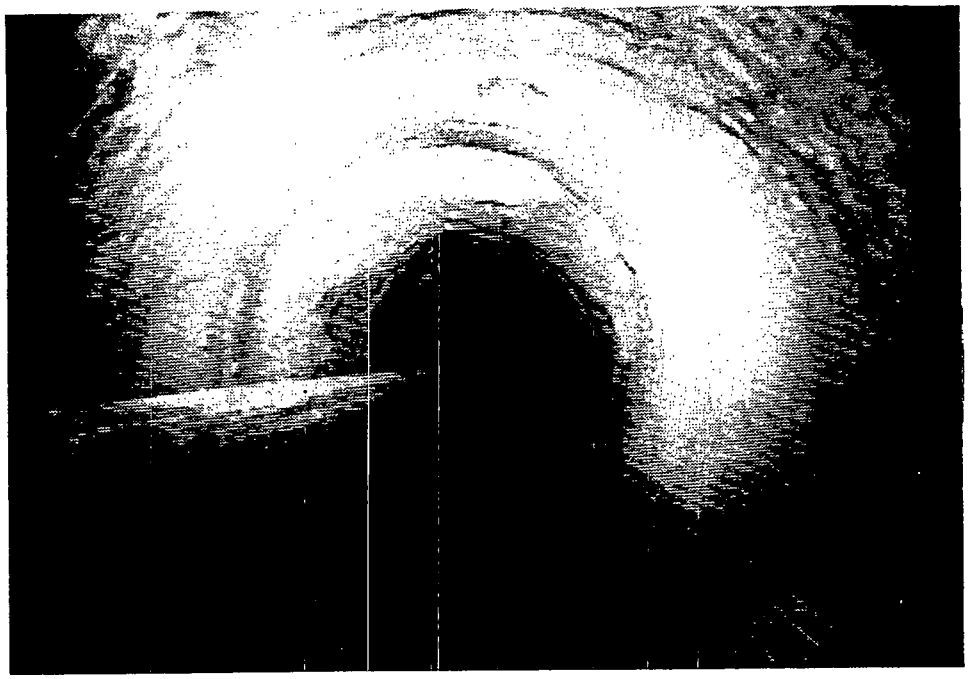
Category 1	*Excellent*, typically smooth surface, few lithophysae and no fractures
Category 2	*Good,* typically smooth surface with small and consistent spacing of lithophysae, none to few fractures
Category 3	*Poor,* typically rough surface, intermediate lithophysae, frequent fractures, hole enlarged but usually symmetrical
Category 4	*Extremely Poor,* rough and very irregular surface, large lithophysae, many fractures, hole enlarged and nonsymmetrical



USW G-4, Tiva Canyon Member, densely welded, devitrified, 60 ft (C4)

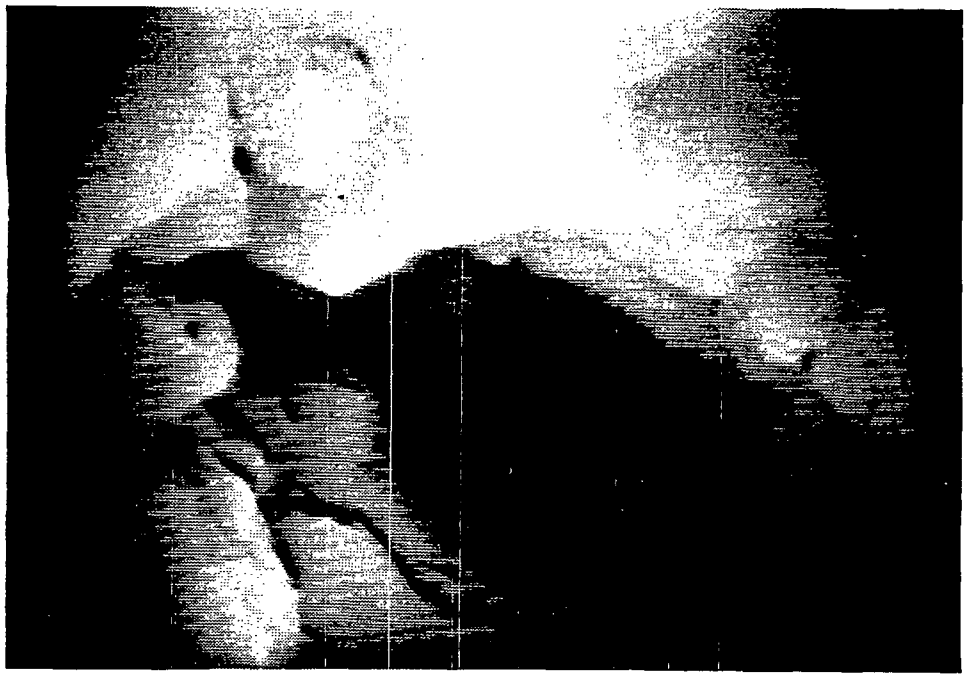


USW UZ-6S, Tiva Canyon Member, densely welded, devitrified, 150 ft (C3)



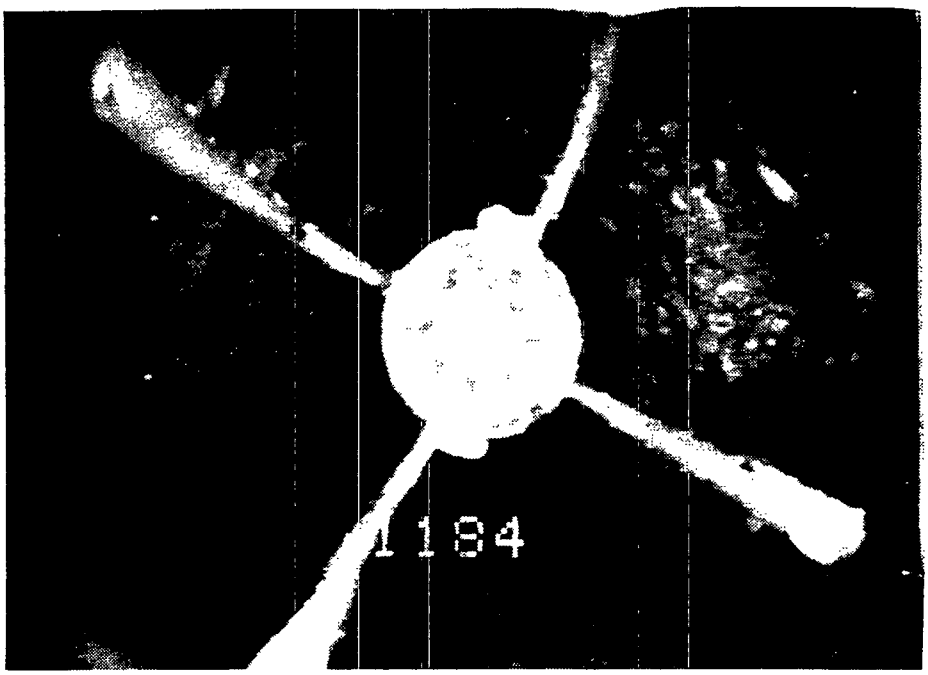
USW UZ-1, Yucca Mountain Member, partly welded to nonwelded, vitric, 80 ft (C1)

USW UZ-1, bedded tuff below the Yucca Mountain Member, 95 ft (C1)

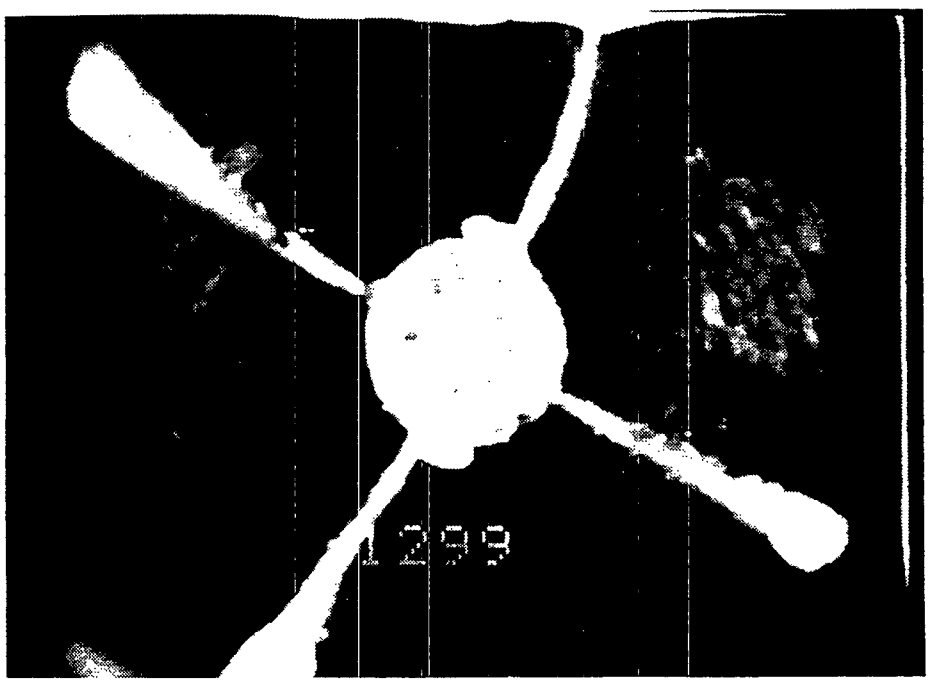


USW UZ-6, Topopah Spring Member caprock, densely welded, devitrified, 520 ft (C4)

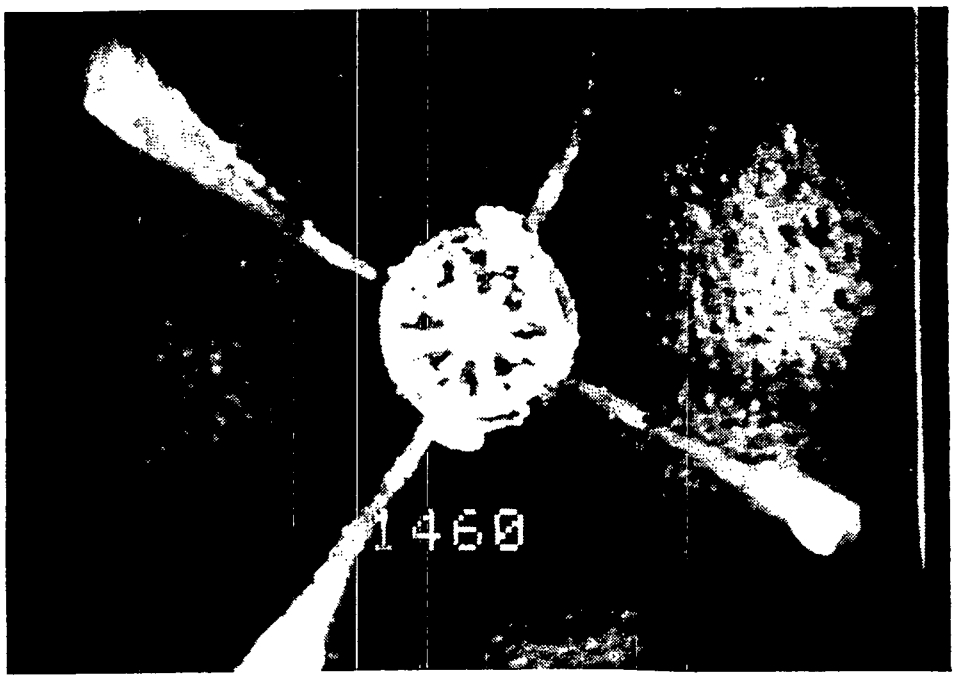
USW UZ-6, Topopah Spring Member, densely welded, devitrified, 850 ft (C4)



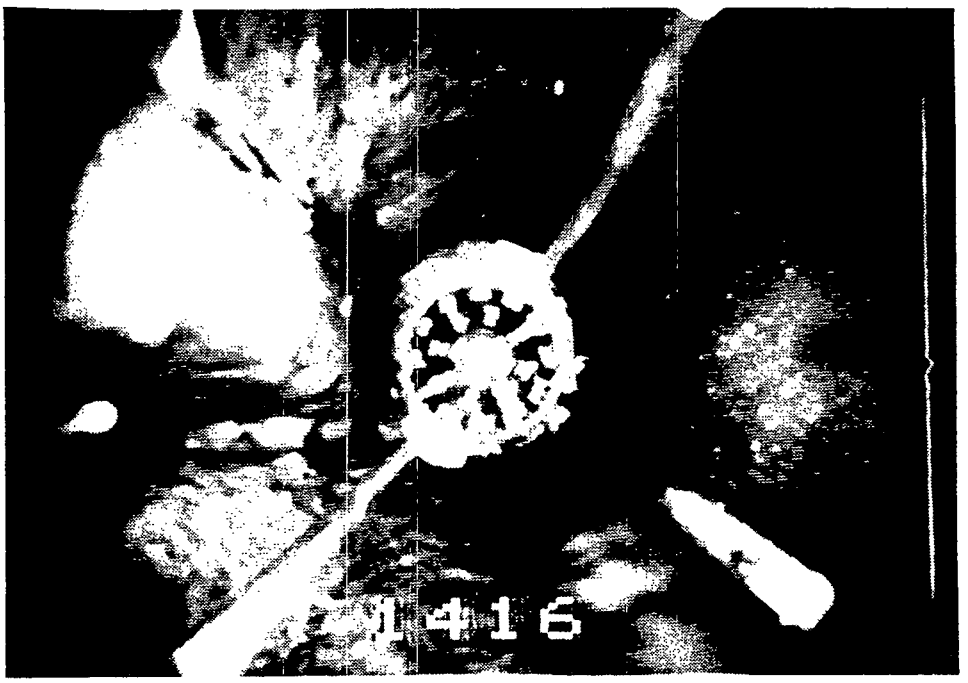
USW WT-2, Topopah Spring Member, densely welded, glassy vitrophyre, 1184 ft (C2)



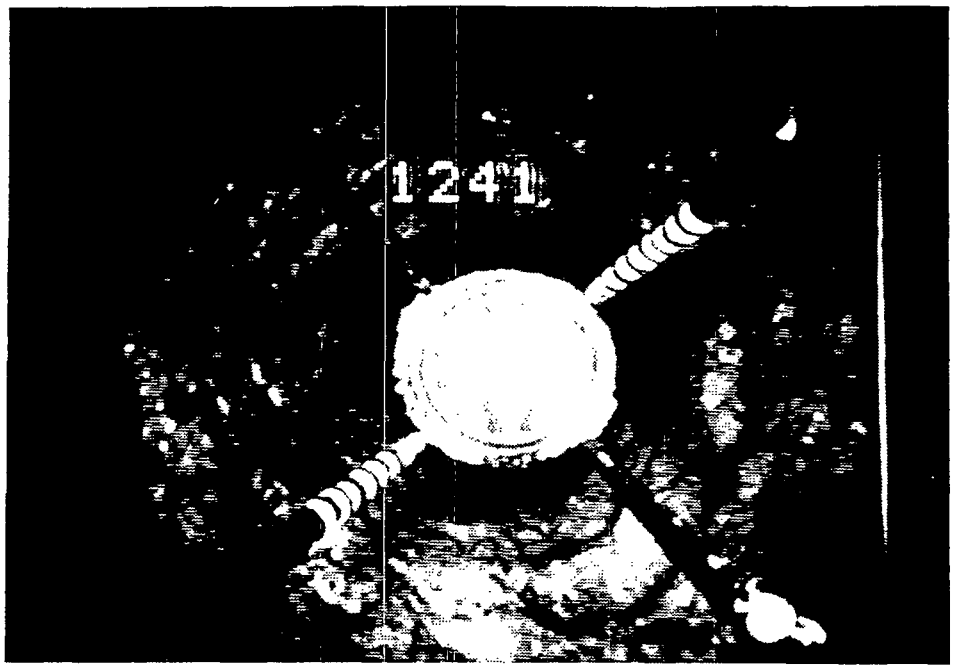
USW WT-2, bedded/reworked tuff at base of Topopah Spring Member, 1299 ft (C1)



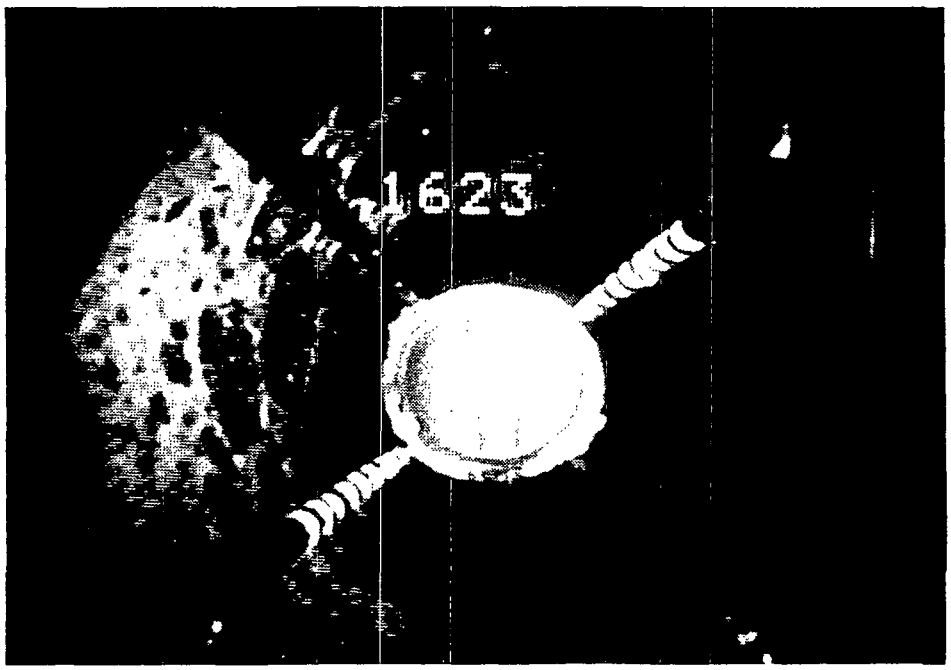
USW WT-2, Calico Hills Member, nonwelded, vitric, 1460 ft (C1)



USW G-4, Calico Hills Member, nonwelded to partly welded, zeolitic, 1416 ft (C3)



UE-25 WT#18, Topopah Spring Member, densely welded, devitrified, 1241 ft (C2)

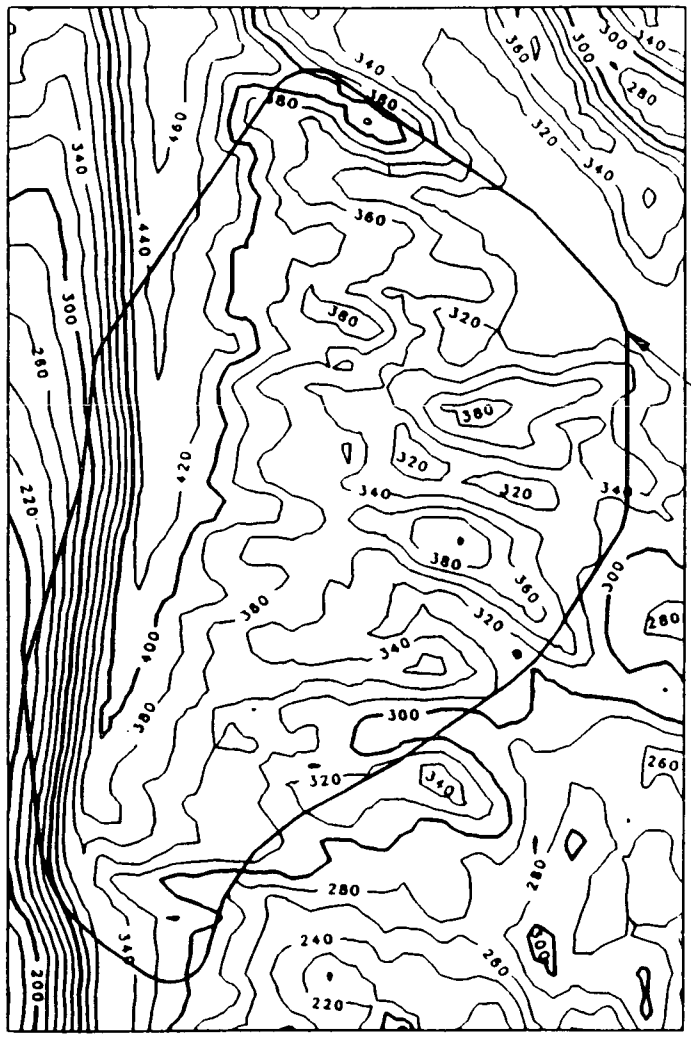


UE-25 WT#18, Calico Hills Member, lava, devitrified, partly zeolitic, 1623 ft (C1)

Generalization of Hole Condition

- Densely welded, devitrified tuff in Tiva Canyon and Topopah Spring, high percentage of Category 3 and 4
- Paintbrush nonwelded tuff, typically Category 1
- Upper portion of Topopah Spring, typically Category 1 and 2
- Calico Hills nonwelded vitric and zeolitic, typically Category 1 and 2

Variability in Rock



MODELS

- Thickness model
- Travel - time model
- Conductance model

ASSUMPTION ON ROCK PROPERTIES

High Intermediate Low

CONCLUSIONS

- Little variability in model provided one set of rock properties considered

FOCUS

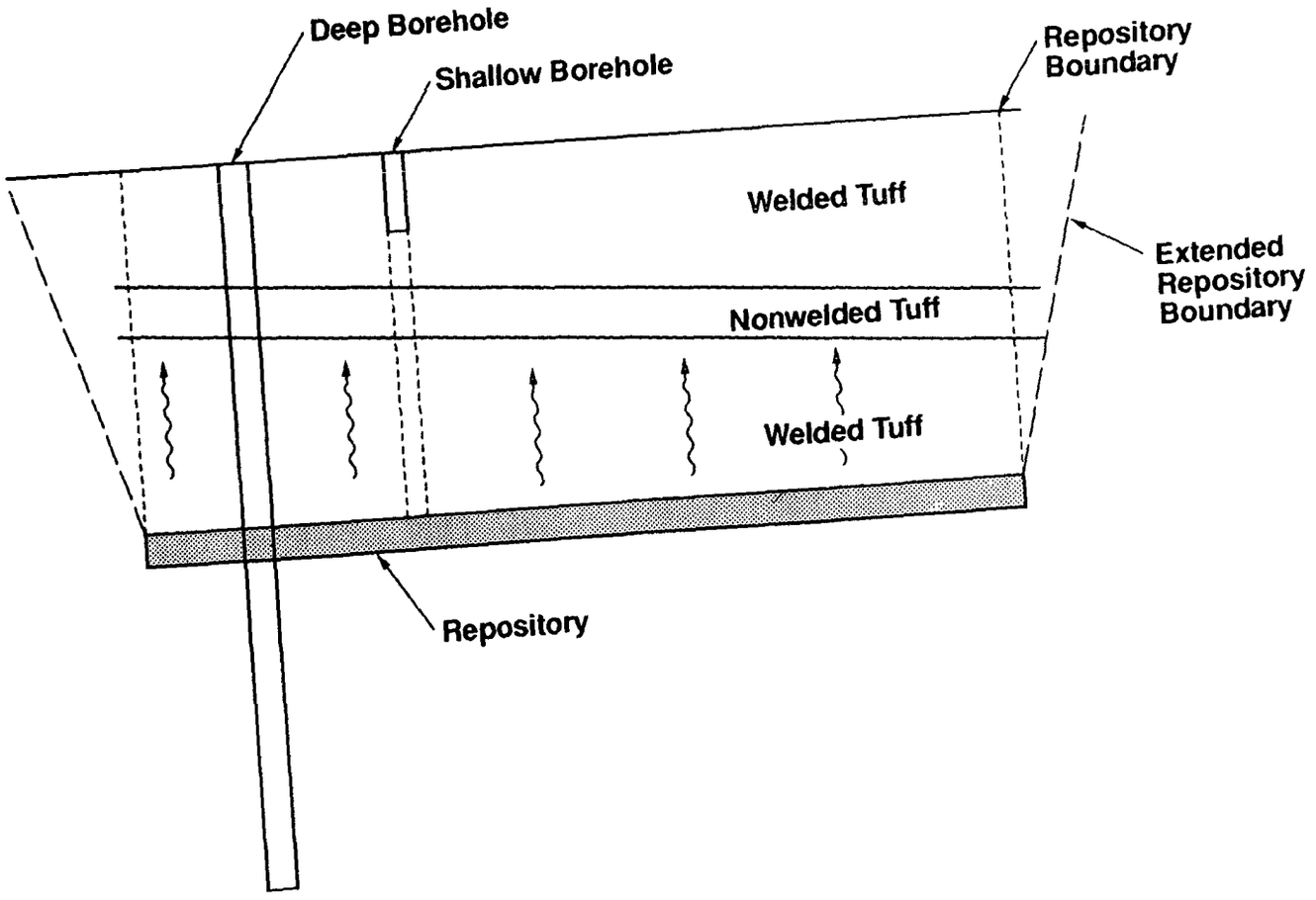
- Develop a common sealing strategy for all boreholes acknowledging variations in some rock properties

Purpose of Performance Calculation

- Establish significance of boreholes potentially contributing to repository performance
  - Air dispersion from repository
  - Flooding from drift
- Establish comparative significance of boreholes
  - Airflow
  - Flooding

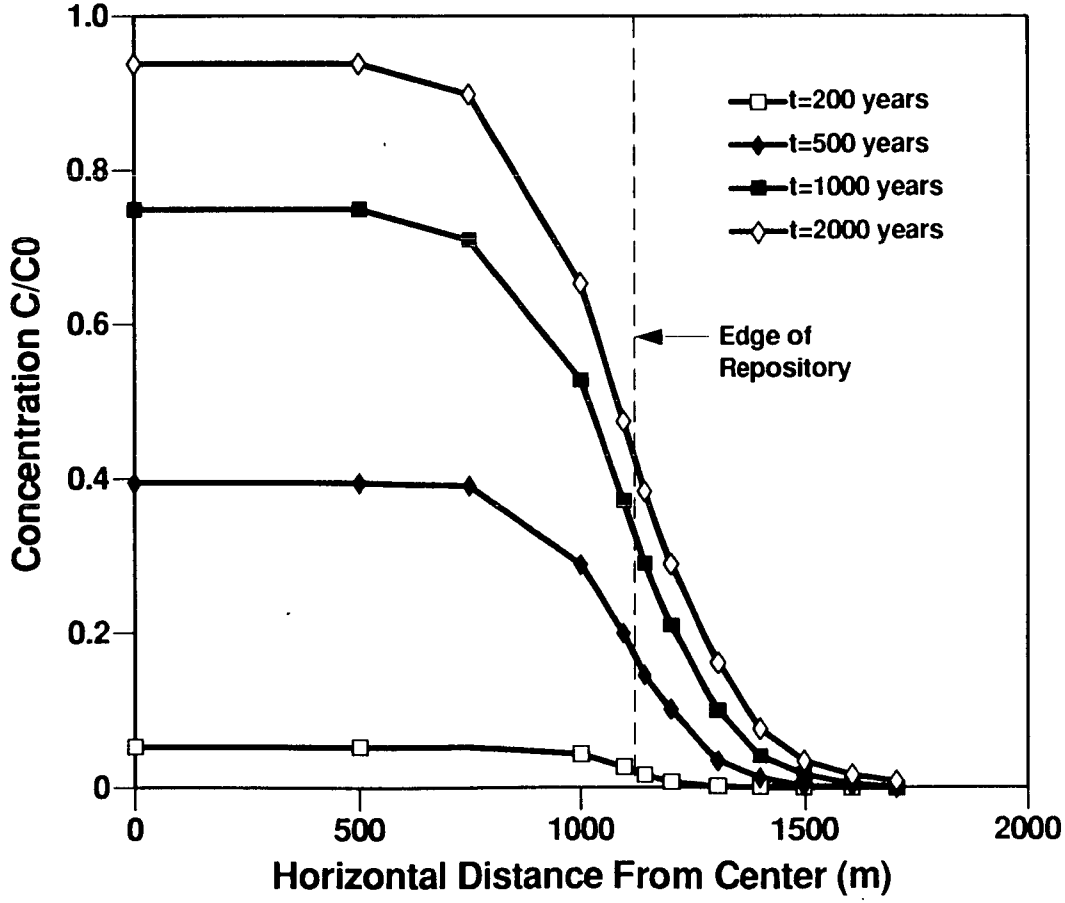
Air Dispersion From Repository

- How far from the repository boundary does air disperse?



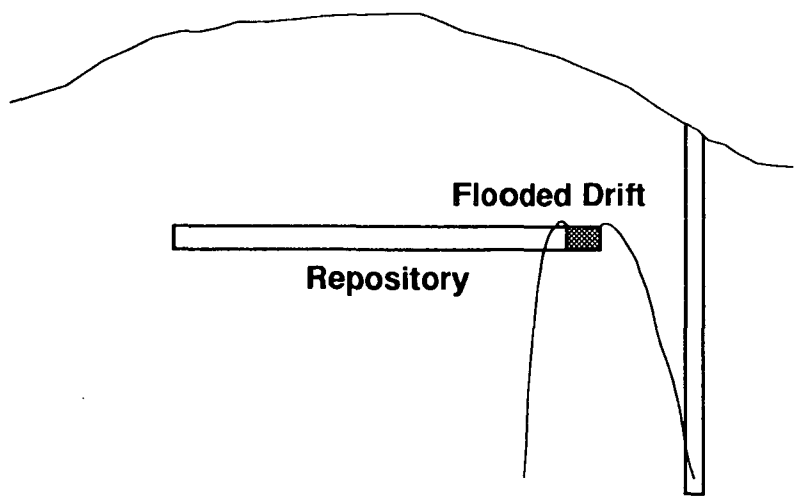
Concentration vs. Distance

Concentration vs. distance at various times at a vertical distance of 300 m (longitudinal dispersivity - 100 m, transverse dispersivity = 100 m, fluid velocity = 0.37 m/year for model 1).



Flooding From Drift

- How far does water from a potentially flooded drift migrate from the edge of the repository?



Water Flow From a Repository Drift

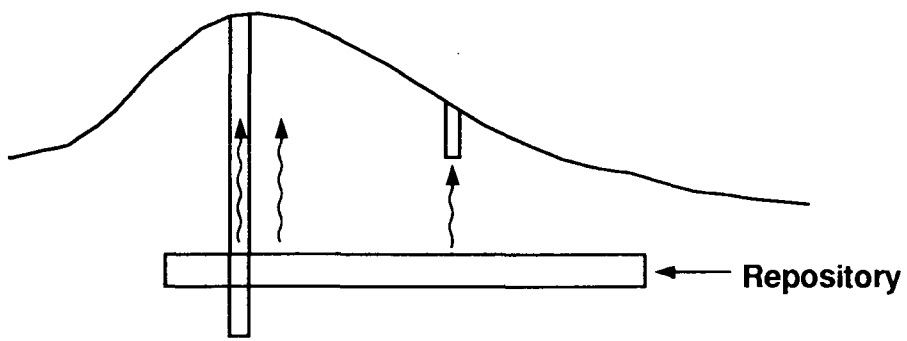
- Approach: Maximize lateral extent of water plume from drift by:

  - Maximizing frequency of low-angle fractures
  - Minimizing frequency of high-angle fractures

- Result: Maximum extent 20° out from repository boundary

Significance of Boreholes - Airflow

- What is the comparative significance of all boreholes with respect to airflow?



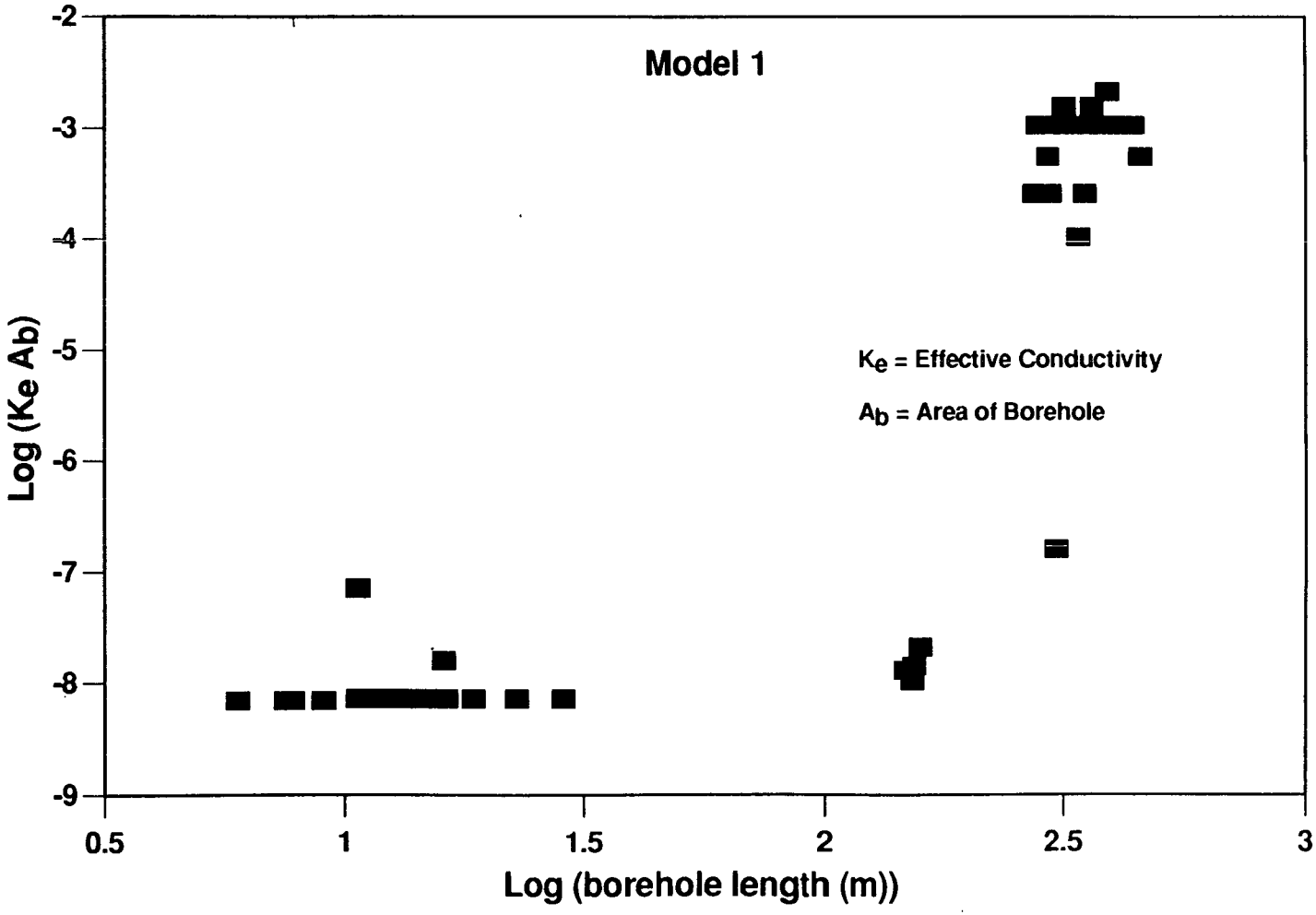
Comparative Significance of Boreholes - Airflow

- Shallow boreholes
  - Air flow occurs through rock web, then
  - Air flow occurs through a backfilled hole
- Deep boreholes
  - Air flow occurs through a backfilled hole assumed to intersect the repository
- Calculate equivalent conductivity using the harmonic mean relationship

$$\frac{t}{k_e} = \frac{t_1}{k_1} + \frac{t_2}{k_2} + \frac{t_3}{k_3} + \frac{t_s}{k_s}$$

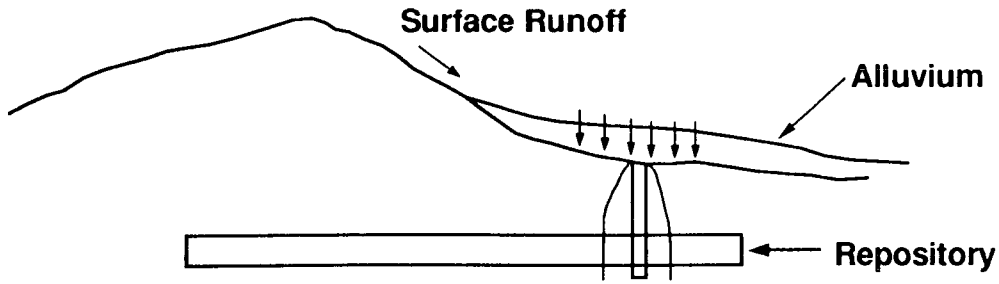
- Select seal conductivity to restrict seal flow to 1% of the total flow

Flow vs. Borehole Length

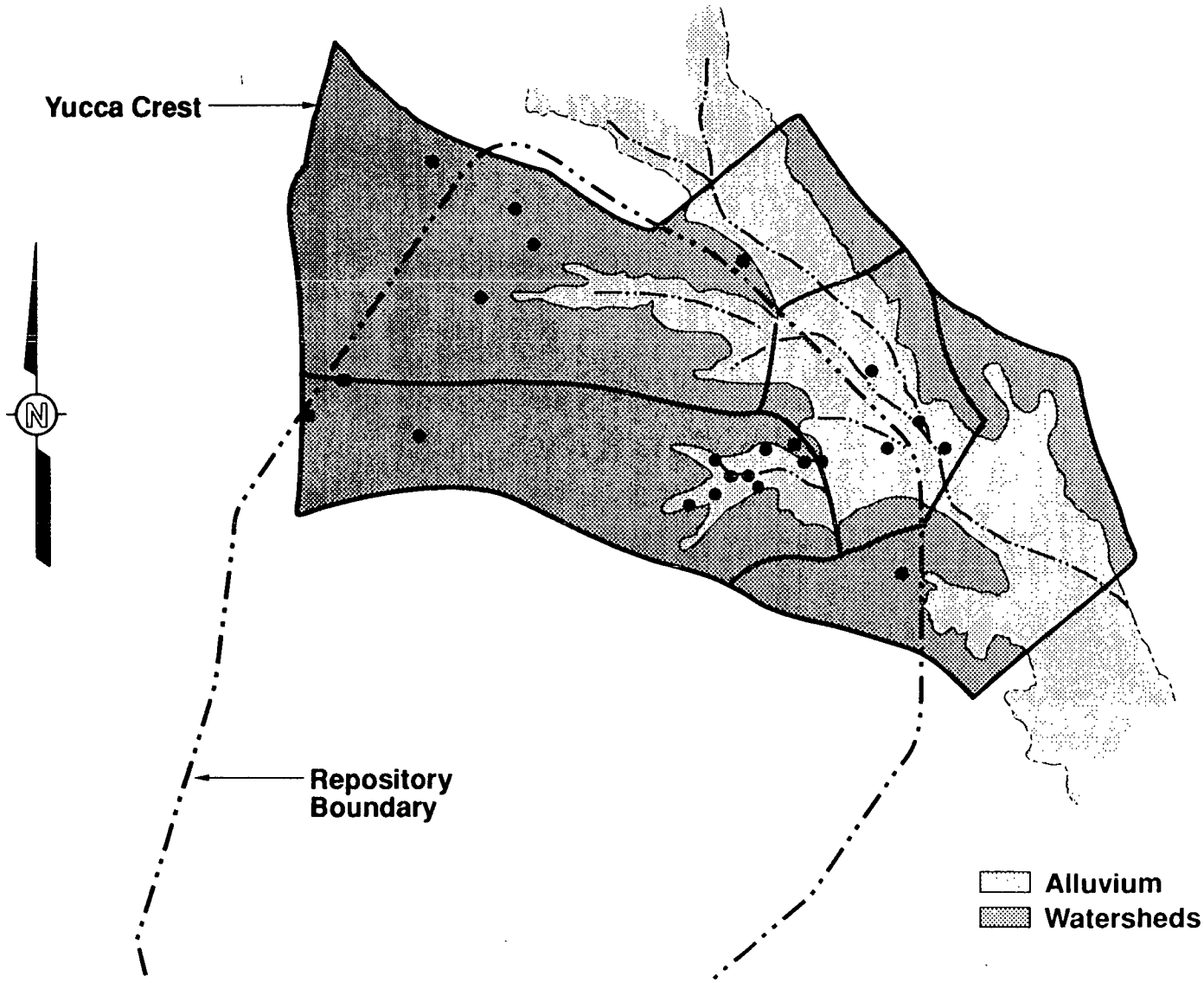


Significance of Boreholes - Flooding

- What is the comparative significance of all boreholes with respect to surface flooding?



Borehole Locations for Borehole Flooding Analysis



Results of Borehole Flooding Calculations

- Existing holes divided into three categories
  - Boreholes within the broad alluvial terraces containing incised channels subject to flooding
  - Boreholes within steeper areas are much less likely to flood
  - Boreholes outside flood zones are not subject to flooding
- Proposed boreholes not subject to flooding
- Deep boreholes are far more significant in enhancing water flow
- Sealing holes eliminates potential flooding of deep holes

Summary of Results From Performance Calculations

Limit of Significance

- **Airflow**
  - ~ 500 - 600 m from northern and southern edge
  - ~ 50 - 60 m from eastern and western edge

- **Waterflow**
  - ~ 20° from vertical and away from repository edge

Significant Boreholes

- **Airflow**
  - Shallow holes less significant by 5 to 6 orders of magnitude

- **Waterflow**
  - Deep boreholes potentially more significant than shallow holes
  - Limited number of boreholes of concern