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

NUCLEAR WASTE TECHNICAL REVIEW BOARD
FULL BOARD MEETING

SUBJECT: CONCEPTUAL MODEL OF FLOW IN THE UNSATURATED ZONE: NEW INSIGHTS

PRESENTER:	**DENNIS R. WILLIAMS**	**BO BODVARSSON**
PRESENTER'S TITLE AND ORGANIZATION:	**DEPUTY, AMSP U.S. DEPARTMENT OF ENERGY LAS VEGAS, NV**	**STAFF SCIENTIST LAWRENCE BERKELEY NATIONAL LABORATORY BERKELEY, CA**
TELEPHONE NUMBER:	**(702) 794-1417**	**(510) 486-4789**

ARLINGTON, VA
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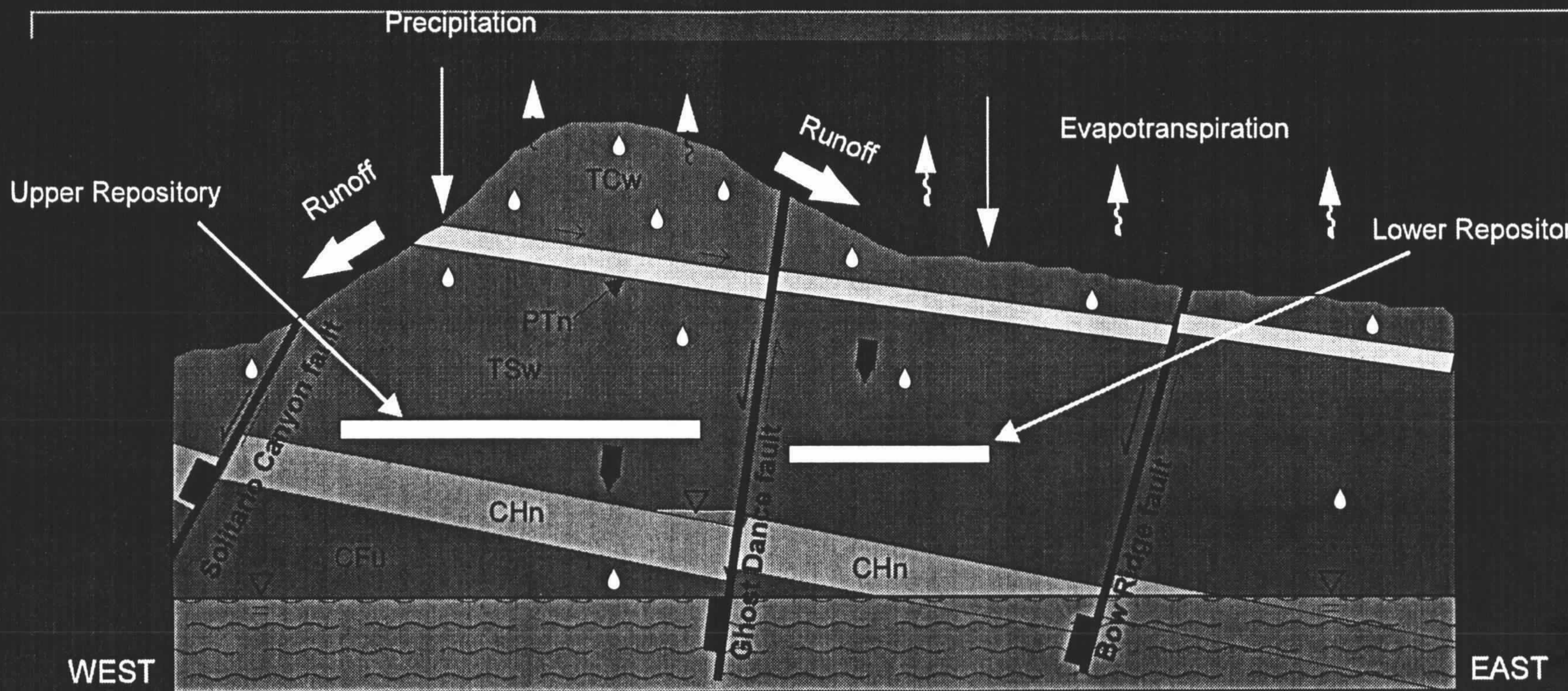
Outline

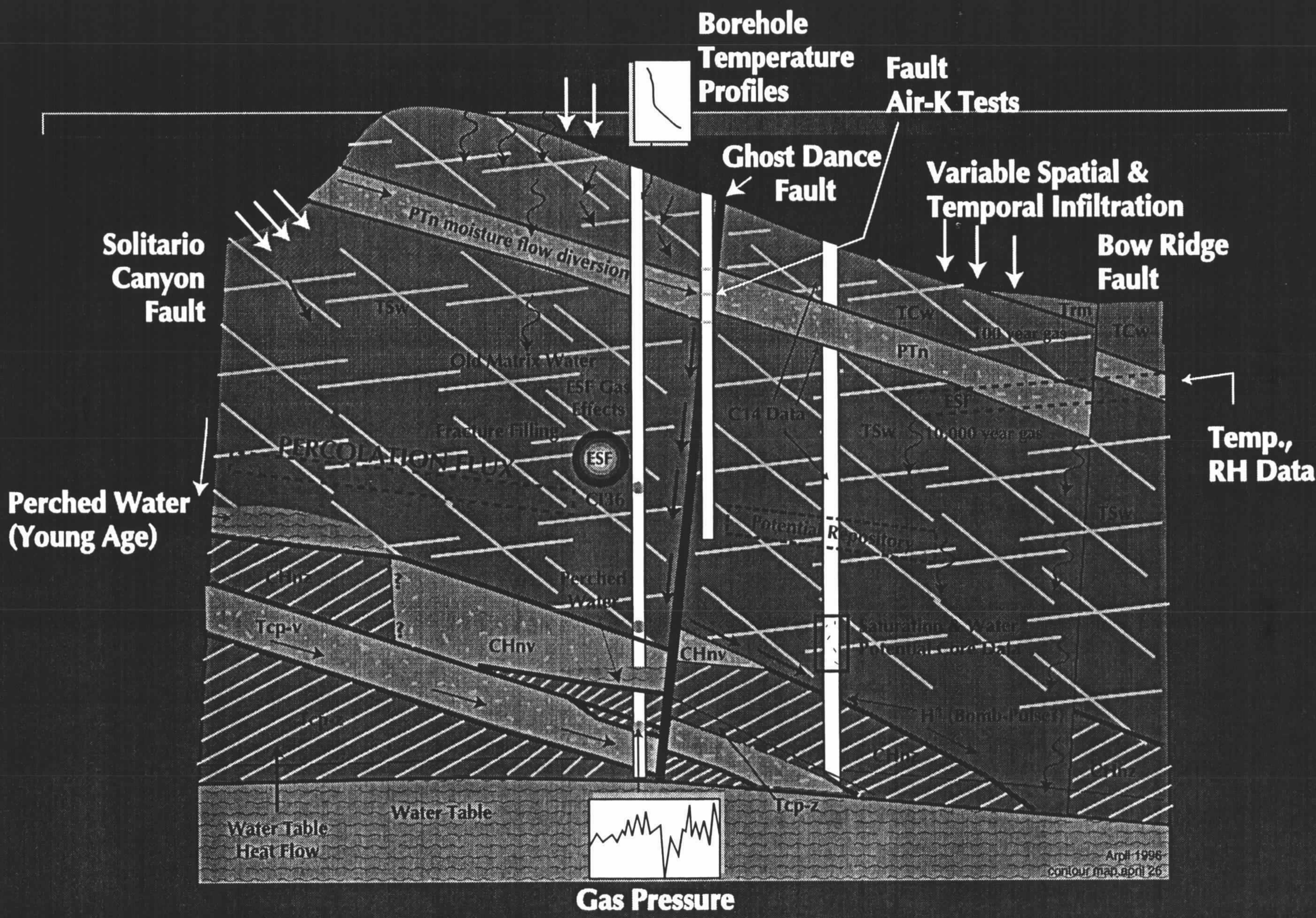
- Introduction
- Conceptual Model of UZ
- UZ Data Collection Activities
- Data Interpretation and Modeling
- Implications of Alternative Conceptual Model
- Uncertainties
- Plans for Future Work
- Conclusion



TCw Tiva Canyon Welded Unit
PTn Paintbrush Nonwelded Unit
TSw Topopah Spring Welded Unit
CHn Calico Hills Nonwelded Unit
CFu Crater Flat (Undifferentiated) Unit

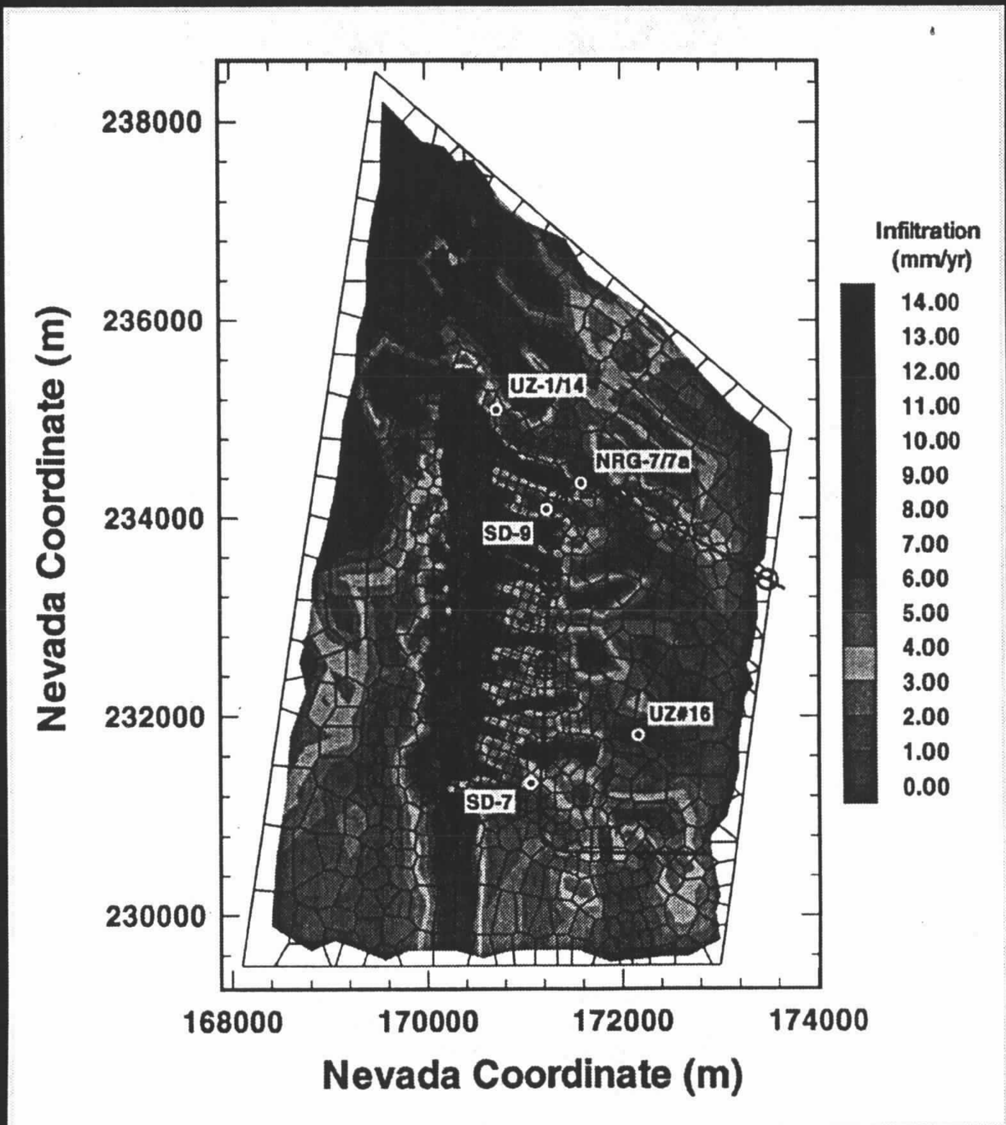
Liquid-water flow
Water-vapor flow
Discontinuous perched water
Normal Fault
Water Table

Conceptual model of Montazer & Wilson (1984)



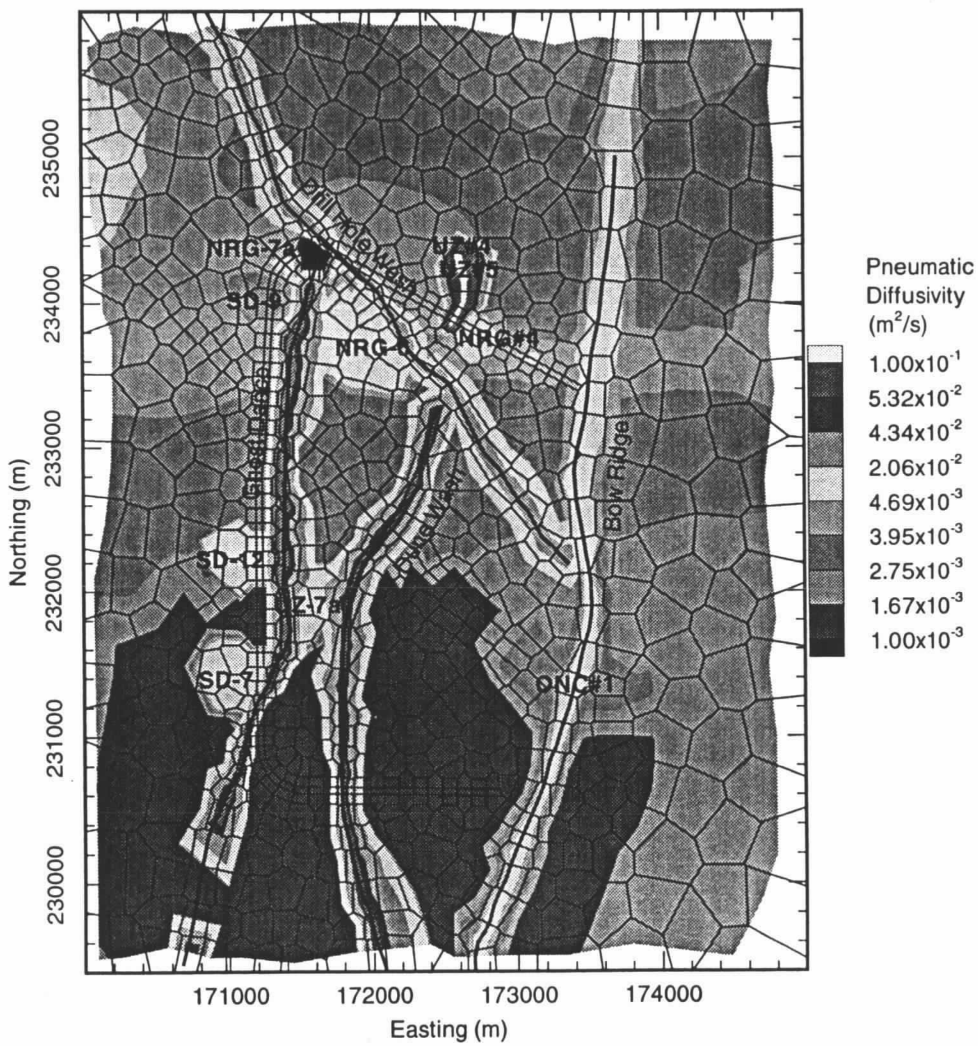
Data and processes defining the conceptual UZ flow model
(Bodvarsson & Bandurraga, eds., 1996)

Infiltration



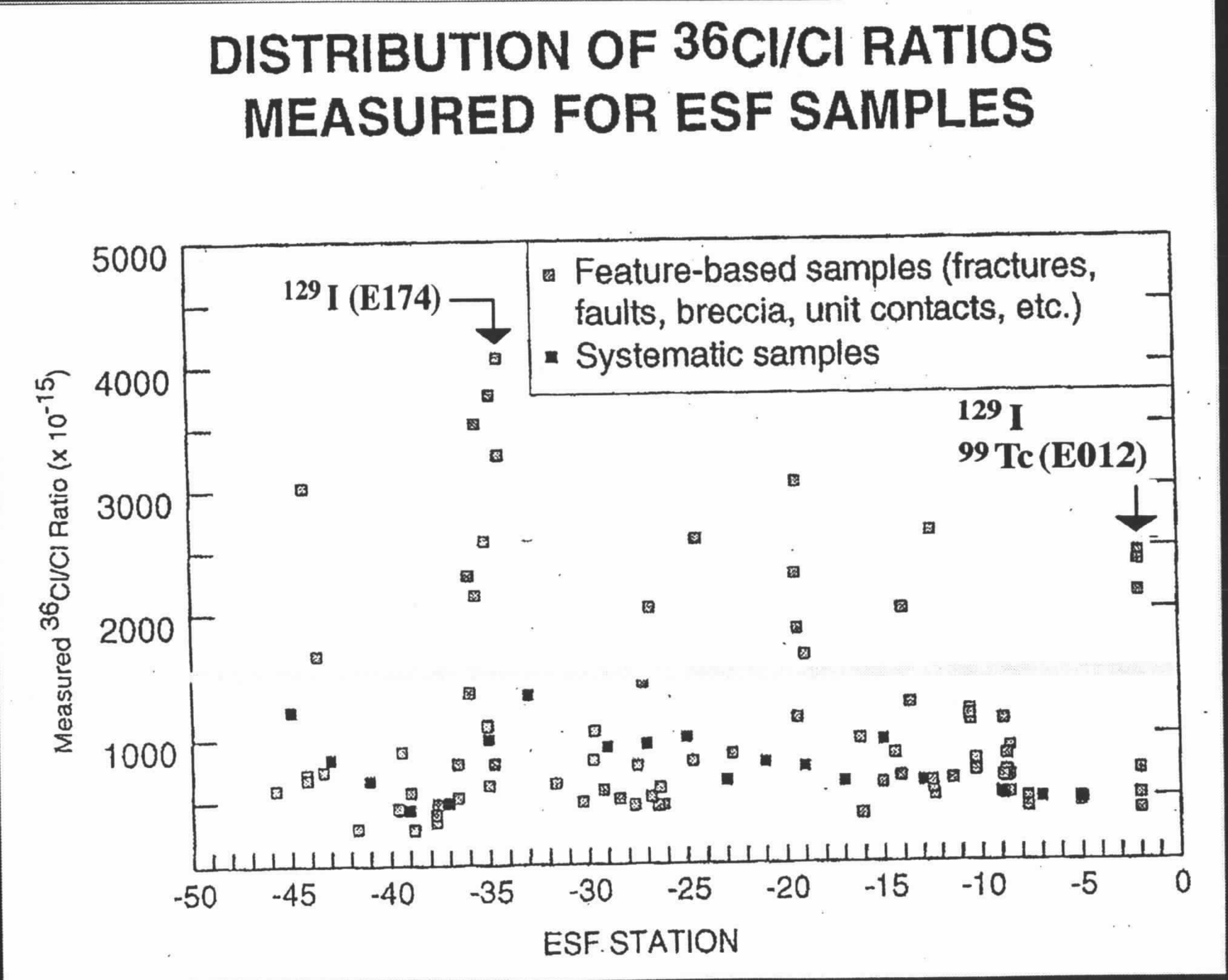
Most recent infiltration map of Yucca Mountain (Flint et al., 1996)

Pneumatic Data



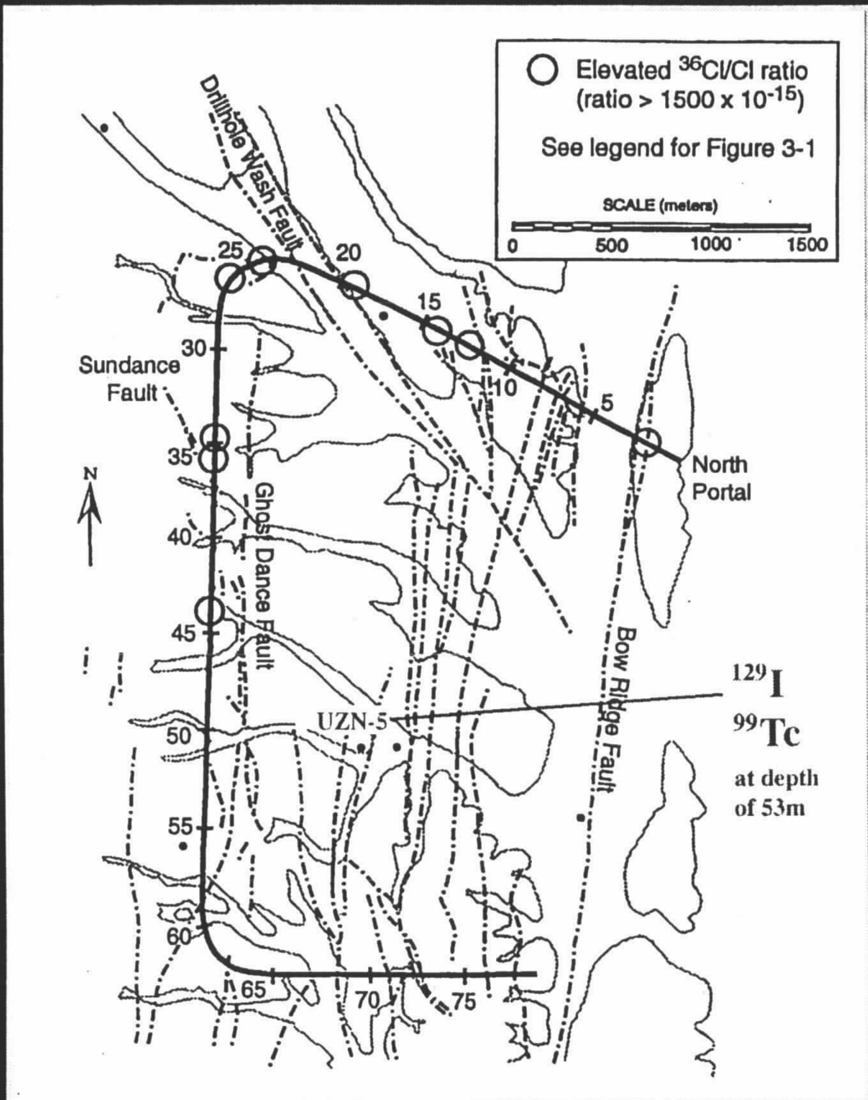
Pneumatic diffusivity map of repository horizon showing increased pneumatic diffusivity along faults (Ahlers et al., 1996)

^{36}Cl Data



Concentrations of ^{36}Cl in ESF, showing location of elevated ^{129}I and ^{99}Tc (Fabryka-Martin, preliminary data, 1996). Samples with ratios exceeding 1500×10^{-15} are considered to contain a component of bomb-pulse ^{36}Cl

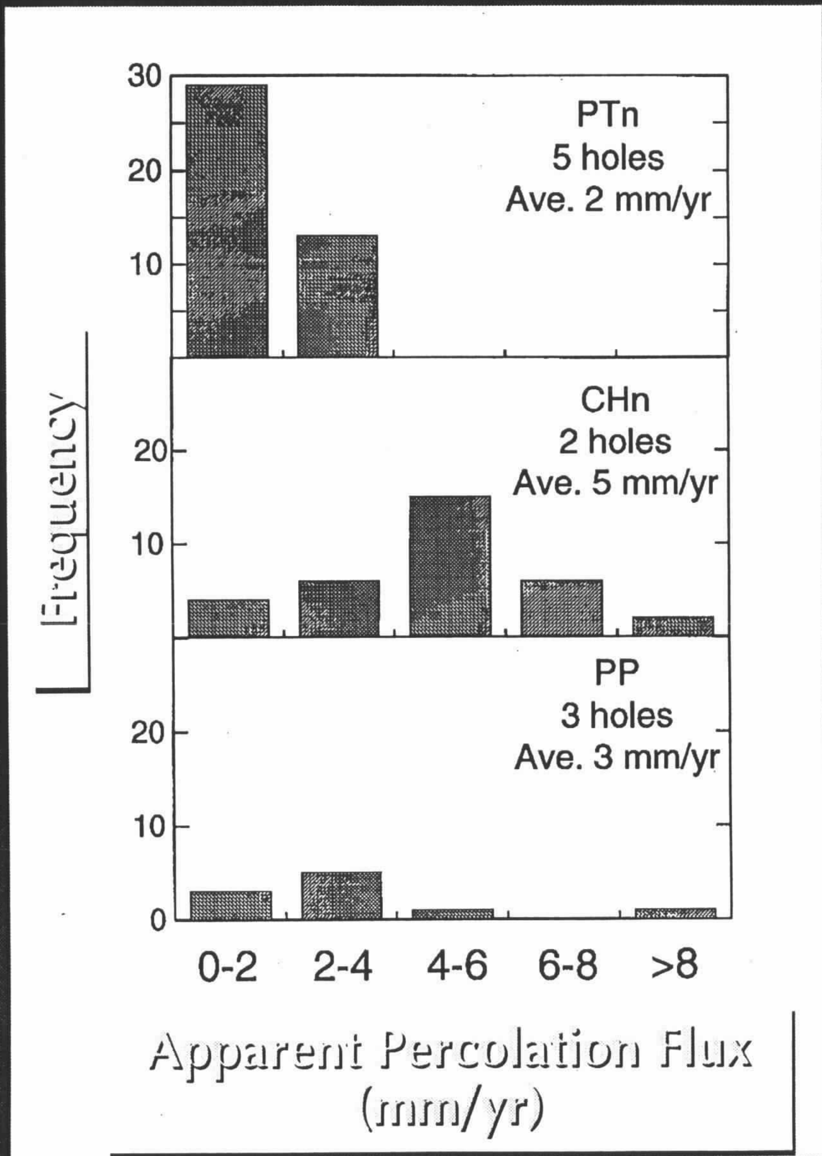
^{36}Cl data



- Identification of fast paths based on distribution of elevated levels of ^{36}Cl
- Indicator of unsaturated-zone percolation rates away from fast paths, based on samples that do not appear to contain elevated levels of ^{36}Cl
- Distribution appears to be influenced by structural control

Map of locations of bomb-pulse ^{36}Cl at repository horizon (Fabryka-Martin et al., 1996)

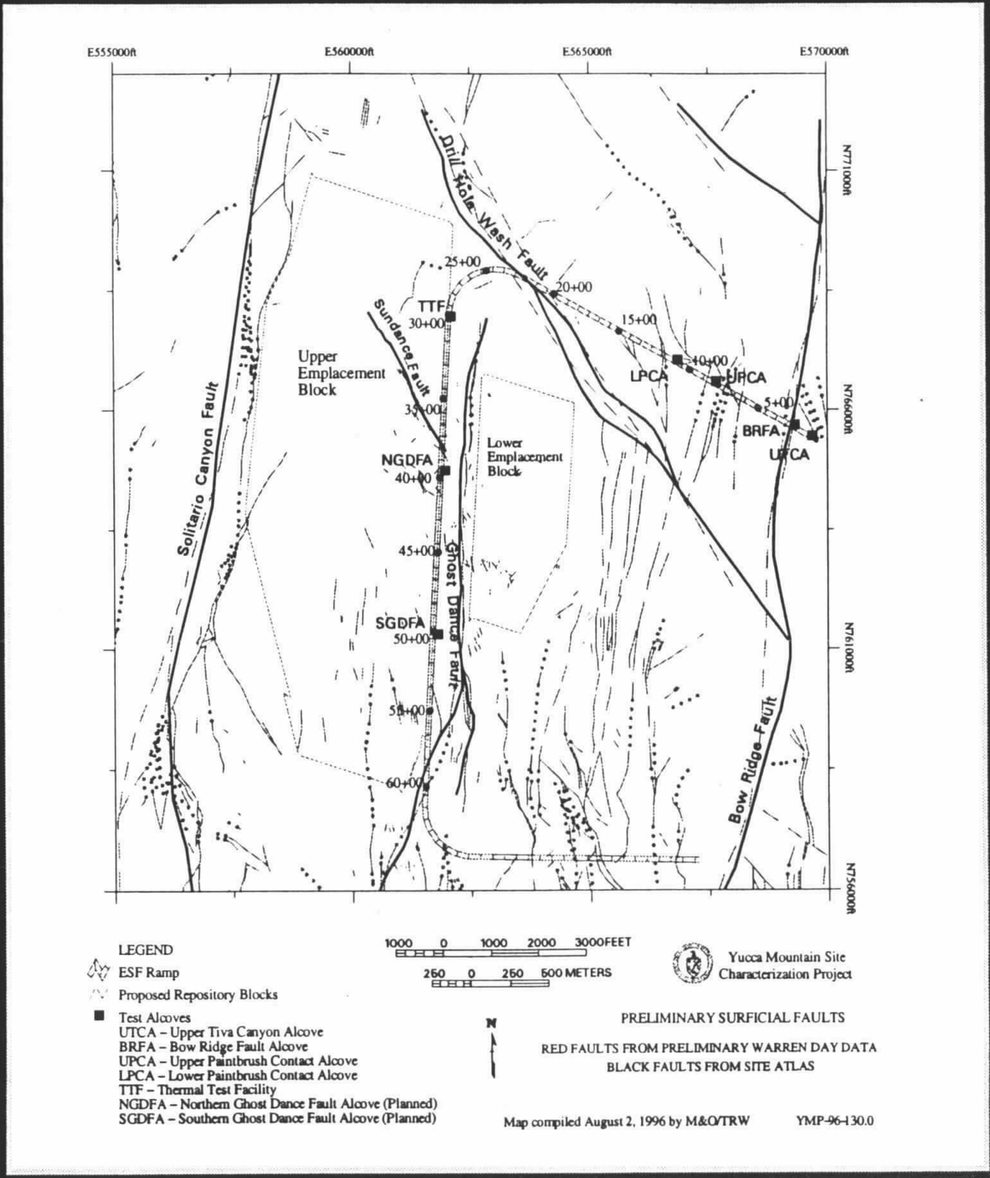
Percolation Flux-Cl Mass Balance



Apparent percolation flux by the chloride mass balance method.

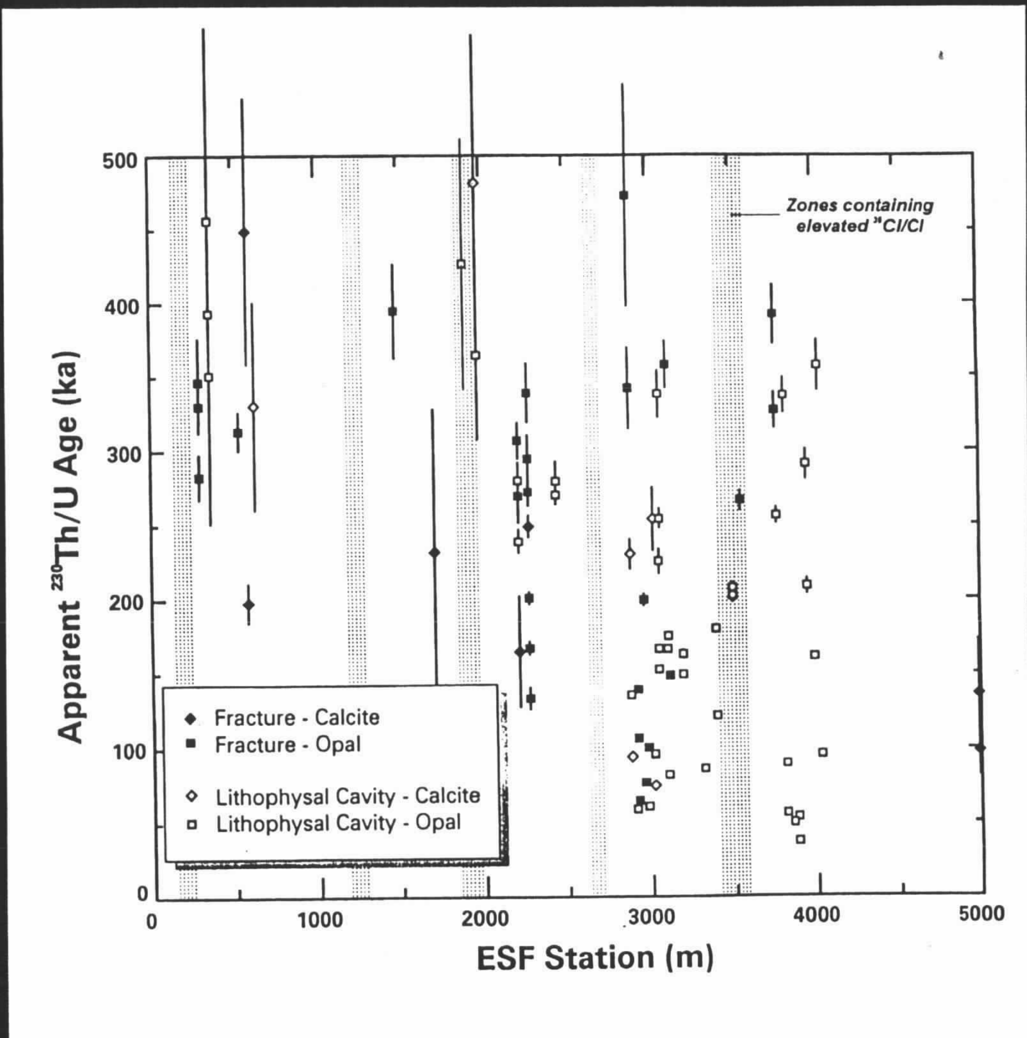
Based on porewater Cl concentrations from Yang et al. (1996); infiltration estimates from Fabryka-Martin et al. (1996)

Fault Map



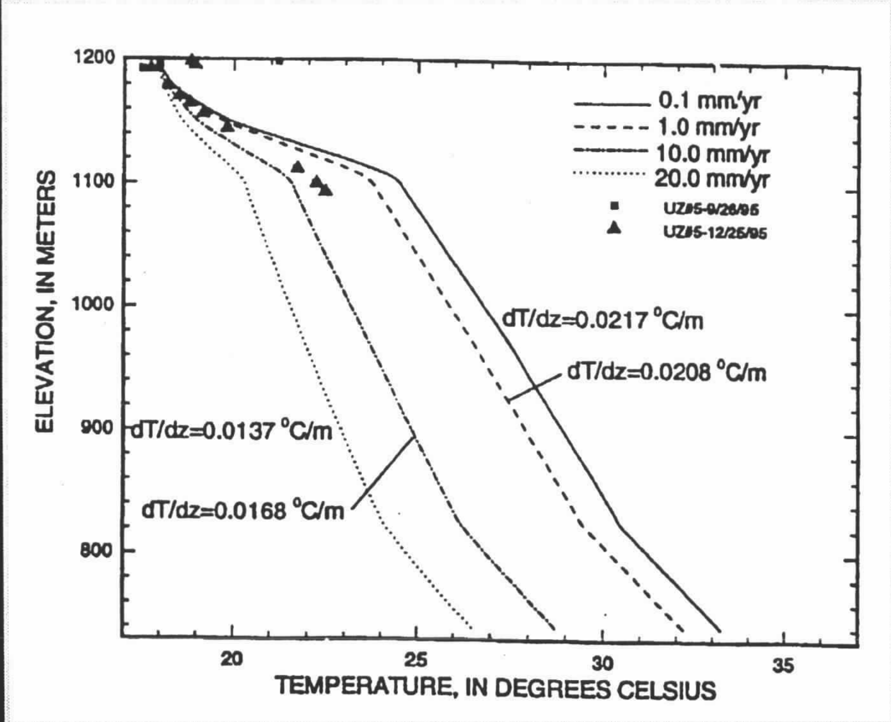
Preliminary surficial fault map of central block from Warren-Day (Day et al., 1996)

Fracture Coating Data (USGS)

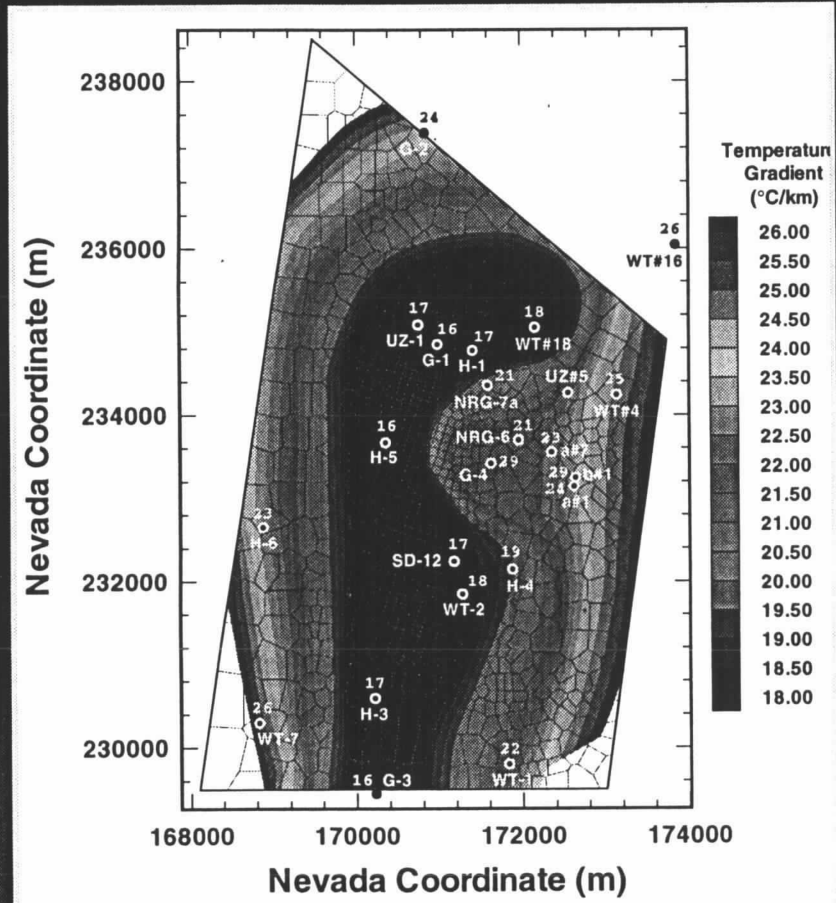


Z. Peterman and J. Paces, preliminary data, 1996

Temperature

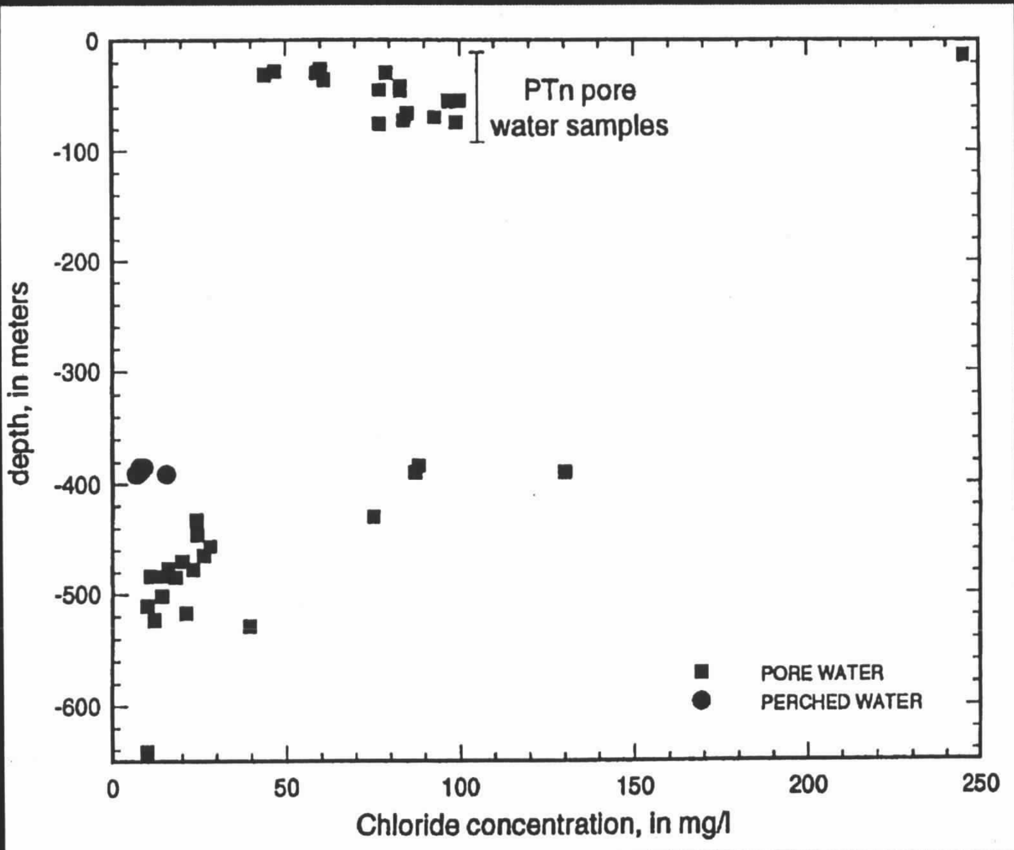


Comparison of measured temperatures at UZ#5 with simulated temperatures using a one-dimensional model and steady-state infiltration fluxes of 0.1, 1.0, 10.0 and 20.0 mm/yr (Rousseau et al., 1996)



Estimated temperature gradient in the TSw based on data from Sass et al. 1988 and Rousseau et al., 1996 (Bodvarsson & Bandurraga, eds., 1996)

Perched Water data



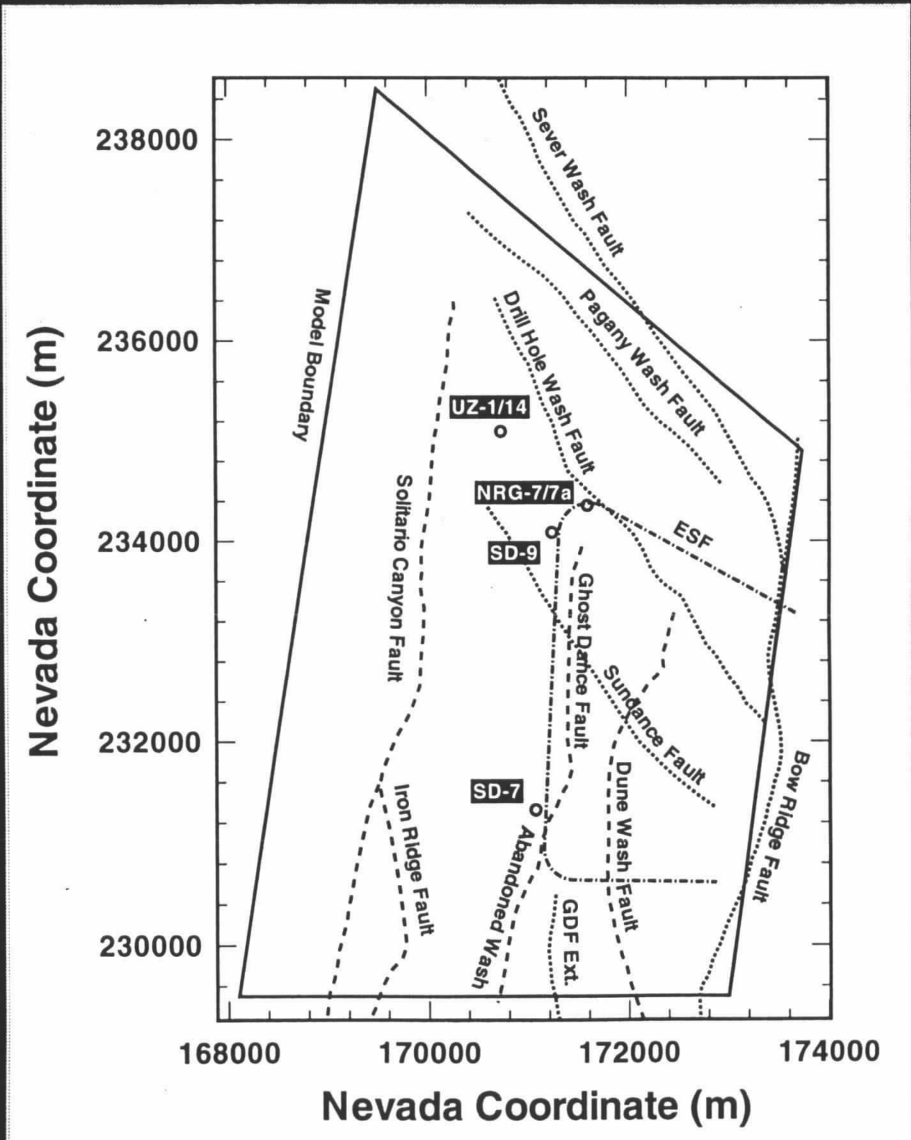
Variation chloride concentration in pore water and perched water (Yang et al., 1996)

- Perched water compositions are out of equilibrium with pore water, showing little fracture/matrix interaction
  - Cl concentration in UZ-14 perched water is 6-15 mg/l
  - Cl concentration in pore water is 87.5 mg/l

Perched Water

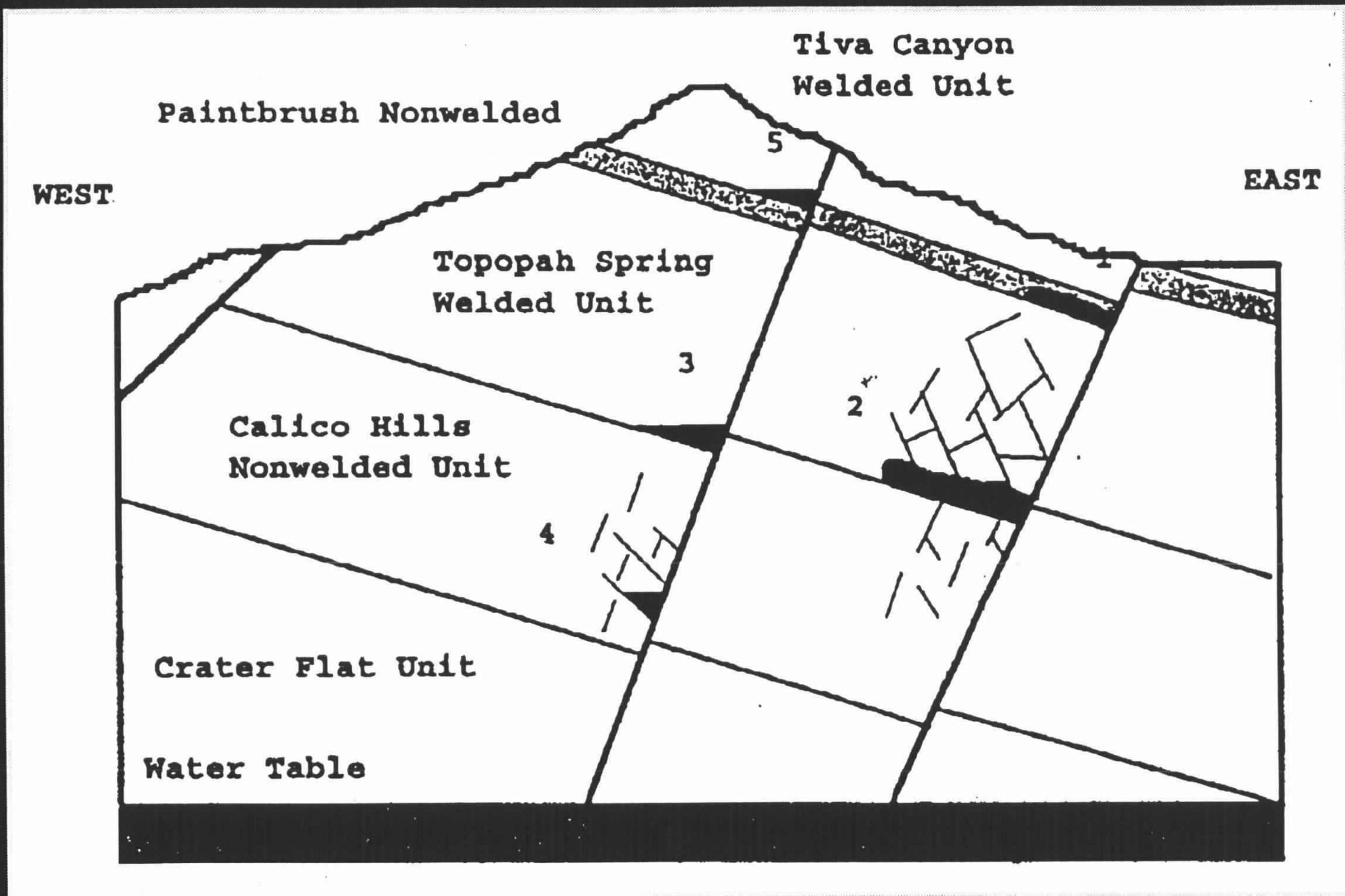
- Pump tests at SD-7 showed perched water volume to be 10^5 liters
- Pump tests at UZ-14 showed minimum perched water volume to be 10^6 liters
- Absolute concentrations of major ions in perched water differ from those of pore water, indicating little interaction with matrix
  - stable isotopes ($\delta^{18}O$ and δD) give residence times of 7000 years, within range of ^{14}C ages
  - tritium concentrations at background levels; no bomb-pulse in perched water

Perched Water (cont.)



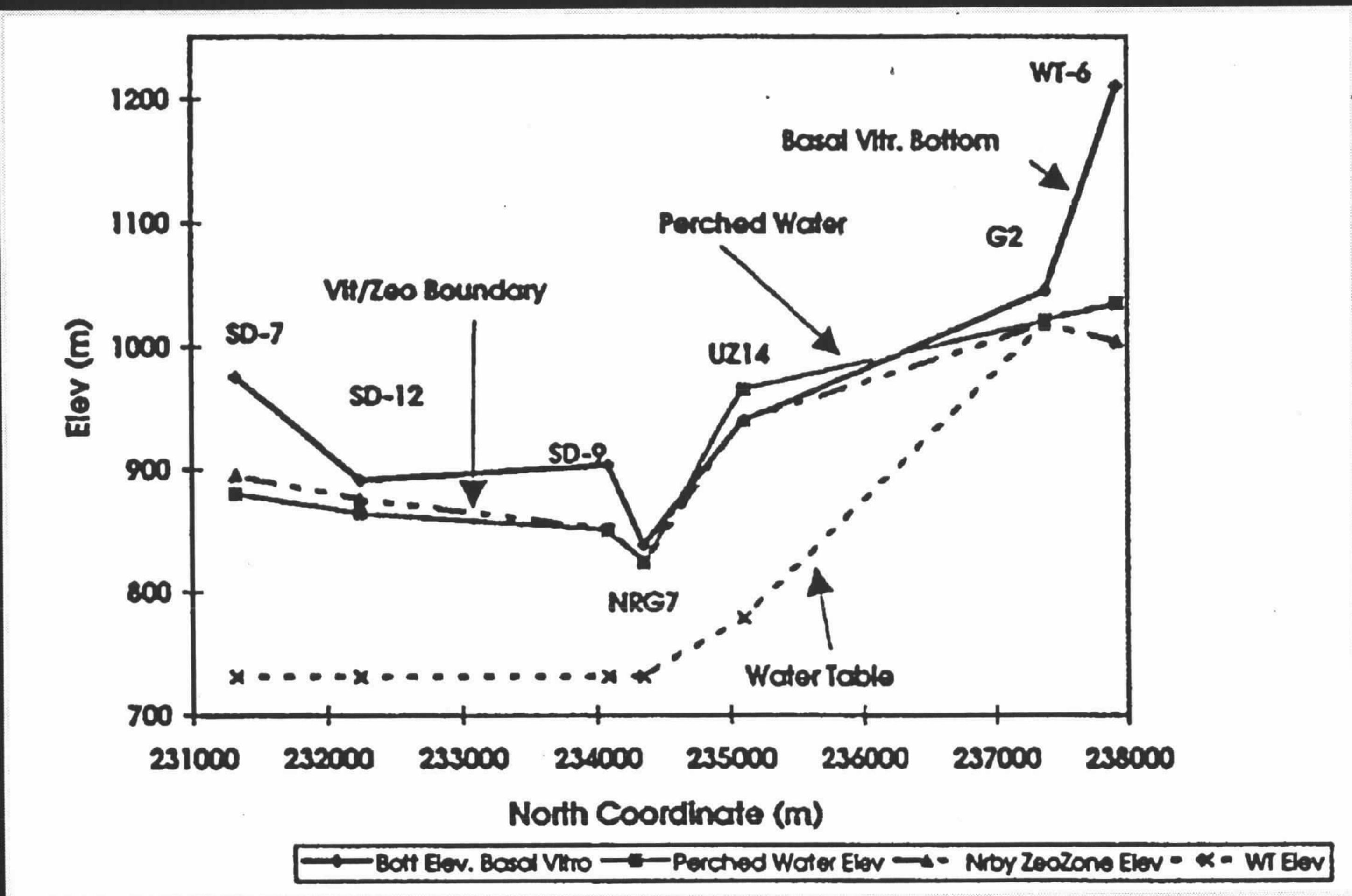
Map of perched water locations in boreholes (Bodvarsson & Bandurraga, eds., 1996)

Perched Water (cont.)



Association of perched water with structural features (from Striffler et al., 1996)

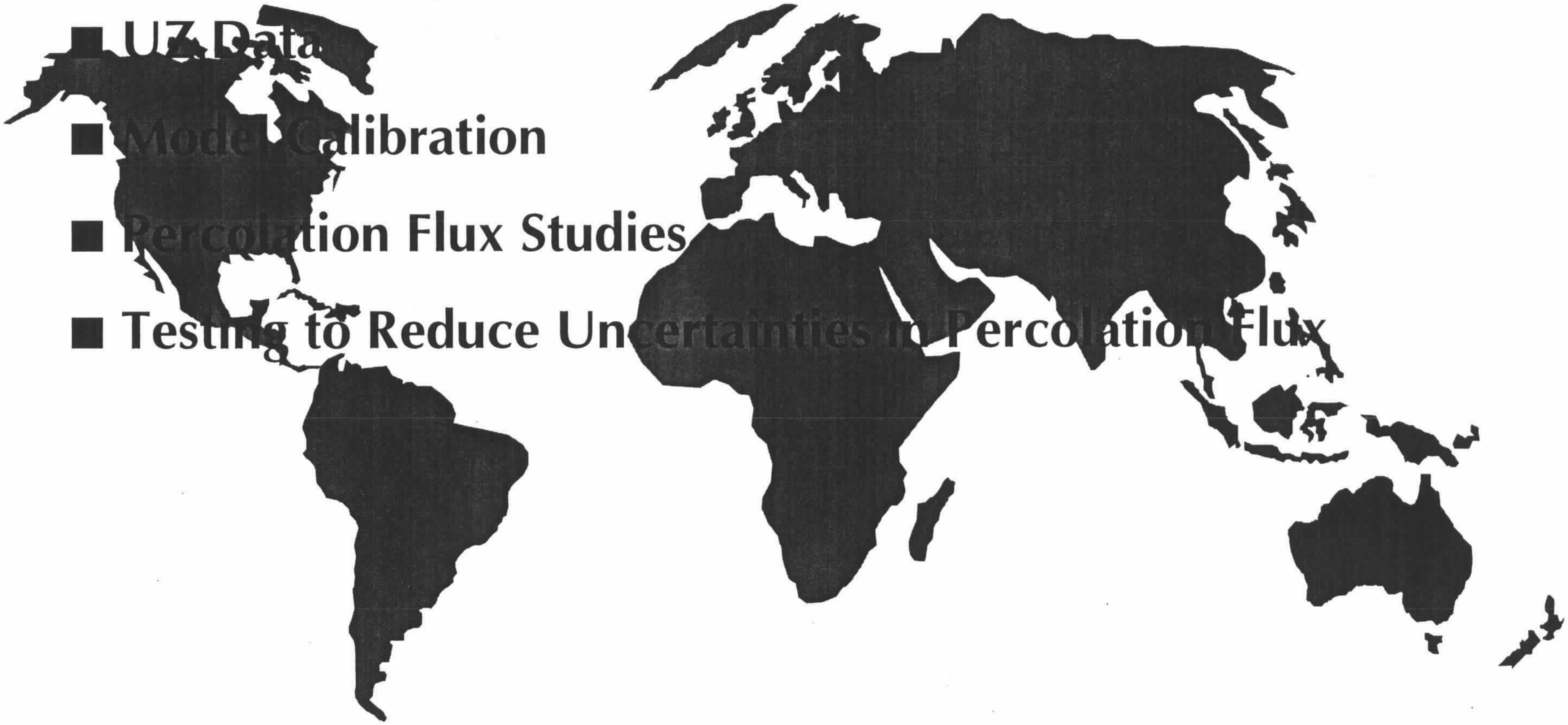
Perched Water (cont.)

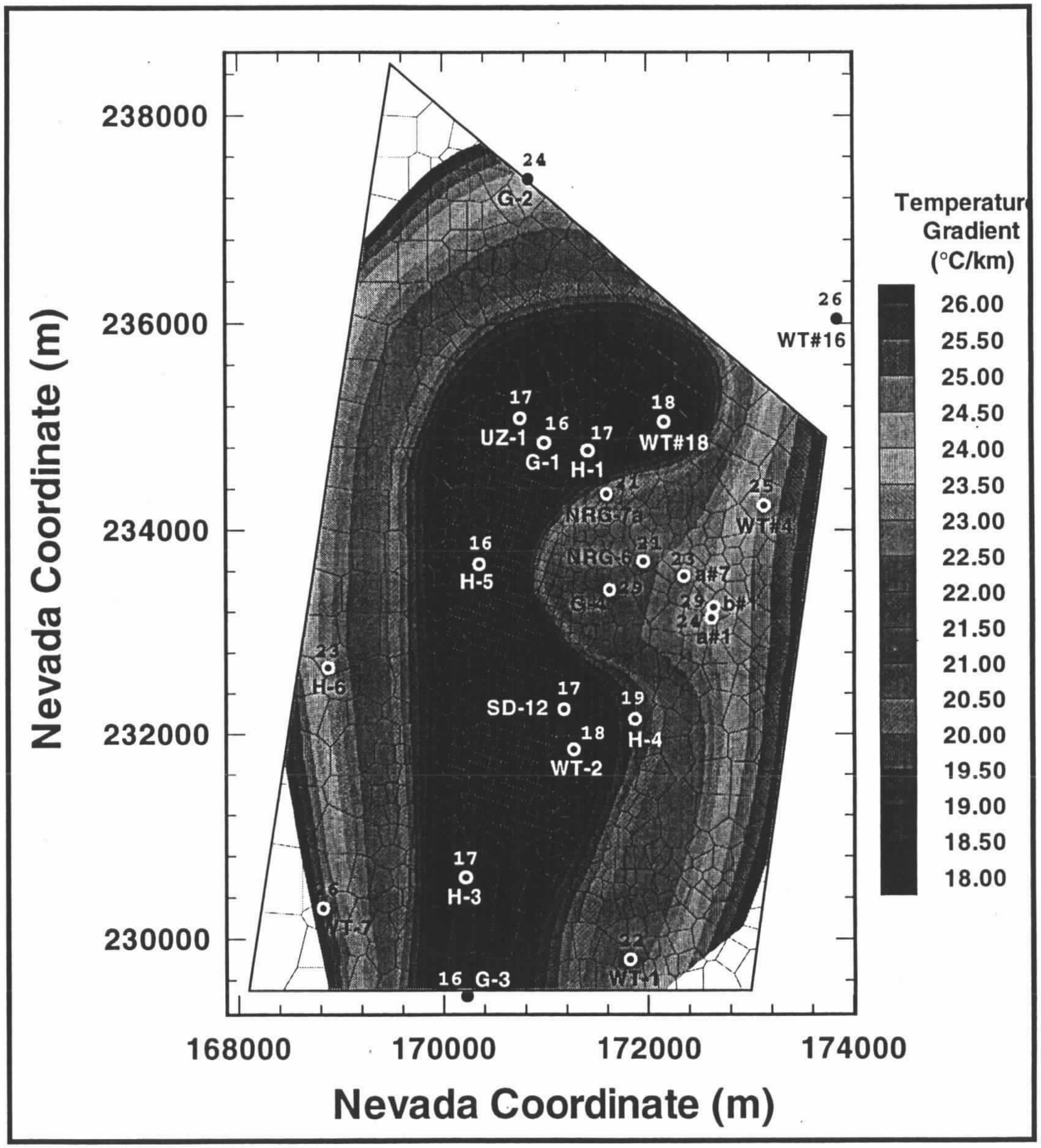


Relationship of perched water to vitric and zeolitic boundaries (Wu in Bodvarsson & Bandurraga, eds., 1996)

Flow Modeling and Percolation

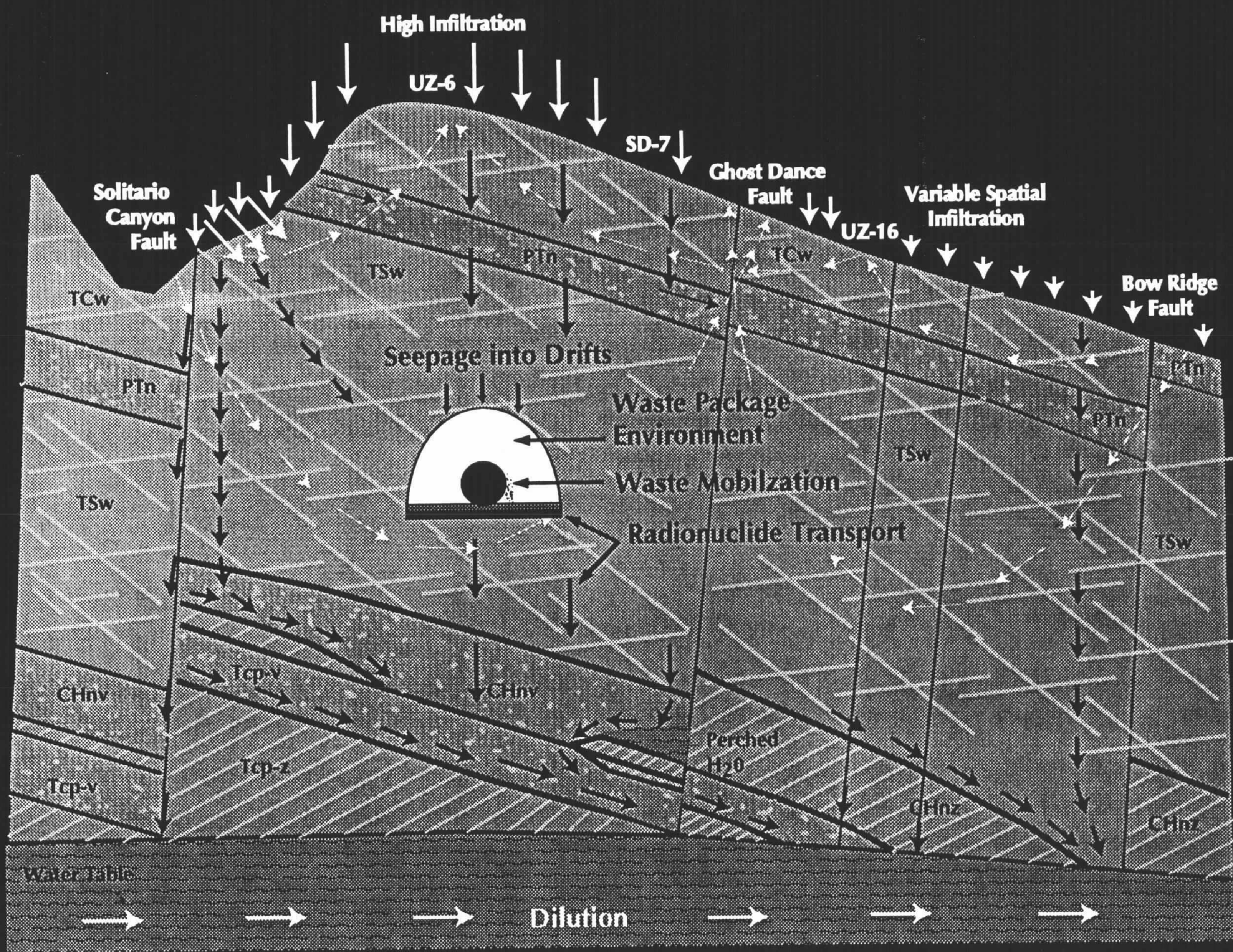
- UZ Model
- UZ Data
- Model Calibration
- Percolation Flux Studies
- Testing to Reduce Uncertainties in Percolation Flux





Temperature Gradient (°C/km)
26.00
25.50
25.00
24.50
24.00
23.50
23.00
22.50
22.00
21.50
21.00
20.50
20.00
19.50
19.00
18.50
18.00
Nevada Coordinate (m)
238000
236000
234000
232000
230000
168000
170000
172000
174000
Nevada Coordinate (m)
24 G-2
26 WT#16
17 UZ-1
16 G-1
17 H-1
18 WT#18
NRG-7a
25 WT#4
16 H-5
NRG-6
G-4
a#1
23 H-6
17 SD-12
19 H-4
18 WT-2
17 H-3
WT-7
16 G-3
WT-1

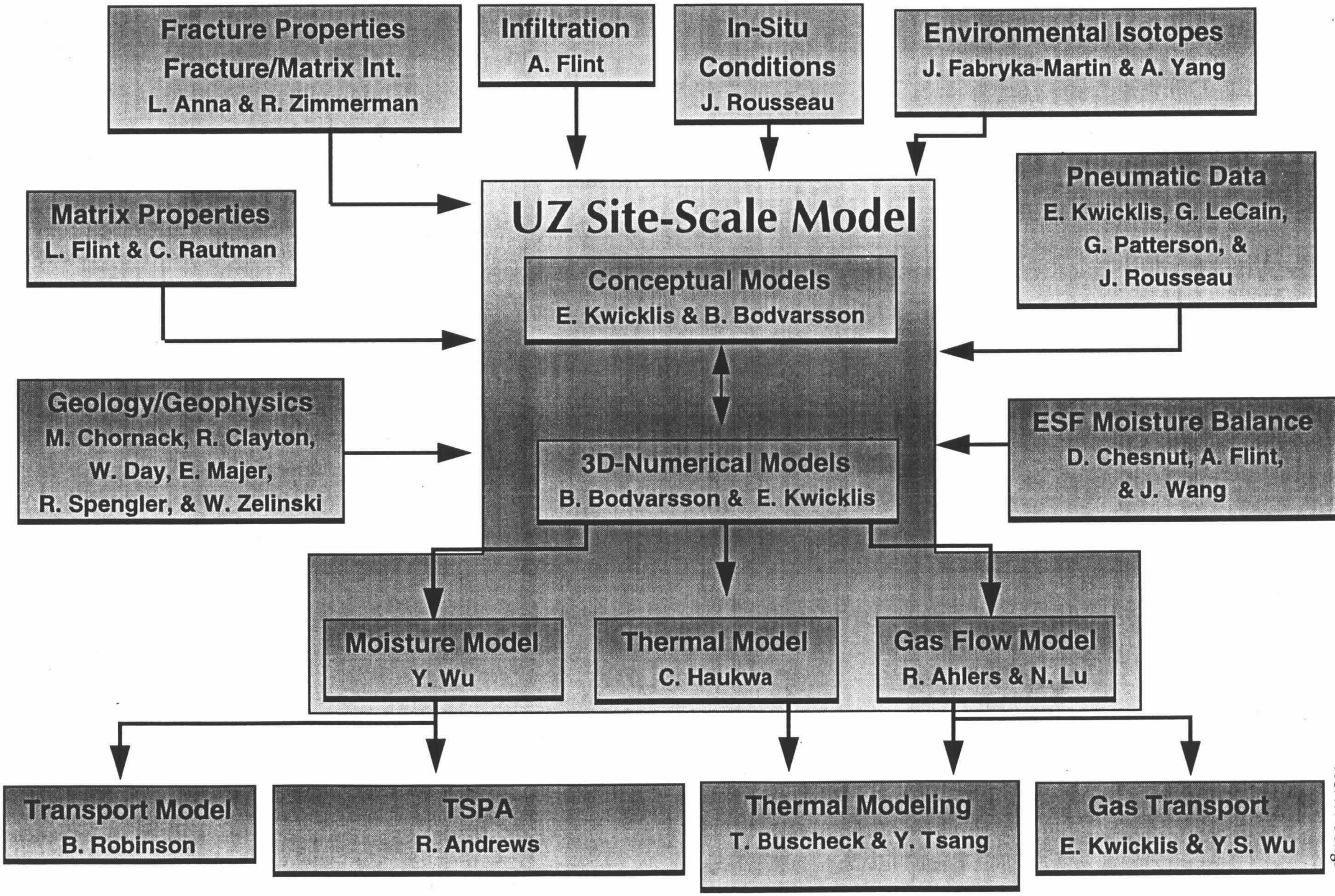
Percolation Flux and Waste Isolation Strategy



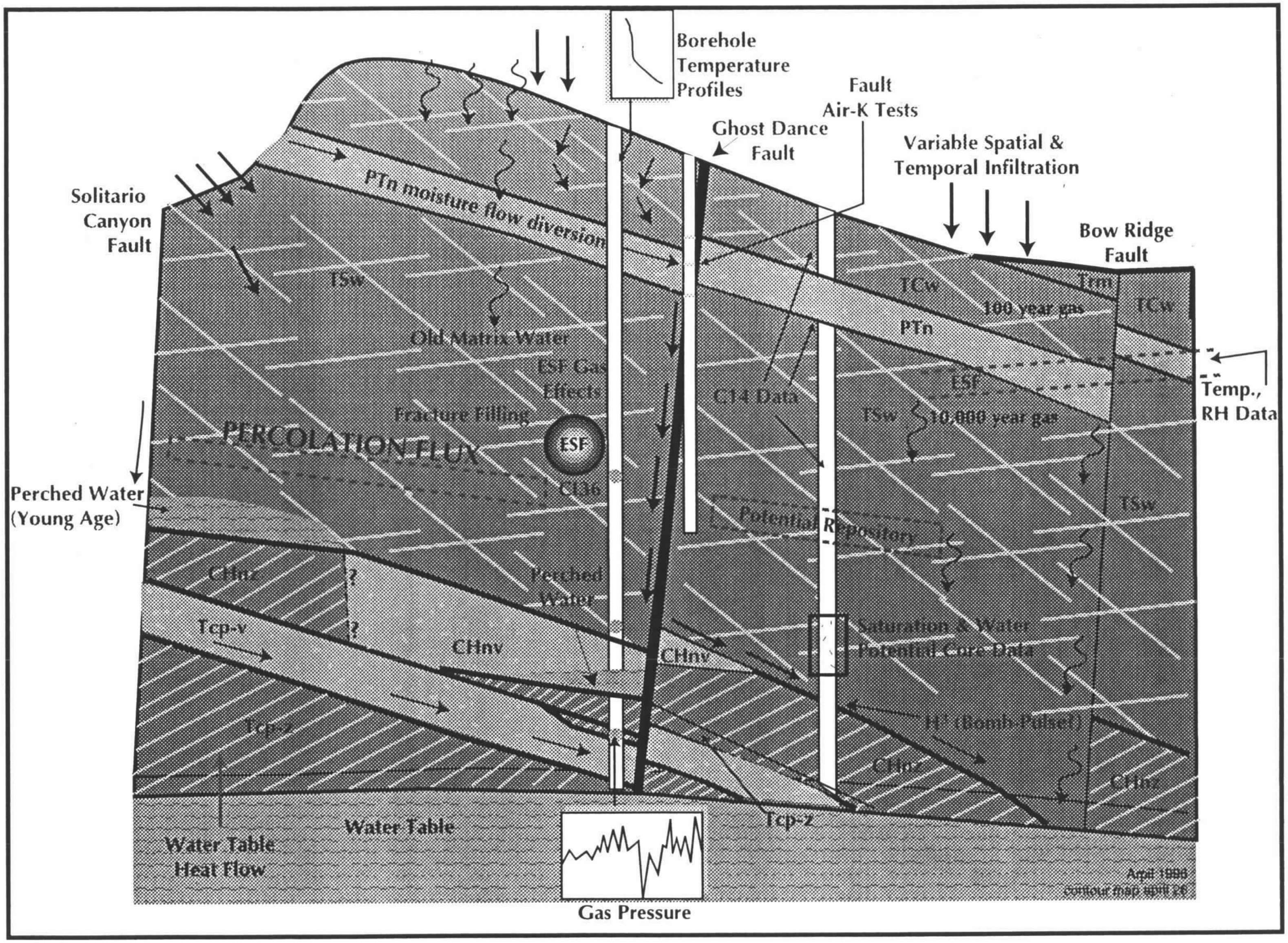
WISxsec

ACNW'96figs

Yucca Mountain Project
UZ Moisture, Gas, Heat and Transport Modeling



ACNW'96figs



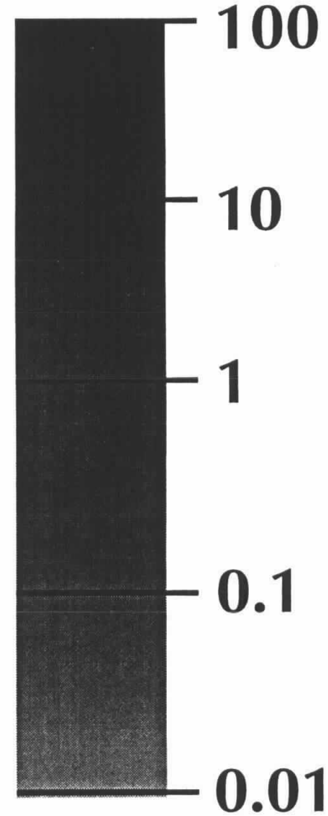
old xsec

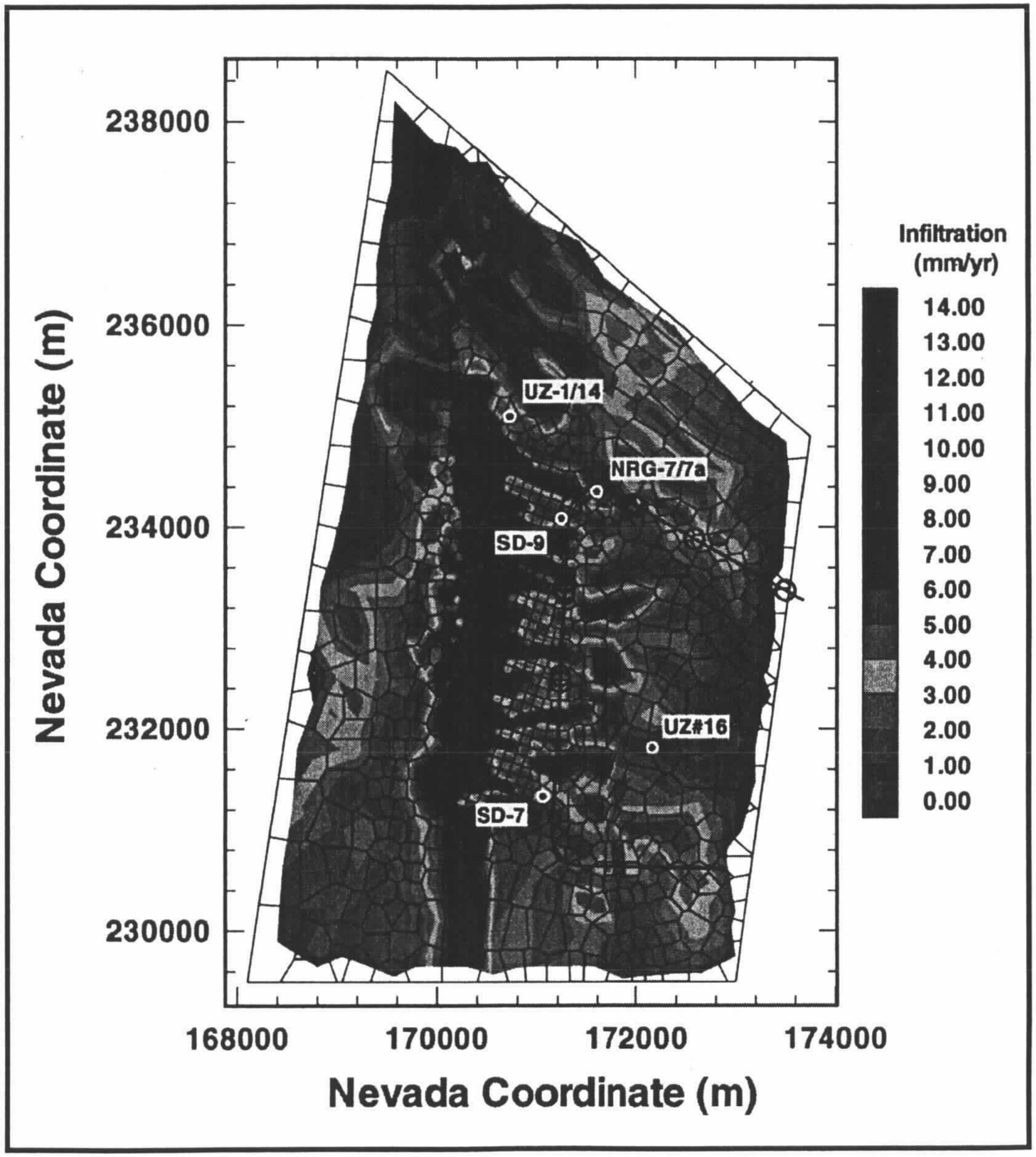
ACNW'96

Percolation Flux Indicators

- Infiltration
- Saturation & Moisture Tension Data
- Pneumatic Data
- Environmental Isotopes
- Fracture Coatings
- Temperature Data
- Perched Water Data

Percolation Flux (mm/yr)





ffig2

ACNW'96

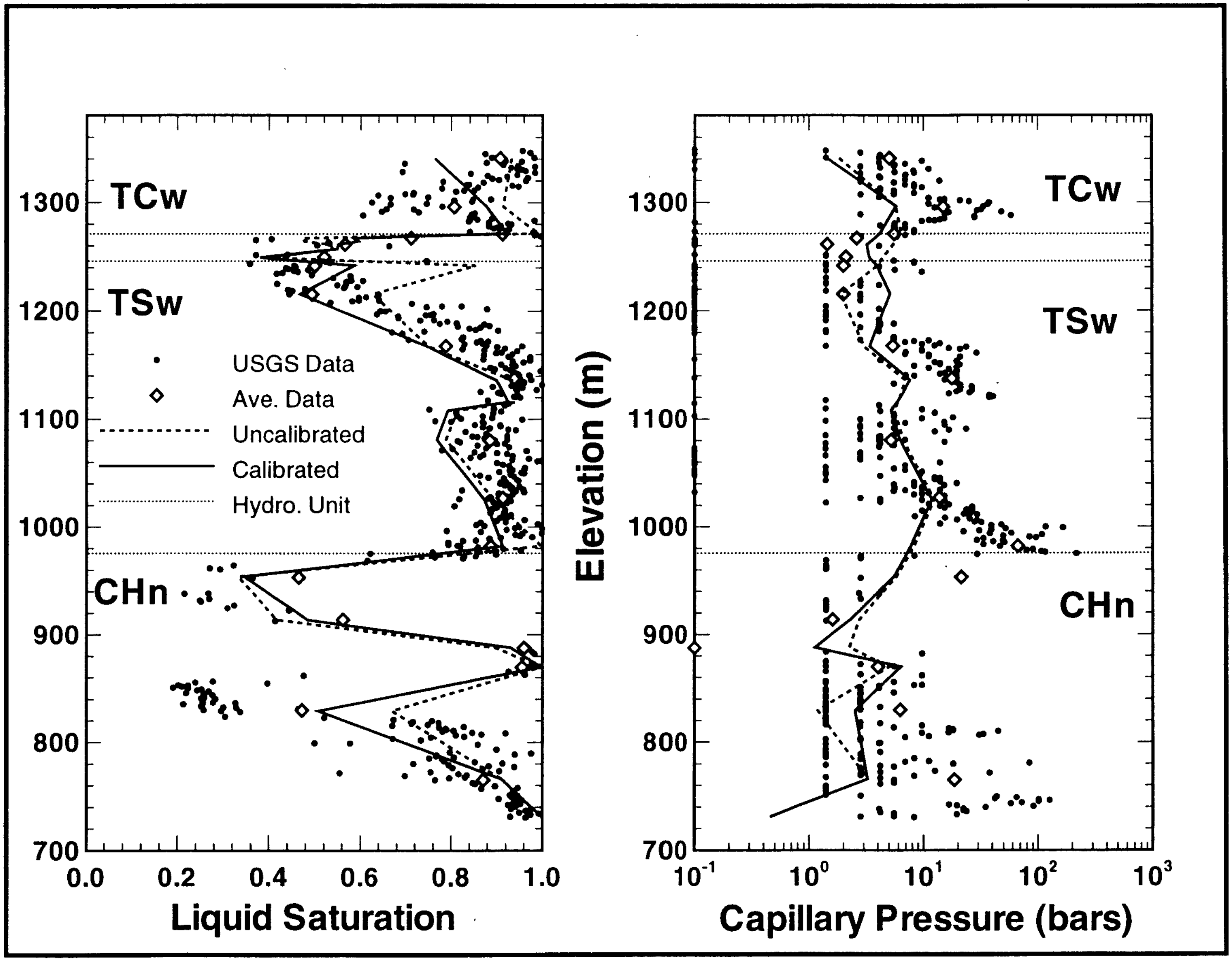
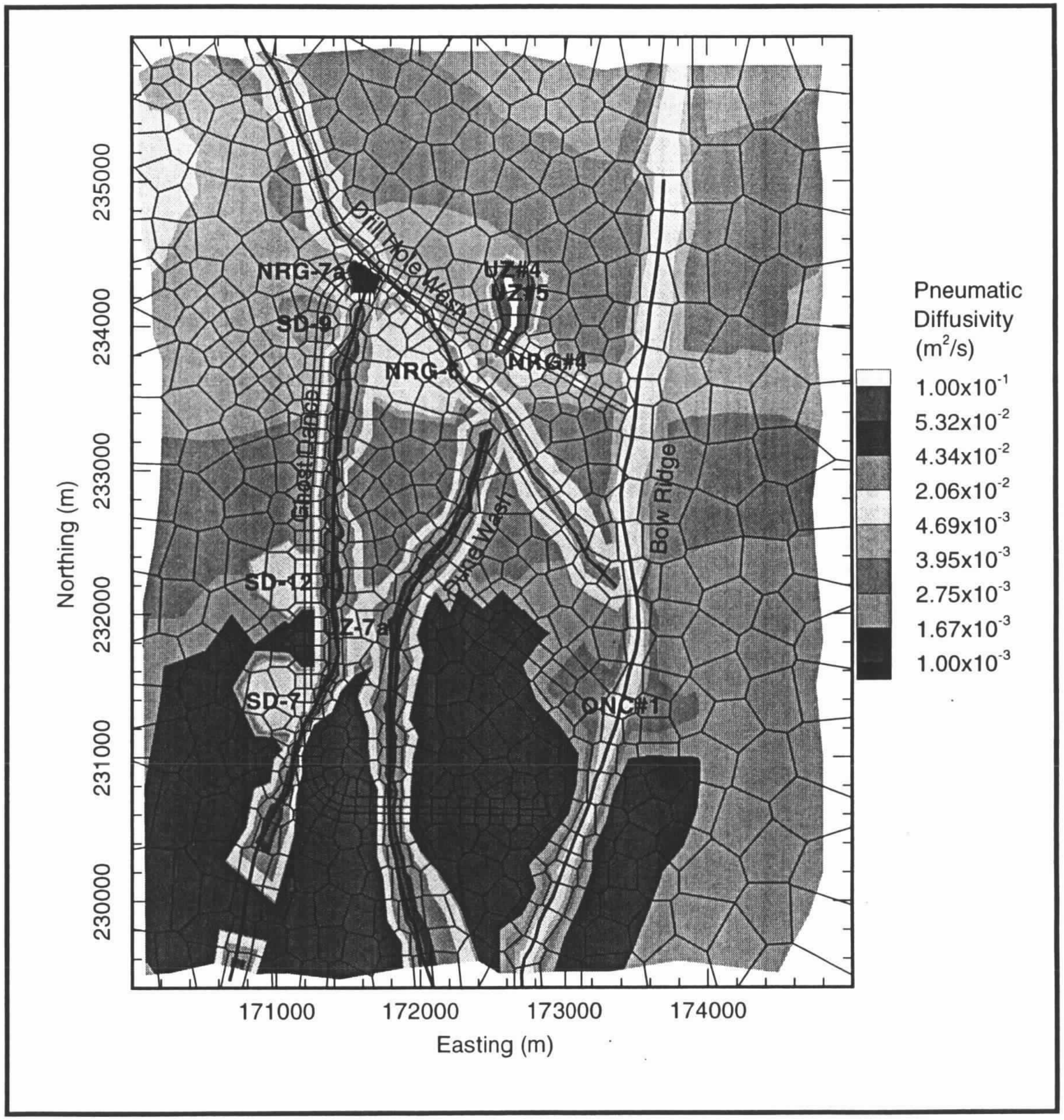
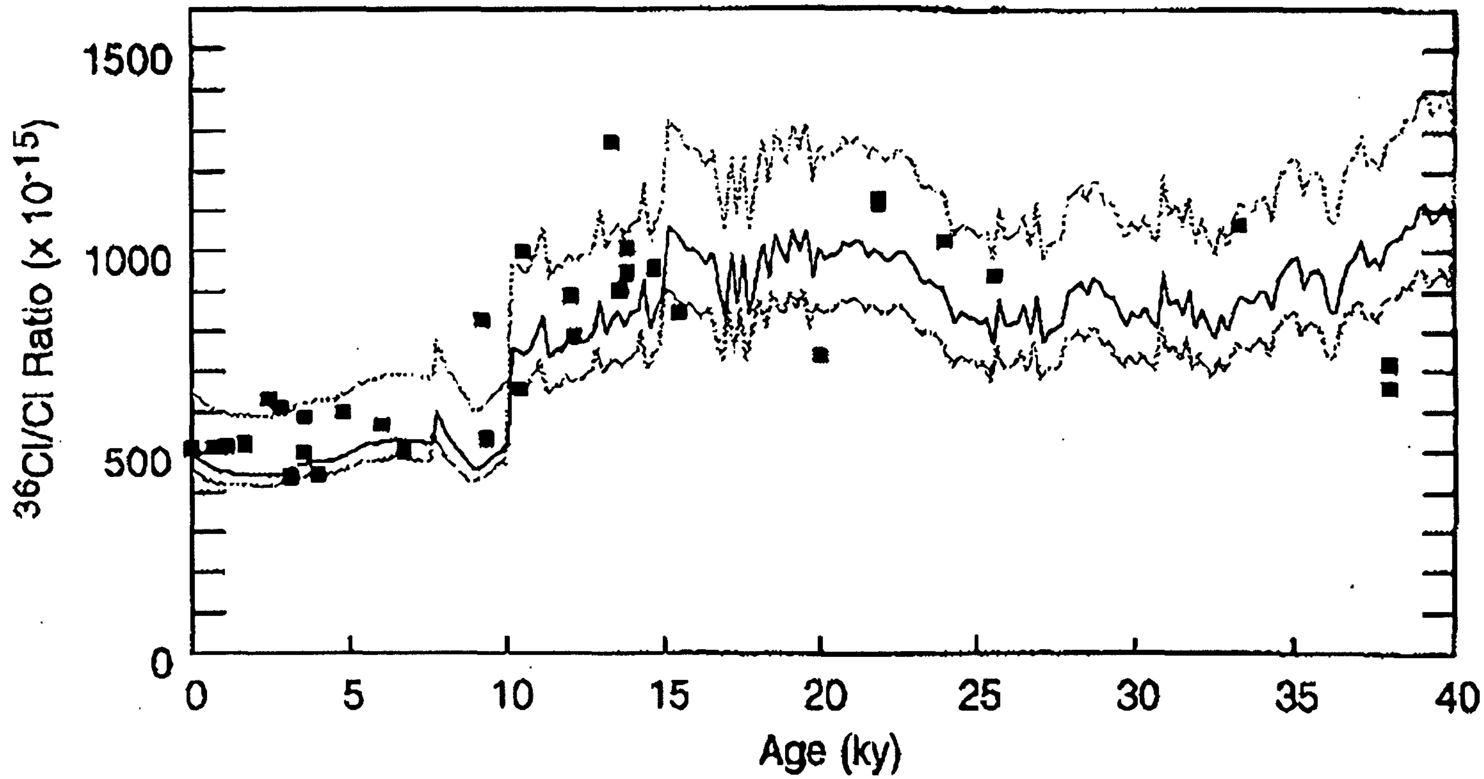


fig3431

ACNW'96

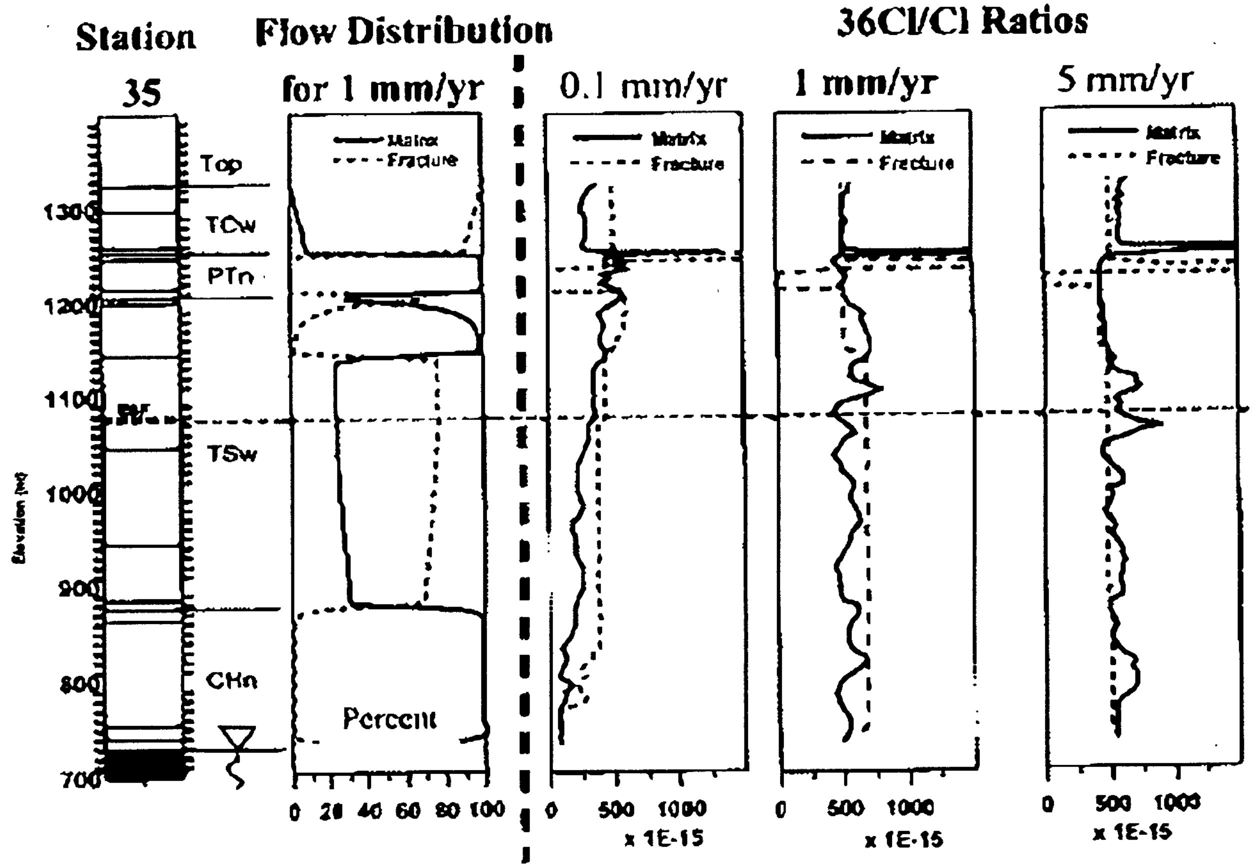


Drill Hole Wash
NRG-7a
UZ#4
UZ#5
SD-9
NRG-6
NRG#4
Ghost Dance
Bow Ridge
Dune Wash
SD-12
UZ-7a
SD-7
ONC#1
Northing (m)
235000
234000
233000
232000
231000
230000
171000
172000
173000
174000
Easting (m)
Pneumatic
Diffusivity
(m^2/s)
$1.00x10^{-1}$
$5.32x10^{-2}$
$4.34x10^{-2}$
$2.06x10^{-2}$
$4.69x10^{-3}$
$3.95x10^{-3}$
$2.75x10^{-3}$
$1.67x10^{-3}$
$1.00x10^{-3}$

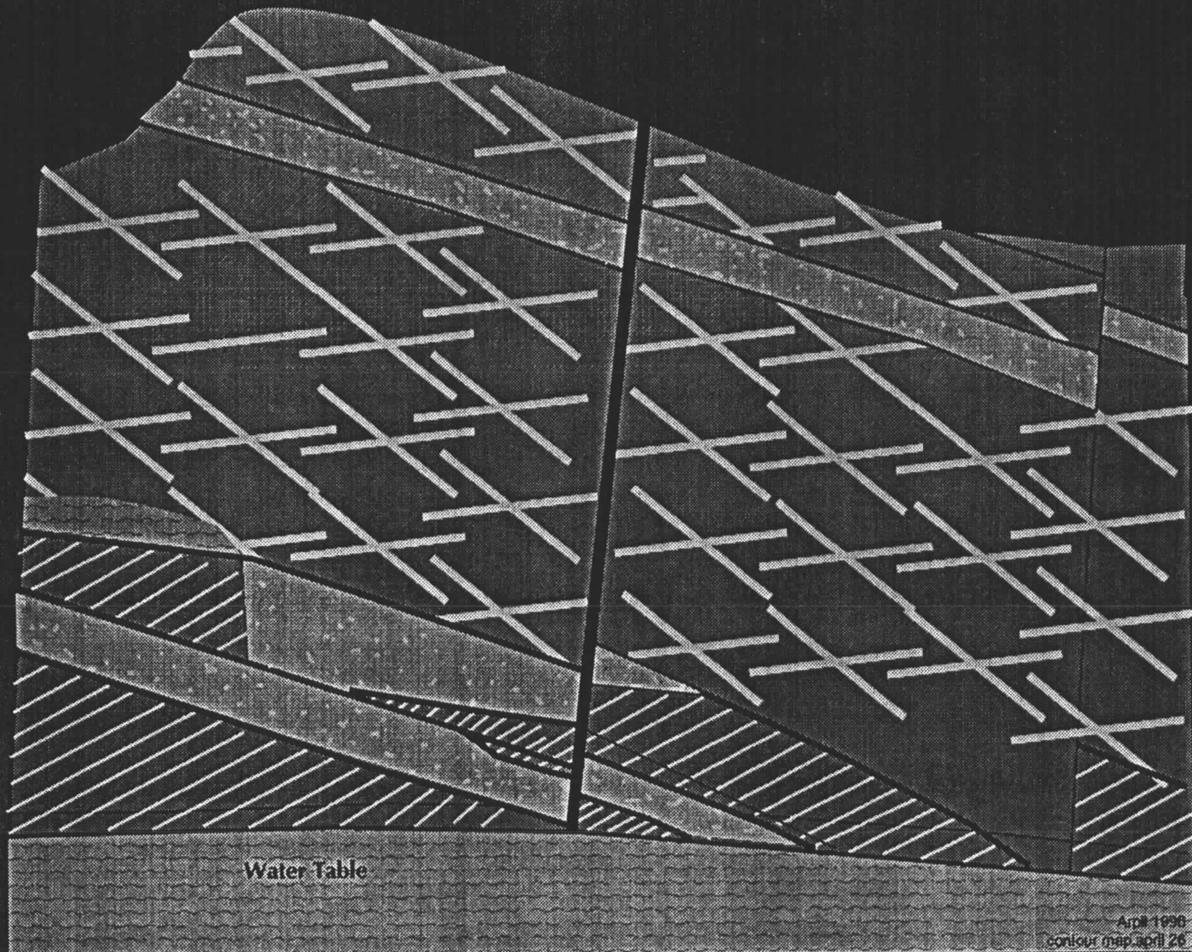


1500
1000
500
0
0
5
10
15
20
25
30
35
40
Age (ky)
^{36}Cl/Cl Ratio (x 10^{-15})

Base-Case Property Simulation at Station 35 Demonstrates Vertical Distribution of Decayed Reconstructed 36Cl/Cl Signal



Fracture Coating Analyses (USGS)



Estimated volume of calcite and volume of water to deposit calcite fracture coatings integrated over 12.7 My gives a 2.1 mm/yr percolation flux

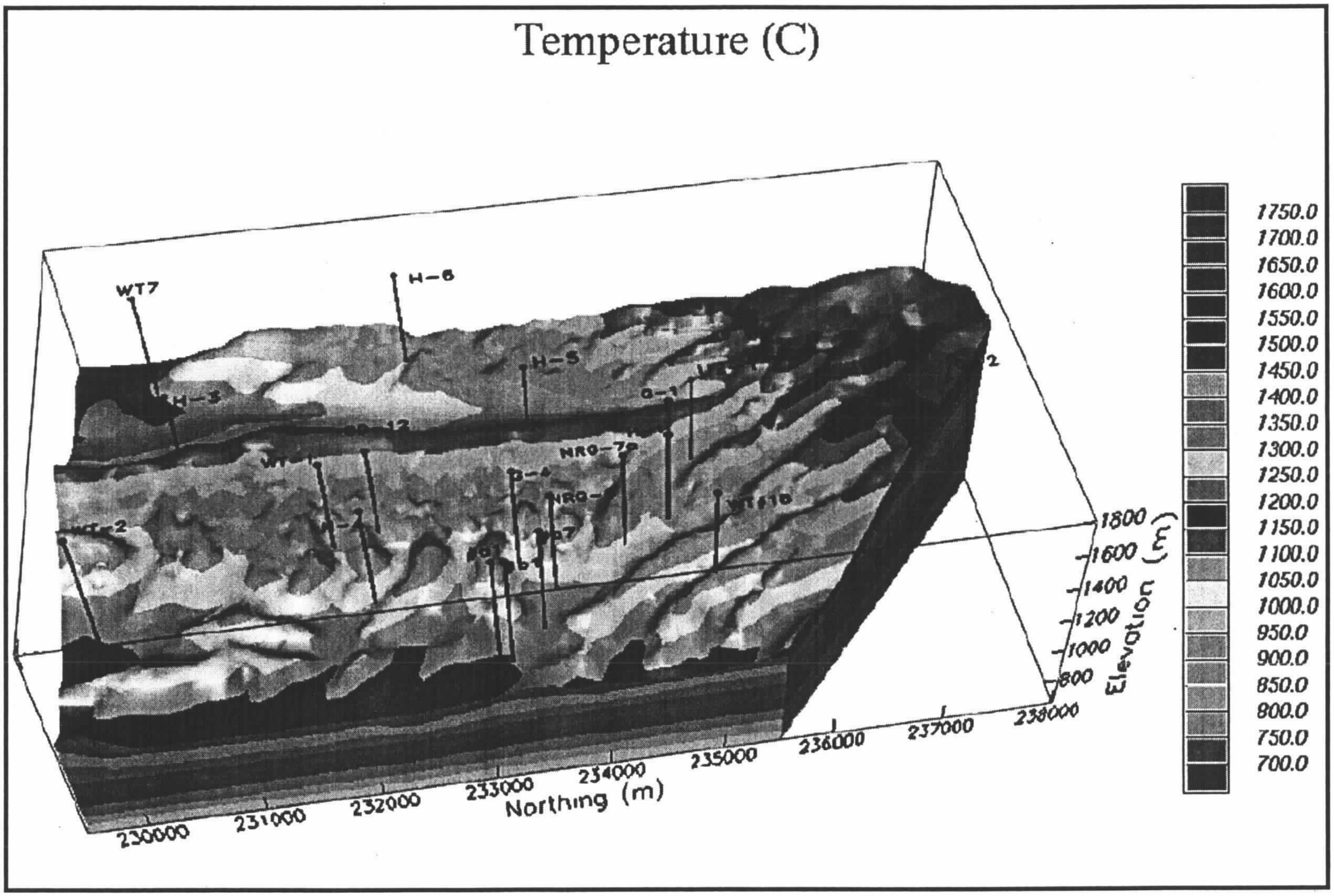
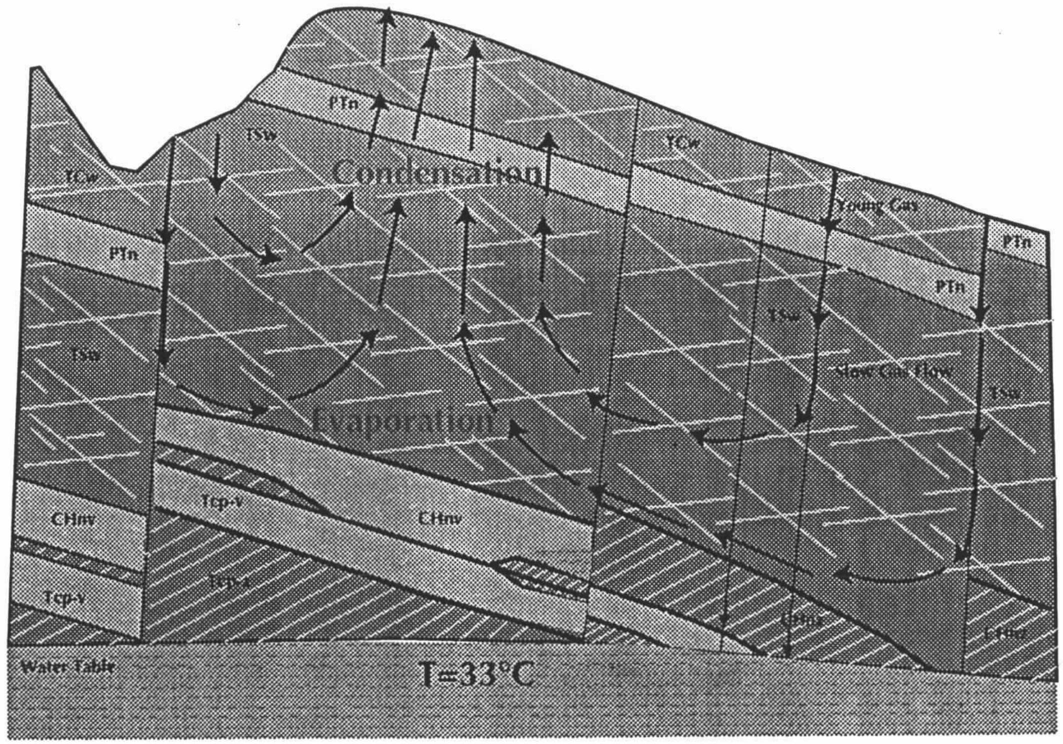


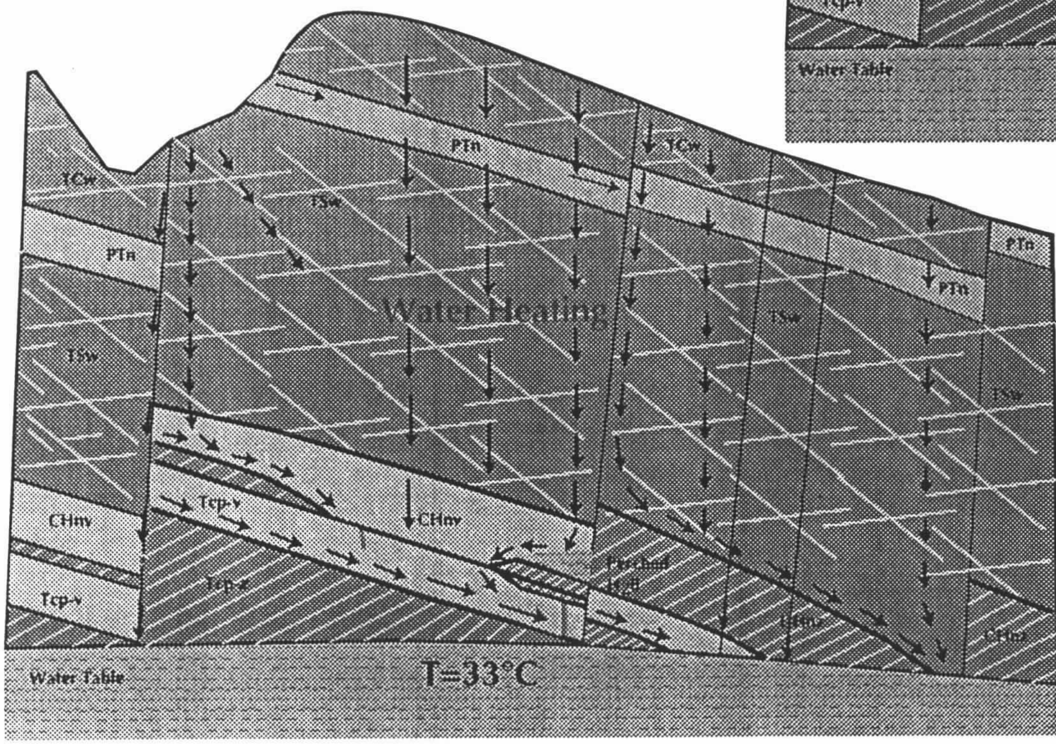
fig951

ACNW'96

Heat Flow Models for Yucca Mountain (Sass et al, 1988)



Gas Movement Model (Evaporization/Condensation)

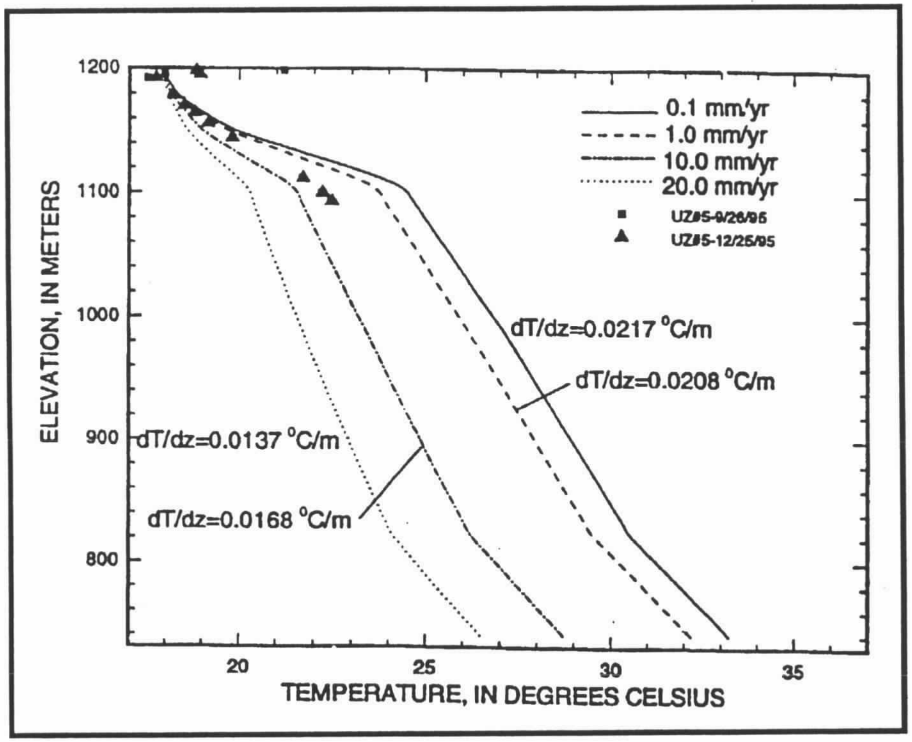


Water Percolation Model (Water Heating)

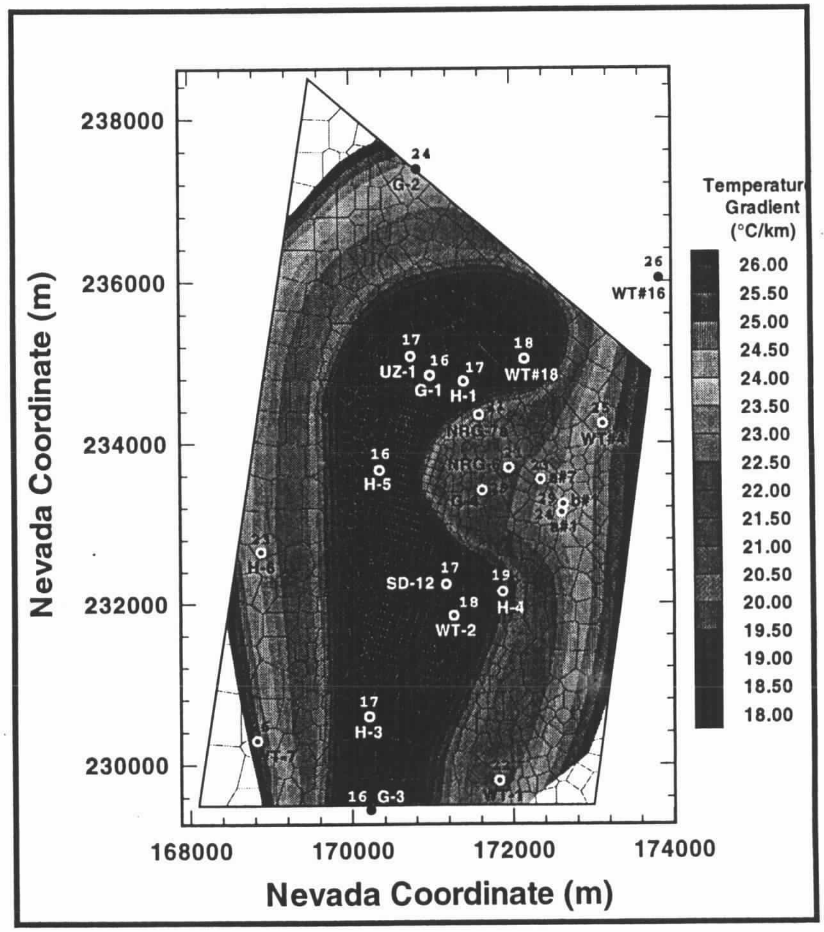
HeatFlowModA/B

ACNW'96figs

Use of Temperature to Estimate Percolation Flux



Comparison of measured temperatures at UZ#5 with simulated temperatures using a one-dimensional model and steady-state infiltration fluxes of 0.1, 1.0, 10.0 and 20.0 mm/yr (Rousseau et al., 1996)



Estimated temperature gradient in the TSw based on data from Sass et al. 1988 and Rousseau et al., 1996 (Bodvarsson & Bandurraga, eds., 1996)

fig3new(nwtrb)/fig952

ACNW'96

Vertical Mass Flux at Repository Horizon

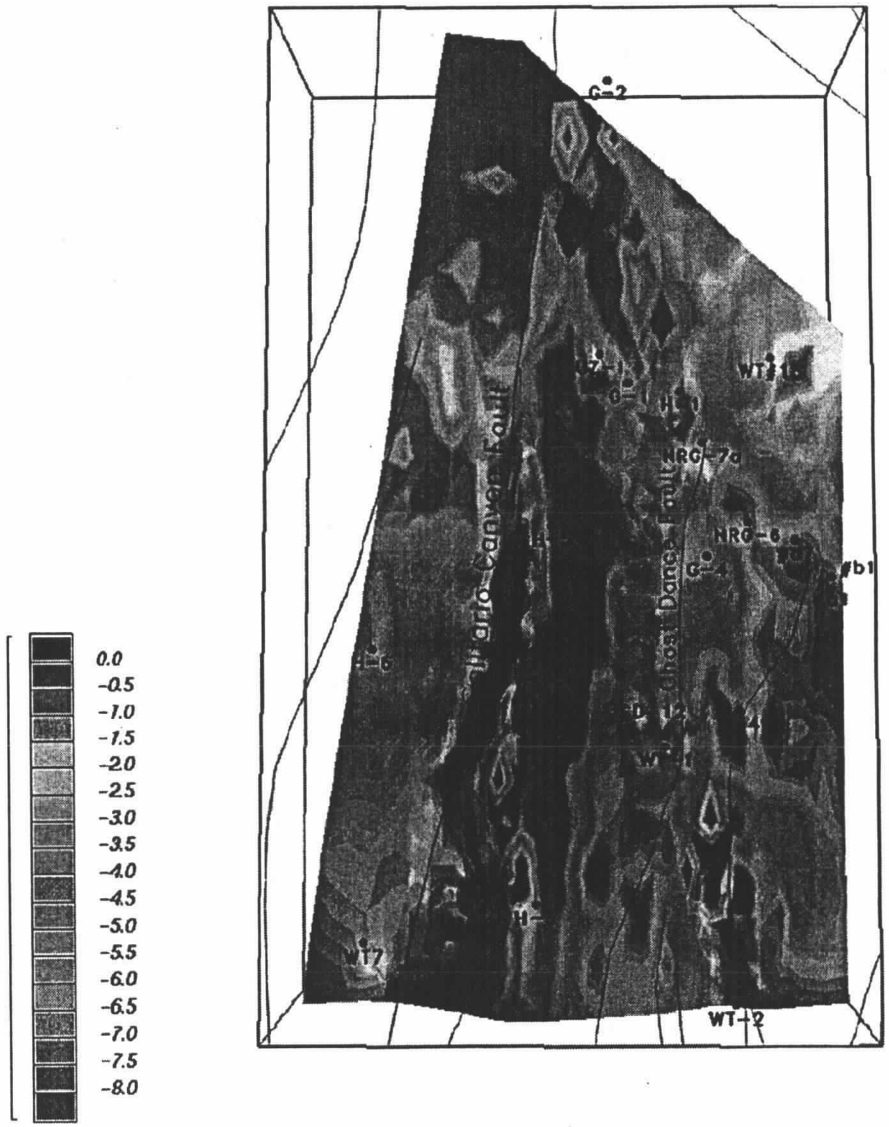


Fig953
ACNW'96

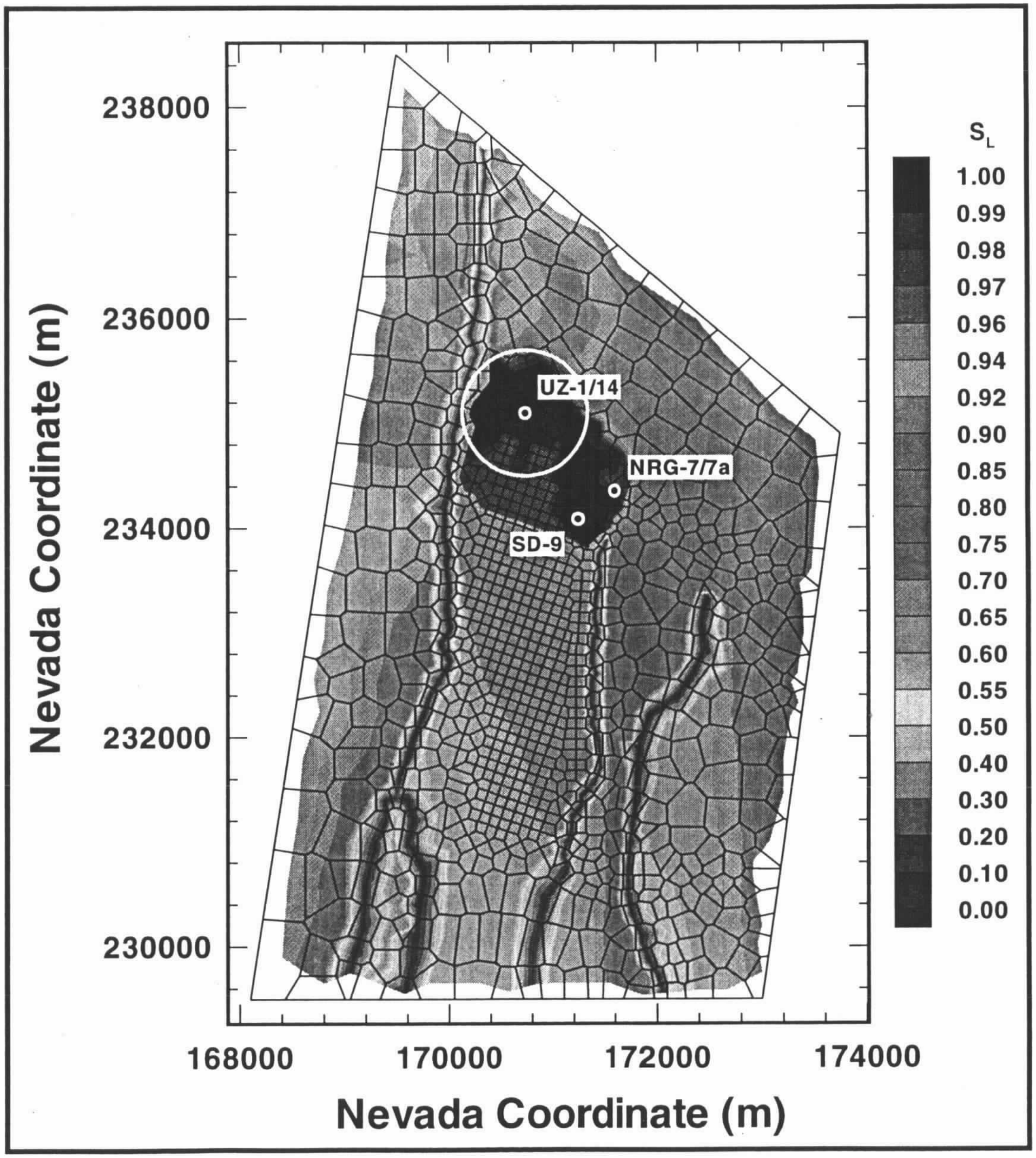


fig7536

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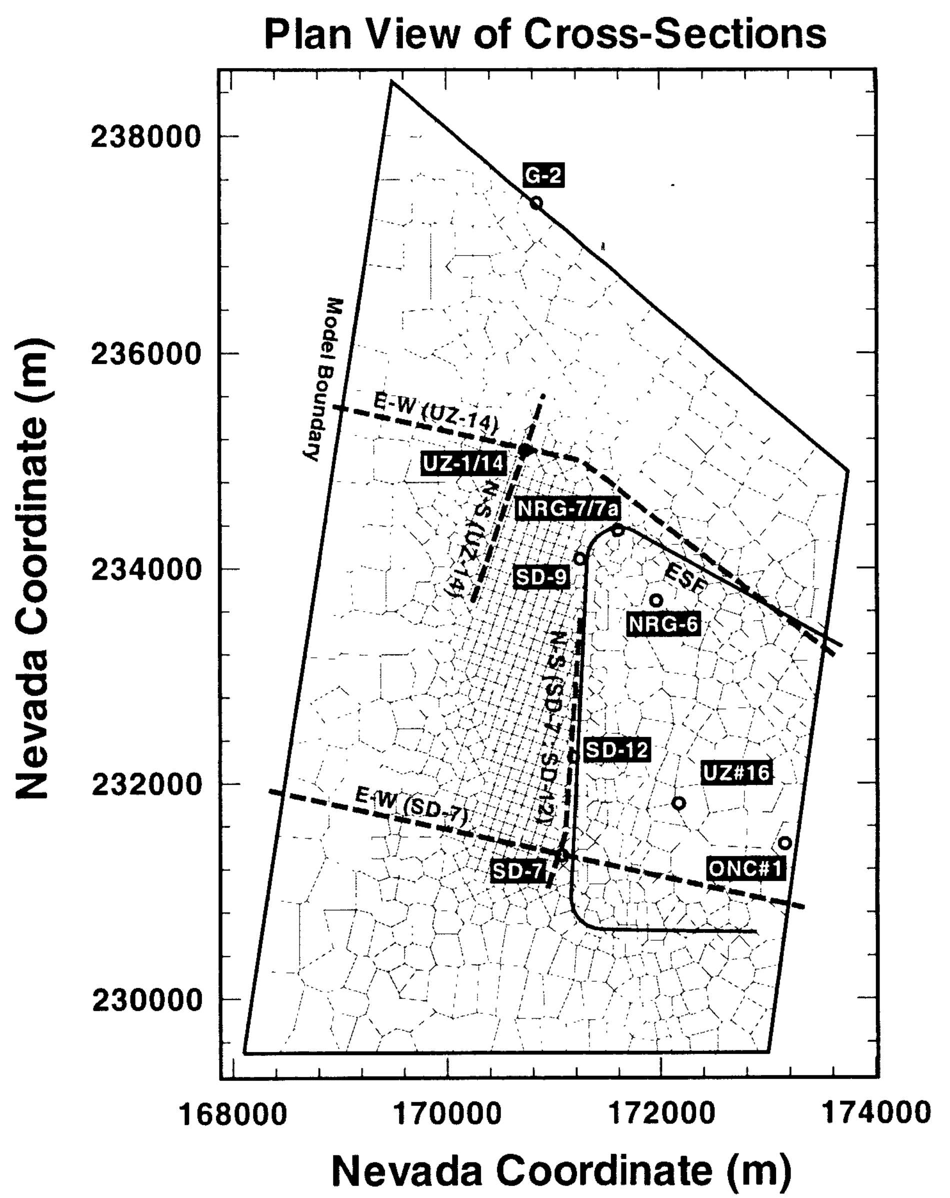


Plan View of Cross-Sections
238000
236000
234000
232000
230000
Nevada Coordinate (m)
168000
170000
172000
174000
Nevada Coordinate (m)
Model Boundary
G-2
E-W (UZ-14)
UZ-1/14
N-S (UZ-14)
NRG-7/7a
SD-9
ESF
NRG-6
N-S (SD-7 - SD-12)
SD-12
UZ#16
E-W (SD-7)
SD-7
ONC#1

Water Saturation

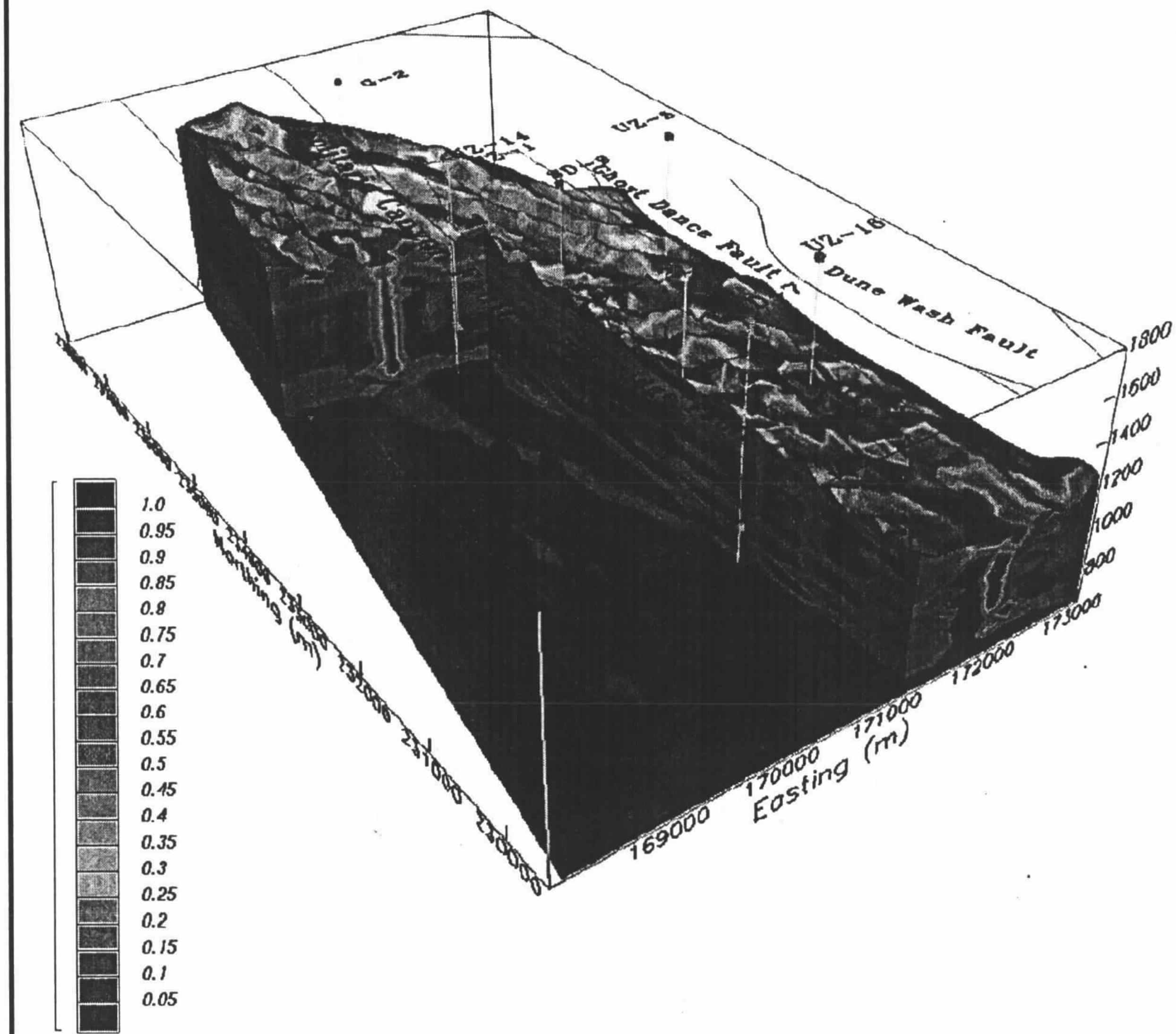


fig8720

ACNW'96

Water Saturation at Repository Horizon

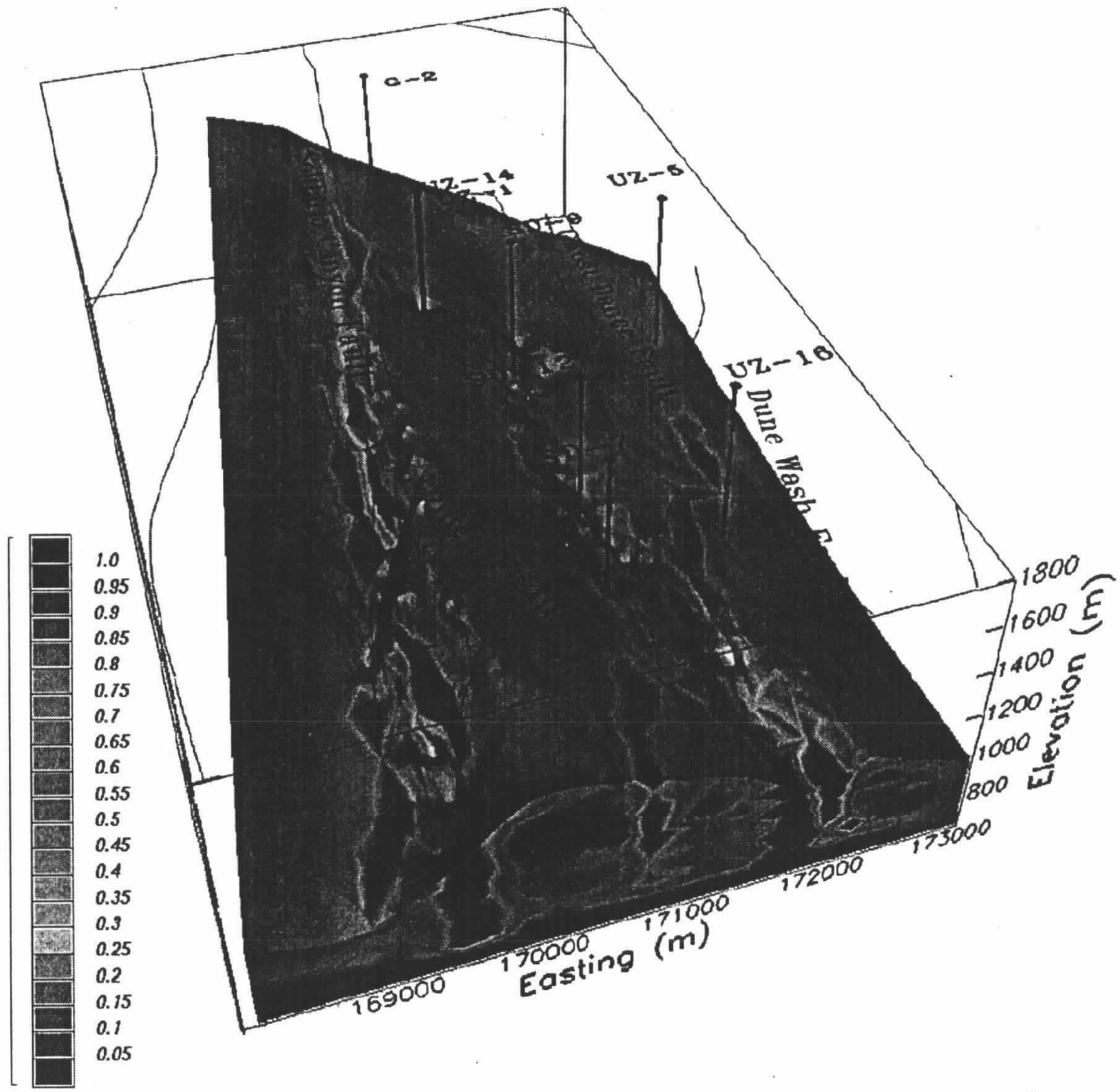


fig8719

ACNW'96

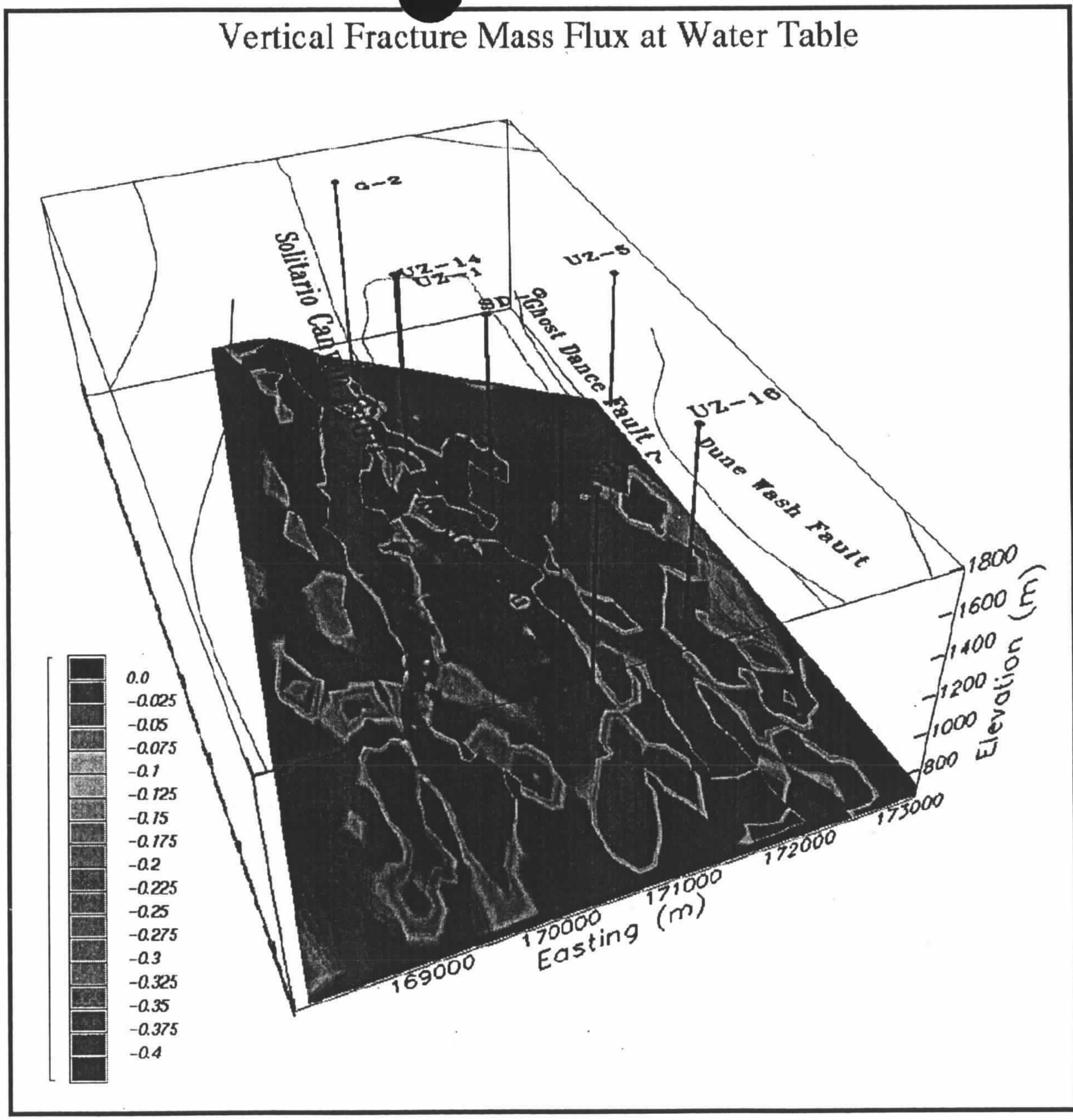


fig81011

ACNW'96

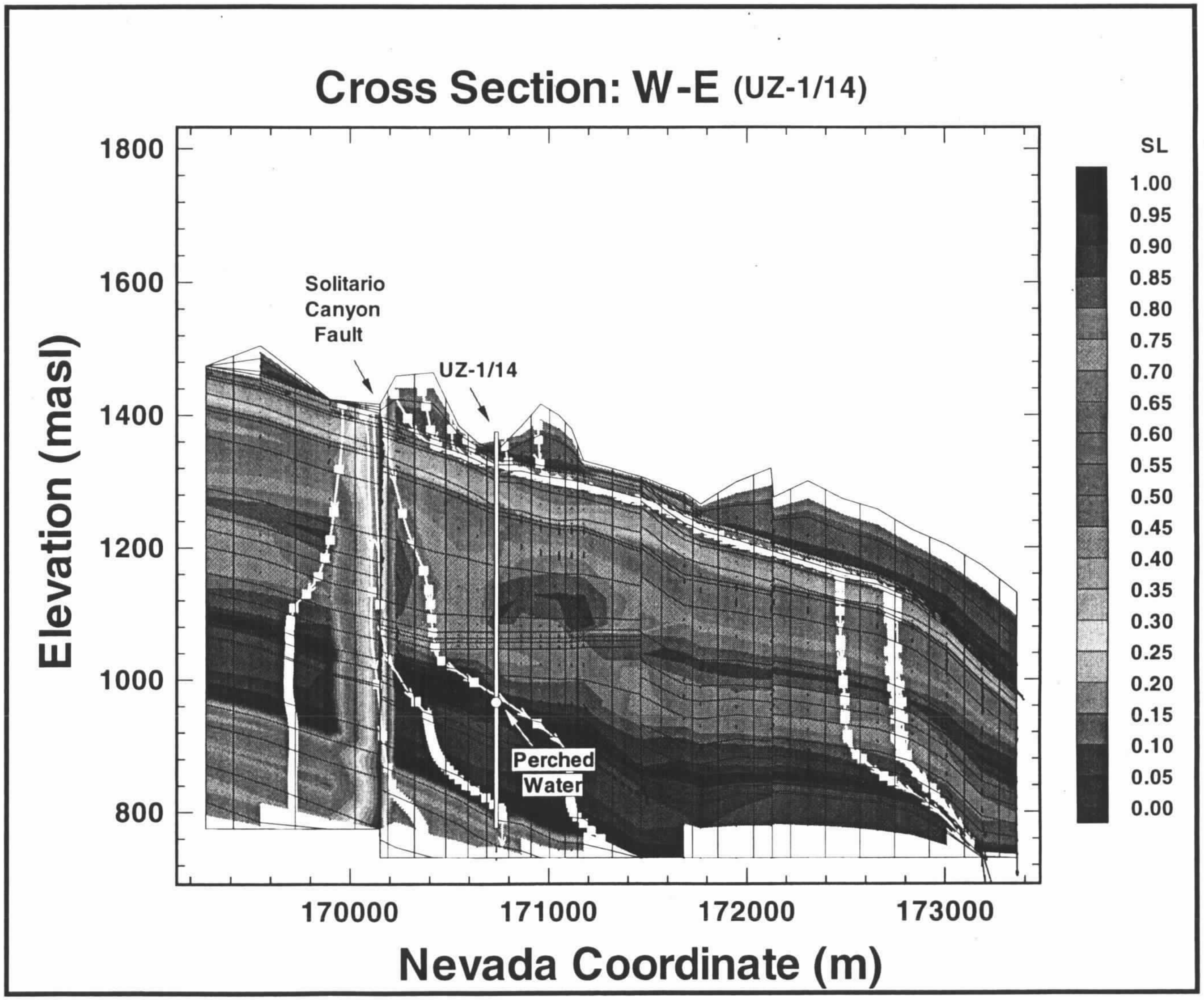
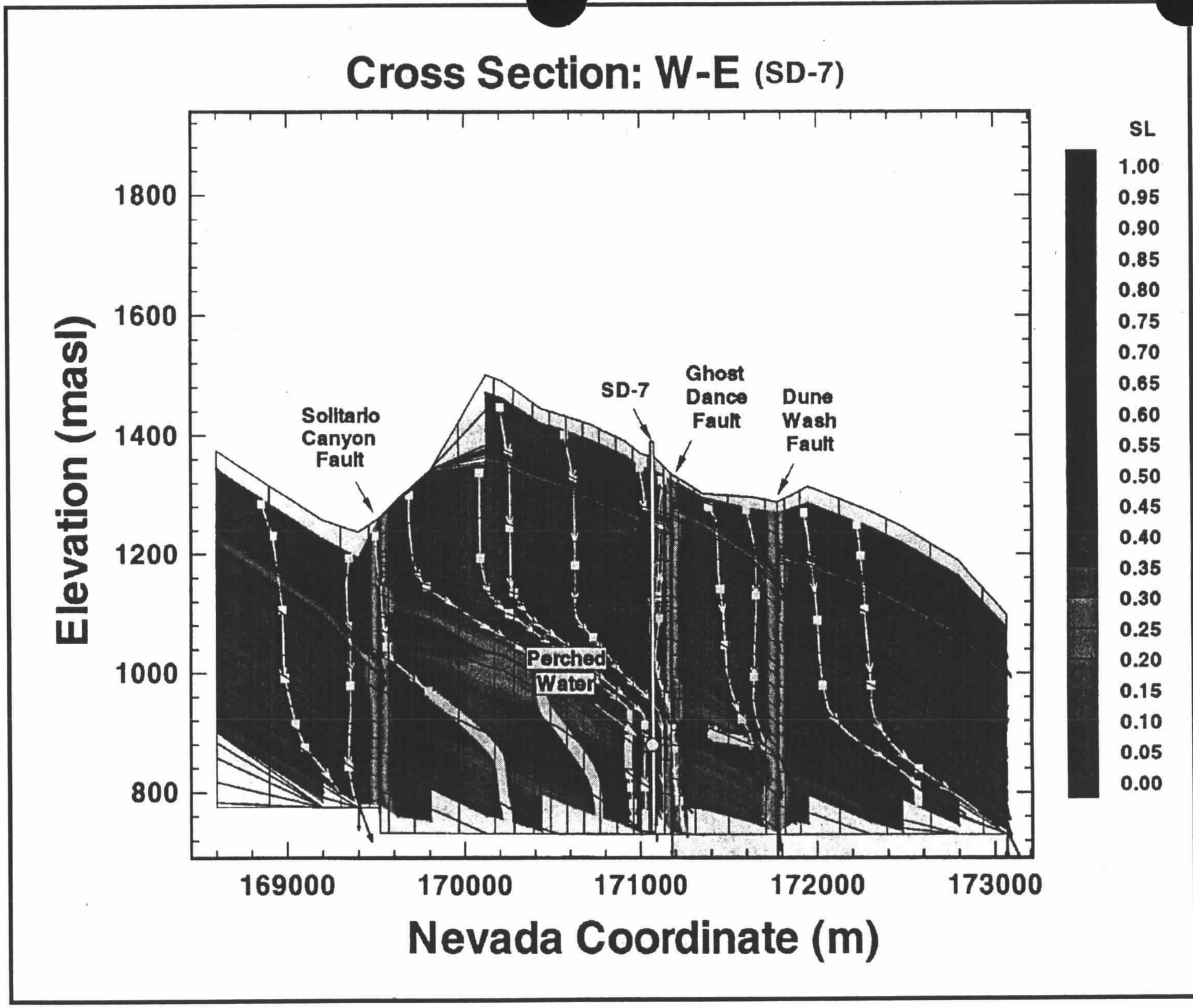
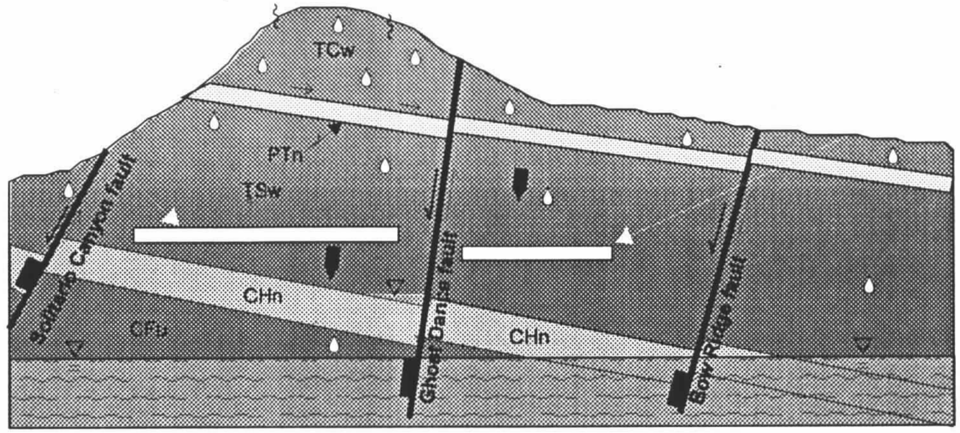


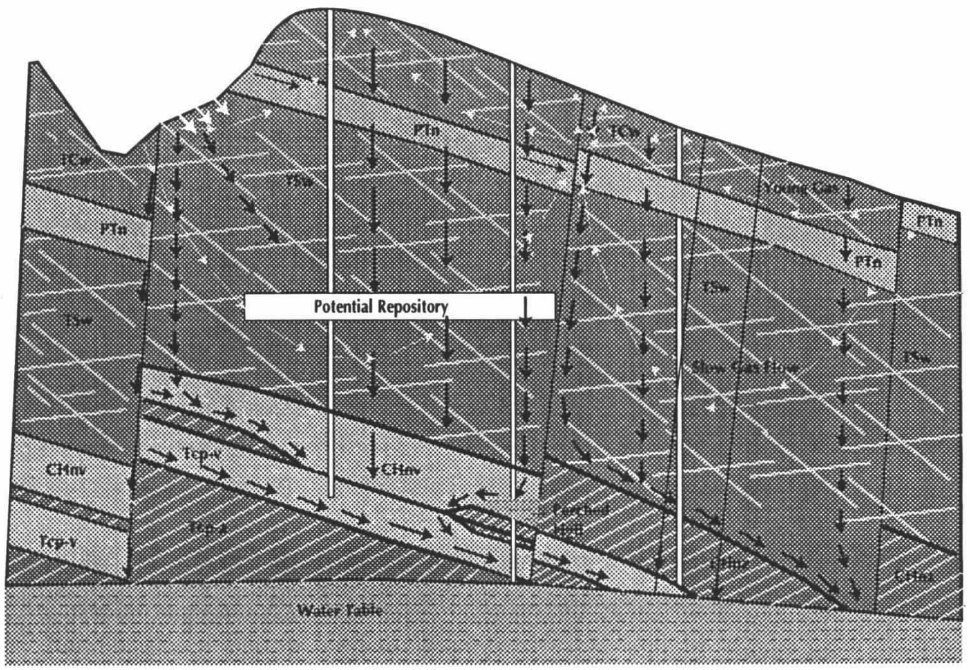
FIG872

ACNW'96


Cross Section: W-E (SD-7)
Elevation (masl)
1800
1600
1400
1200
1000
800
Nevada Coordinate (m)
169000
170000
171000
172000
173000
Solitario Canyon Fault
SD-7
Ghost Dance Fault
Dune Wash Fault
Perched Water
SL
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

Montazer & Wilson (1984)





Alternative Model

oldsxec/newxsec

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Implication of Evolved Model

- **Higher percolation flux at repository horizon**
  - if higher flux:
    - relative humidity may stay higher
    - increased percolation flux to water table
- **Transport Pathways**
  - can we expect retardation of radionuclides along fast pathways?
  - are flow pathways different from transport pathways?
  - what potential of lateral diversion at top of zeolites?

Uncertainties

- Percolation flux affects four out of five attributes in the Waste Isolation Strategy and cannot be measured directly
- Project is using a variety of approaches to evaluate local and global percolation flux; many corroborating lines of evidence are needed for the full picture
- Uncertainties in data are due to data scarcity and assumptions in methods; e.g. Cl mass balance method not being applied in setting for which it was designed
- Temperature, ^{36}Cl, and fracture coating methods leading to estimates of higher flux at repository horizon need further study to test robustness

Uncertainties (cont.)

- **Flow regime below repository**
  - extent of lateral flow in CH
  - fracture/matrix interaction
  - fast pathways to water table

Plans for Future Work

FY97:

- Utilization of ESF:
  - Continue sampling fracture coatings
  - Continue sampling for environmental isotopes
  - Plan Percolation Flux Test and other possible hydrologic tests
  - Continue moisture monitoring
  - Continue study of Ghost Dance Fault
- Refine UZ Flow and Transport Models for TSPA VA

Plans for Future Work (cont.)

Long Range Plan:

- **Utilize ESF as much as possible for a variety of tests**
  - Continue study of Ghost Dance Fault
  - Conduct Percolation Flux Test
  - Conduct UZ Transport Test
  - Conduct other hydrologic properties tests

Conclusions

- Various new data and analyses suggest an alternative conceptual model that results in percolation flux at the repository horizon of ~5mm/yr.
- The alternative conceptual model de-emphasizes the importance of lateral flow in the PTn and the role of faults as drains above the repository horizon.
- Flow paths below the repository horizon are more complicated due to perched water occurrences, potential for lateral flow above the zeolitic units and age inversions from geochemical signatures.
- Implications of higher percolation flux include: (a) relative humidity may stay higher; (b) increased percolation flux to water table.
- The Long Range Plan includes tests and activities designed to determine various estimates of percolation flux and flow patterns in the UZ.