ATTACHMENT 4

PRESENTER'S SLIDES

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Saturated Zone Flow Under Isothermal Conditions

Presented to:
DOE/NRC Technical Exchange on the Key Technical Issue Subissues Related to Saturated Zone Flow

Presented by:
Claudia Newbury
Yucca Mountain Site Characterization Office
Department of Energy

October 31 - November 2, 2000
Albuquerque, NM

YUCCA MOUNTAIN PROJECT

Unsaturated and Saturated Flow Under Isothermal Conditions Subissues

Subissue 1: Climate Change	Discussed at 8/16-17 technical exchange - remains closed
Subissue 2: Hydrologic Effects on Climate Change	Discussed at 8/16-17 technical exchange - remains closed
Subissue 3: Shallow Infiltration	Discussed at 8/16-17 technical exchange - one item reopened-to be discussed at this meeting
Subissue 4: Deep Percolation	Discussed at 8/16-17 technical exchange - remains closed-pending
Subissue 5: Ambient Flow	To be discussed at this meeting
Subissue 6: Matrix Diffusion	To be discussed at this meeting

Subissue 3: Shallow Infiltration

Acceptance Criteria	NRC IRSR Status	DOE Proposed Status
1) … estimated present-day shallow infiltration at YM for use in TSPA using…	Closed	Closed
2) … analyzed infiltration at appropriate time and space scales for performance assessment, and…	Closed	Closed
3) … characterized shallow infiltration in the form of either probability distributions…	Closed*	Closed-pending
4) … show through Total System Performance Assessment and associated sensitivity analyses that refinements of shallow infiltration estimates will not…	Closed	Closed
5) If used expert elicitations are conducted…	Closed	Closed
6) …collection, documentation, and development of data, models, and…	TBD	Closed-Pending

***Note: Reopened at August 2000 Key Technical Issue Technical Exchange on Unsaturated Flow**

Shallow Infiltration Background

- At the August 2000 Unsaturated Flow Key Technical Issue Technical Exchange, the NRC questioned the upper bound values for shallow infiltration and that DOE should provide additional justification for their current numbers or use another number
- This subissue was to remain open until DOE provided its approach
- Plan has been provided. Therefore, this Subissue should be closed-pending confirmatory actions

Subissue 6: Matrix Diffusion

Acceptance Criteria	NRC IRSR Status	DOE Proposed Status
1) If credit for matrix diffusion in the UZ is taken, then transport predictions must be consistent with site geochemical and isotopic data	N/A	N/A
2) If credit for matrix diffusion in the SZ is taken, rock matrix and solute diffusion parameters must be…	Open	Closed
3) If used, expert elicitations are conducted…	Closed	Closed
4) …collection, documentation, and development of data, models, and…	TBD	Closed-Pending

Based on information to be presented today, this Subissue should be closed-pending closure of Acceptance Criterion 4

Matrix Diffusion Topics

- **Today DOE will:**
  - Provide an explanation of the Matrix Diffusion Model
  - Show how it is broadly consistent with observed data
  - Discuss what, if any, credit will be taken in performance predictions

Subissue 5: Ambient Flow and Dilution

Acceptance Criteria	NRC IRSR Status	DOE Proposed Status
1) Conceptual flow and data uncertainties	Open	Closed
2) Flow paths from beneath the repository to potential receptor locations	Open	Closed
3) Causes of the moderate hydraulic gradient and the large hydraulic gradient	Open	Closed
4) Maps of potentiometric contours of the regional uppermost aquifer	Open	Closed
5) Hydrologic parameters are described in the form of probability distributions or deterministic bounding values that are reasonably consistent with site data	Open	Closed-Pending

Subissue 5: Ambient Flow and Dilution
(Continued)

Acceptance Criteria	NRC IRSR Status	DOE Proposed Status
6) …mathematical groundwater model(s) that incorporate site-specific climatic and subsurface information…	Open	Closed
7) …wellbore dilution…	Closed	Closed
8) …dilution due to dispersion… or mixing…	Open	Closed
9) …potential geothermal and seismic effects on the ambient SZ flow system…	Open	Closed
10) …expert elicitations are conducted…	Closed	Closed
11) …acceptable Quality Assurance Procedures…	TBD	Closed-Pending

Based on information presented today, this Subissue should be closed-pending confirmation

Ambient Flow and Dilution Topics

- **Uncertainties**
  - Consideration of uncertainty in models
  - Incorporation of Saturated Zone expert elicitation panel suggestions to reduce uncertainty
- **Flow Paths**
  - Delineation of flow paths
  - Location of transition from flow in tuff to flow in alluvium

Ambient Flow and Dilution Topics
(Continued)

- **Moderate and Large Hydraulic Gradients results from USW SD-6 and USW WT-24 testing**
- **Potentiometric Contour Maps**
  - Inclusion of Nye County potentiometric data

Ambient Flow and Dilution Topics
(Continued)

- **Hydrologic Parameters**
  - Probability distributions and deterministic bounding values used as parameters in hydrologic models
  - Determination of total and effective porosity
  - Incorporation of transmissivity estimates from single-hole tests in the calibrated model
  - Correction of transmissivity estimates to account for bias toward low values

Ambient Flow and Dilution Topics
(Continued)

- **Mathematical Groundwater Models**
  - Incorporation of site specific climatic and subsurface data into models
- **Dilution Due to Dispersion or Mixing**
  - Handling of dispersion in the new particle tracking model
- **Potential Geothermal and Seismic Effects**
  - Results of recent investigations

Summary

	Status	
	IRSR	DOE Proposed
• Subissue 3: Shallow Infiltration	Open	Closed-Pending
• Subissue 5: Ambient Flow and Dilution	Open	Closed-Pending
• Subissue 6: Matrix Diffusion	Open	Closed-Pending

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Present-Day Shallow Infiltration

Presented to:
DOE/NRC Technical Exchange on the Key Technical Issue Subissues Related to Saturated Zone Flow

Presented by:
James Houseworth
Civilian Radioactive Waste Management System Management and Operating Contractor

October 31 - November 2, 2000
Albuquerque, NM

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Outline

- **Presentation Objectives**
- **Current Subissue and Acceptance Criterion 3 Status**
- **Proposed infiltration plan**
  - Derive new upper bound infiltration maps and weighting factors based on Monte-Carlo methodology
  - Incorporate new results in models for Total System Performance Assessment - License Application
- **Conclusions**

Presentation Objectives

- Provide the basis for resolving the Present-Day Shallow Infiltration Subissue and Acceptance Criterion 3 of that Subissue
- Subissue 3, Acceptance Criterion 3: Department of Energy (DOE) has characterized shallow infiltration in the form of either probability distributions or deterministic upper-bound values for performance assessment, and provided sufficient data and analyses to justify the chosen probability distribution or bounding value

Current Subissue and Acceptance Criterion 3 Status

- **Unsaturated and Saturated Flow Under Isothermal Conditions Issue Resolution Status Report, Rev. 02 indicated that Acceptance Criterion 3 status was open**
  - Staff noted an apparent bias in upper bound Mean Annual Infiltration (MAI) multipliers and that equal weights should be assigned to the upper and lower bounds for MAI multipliers or demonstrate that another approach achieves the same result
- **April 2000 Key Technical Issue Status Technical Exchange identified the Present-day Shallow Infiltration Subissue as closed**

Current Subissue and Acceptance Criterion 3 Status (Continued)

- At the August 2000 Unsaturated Zone Key Technical Issue Technical Exchange, the NRC questioned the upper bound values for shallow infiltration and asked that DOE provide additional justification for their current numbers or use another number
- NRC indicated that this subissue and Acceptance Criterion 3 would remain open until DOE provided their approach addressing the NRC concern on the probability distributions for shallow infiltration

Draft plan to address concerns

- **Develop upper-bound infiltration case based on the Monte-Carlo analysis for the glacial-transition climate**
  - Upper bound will be based on the 90th percentile case from the Monte Carlo analysis
  - New weighting factors for the lower bound, mean, and upper bound cases will be derived based on the documented methodology (*Analysis of Infiltration Uncertainty Analysis and Model Report*: ANL-NBS-HS-000027)
- **Develop upper bound infiltration cases for the monsoon and modern climates by proportional scaling based on the average infiltration ration between the upper bound and mean cases for the glacial-transition climate**
- **Incorporate the new infiltration maps and weighting factors into the models that support Total System Performance Assessment - License Application**

Conclusions

- DOE has developed a plan to develop upper bound infiltration values tied to the Monte-Carlo analyses
- Based upon the submittal of the plan for work that will provide new upper bound values for shallow infiltration, the subissue and acceptance criterion should be closed-pending completion of the planned work

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Subissue 6, Acceptance Criterion 2: Matrix Diffusion, Saturated Zone Aspects

Presented to:
DOE/NRC Technical Exchange on the Key Technical Issue Subissues Related to Saturated Zone Flow

Presented by:
Al Aziz Eddebbarh, Ph.D
Paul Reimus
Civilian Radioactive Waste Management System Management and Operating Contractor
M. J. Umari
U.S. Geological Survey

October 31 - November 2, 2000
Albuquerque, NM

YUCCA MOUNTAIN PROJECT

Outline

- **Presentation Objectives**
- **Current Acceptance Criterion Status**
- **For Subissue 6, Acceptance Criterion 2, presentation will:**
  - Summarize technical basis for item resolution
  - Identify basis documents (References)
  - Summarize technical adequacy of basis
- **Conclusions**

Note: Additional summary information is provided in the delta analysis

Presentation Objectives

- Provide the basis for resolving Subissue 6, Acceptance Criterion 2 associated with the matrix diffusion in the Saturated Zone
- Subissue 6, Acceptance Criterion 2: If credit for matrix diffusion in the Saturated Zone is taken, rock matrix and solute diffusion parameters must be (i) based on a Saturated Zone transport model that reasonably matches the results of the field tracer tests that are conducted over different distance scales and flow rates with multiple tracers of different diffusive properties, and (ii) consistent with laboratory data

Current Acceptance Criterion 2 Status

- Unsaturated and Saturated Flow under Isothermal Conditions Issue Resolution Status Report, Rev. 02 indicates status is open, pending review of future DOE performance assessments and milestone reports
- April 2000 Key Technical Issue Status Technical Exchange identified the Matrix Diffusion Subissue as open, nearing resolution; did not specifically provide status of Acceptance Criterion 2

Subissue 6, Acceptance Criterion 2

- **Action or information needs identified**
  - At the April 2000 KTI Status Technical Exchange, the NRC indicated that DOE needed to provide and analyze data from the C-wells
  - Information submitted regarding agenda-setting telecons indicated that the NRC wanted DOE to publish reports on the C-wells

Subissue 6, Acceptance Criterion 2
(Continued)

- **Basis for closure**
  - The C-wells conservative and reactive tracer tests demonstrated that models that incorporate matrix diffusion provide more reasonable fits to the tracer-experiment data than those that assume a single continuum
  - The matrix sorption coefficients that fit the data for the lithium tracer in the C-wells reactive tracer experiment agreed well with the values determined in laboratory sorption tests
  - This provides confidence that the matrix-diffusion model is appropriate

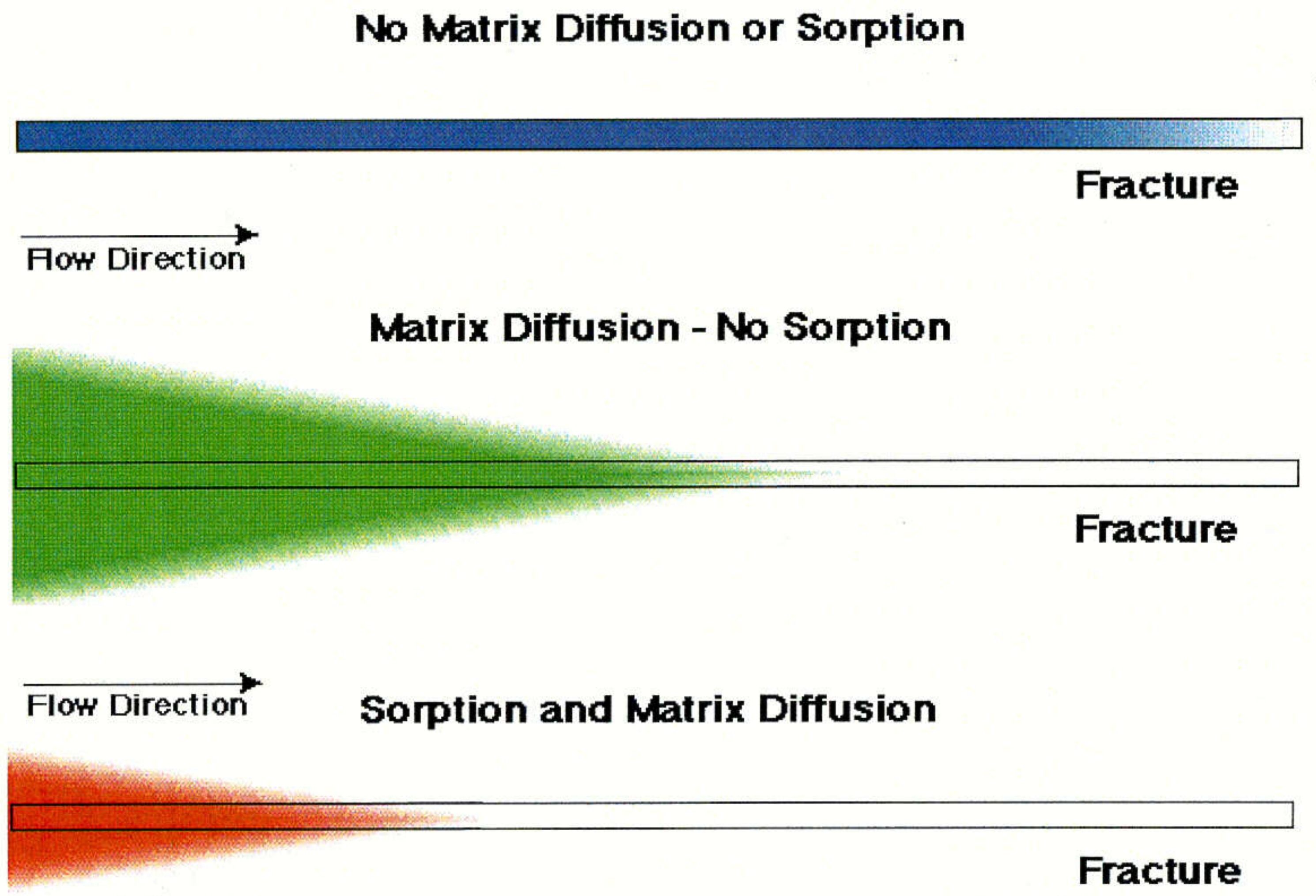
Subissue 6, Acceptance Criterion 2
(Continued)

- **This acceptance criterion has been fully addressed**
  - DOE has appropriately used rock matrix and solute diffusion parameters based on a Saturated Zone transport model that reasonably matches the results of the field tracer tests conducted over different distance scales and flow rates with multiple tracers of different diffusive properties. These parameters are consistent with laboratory data

C-Wells Testing

- **Basis for Resolution**
  - C-Wells multiple tracer tests in both the Bullfrog Tuff and the Prow Pass Tuff have been conducted and indicate the validity of the matrix diffusion model

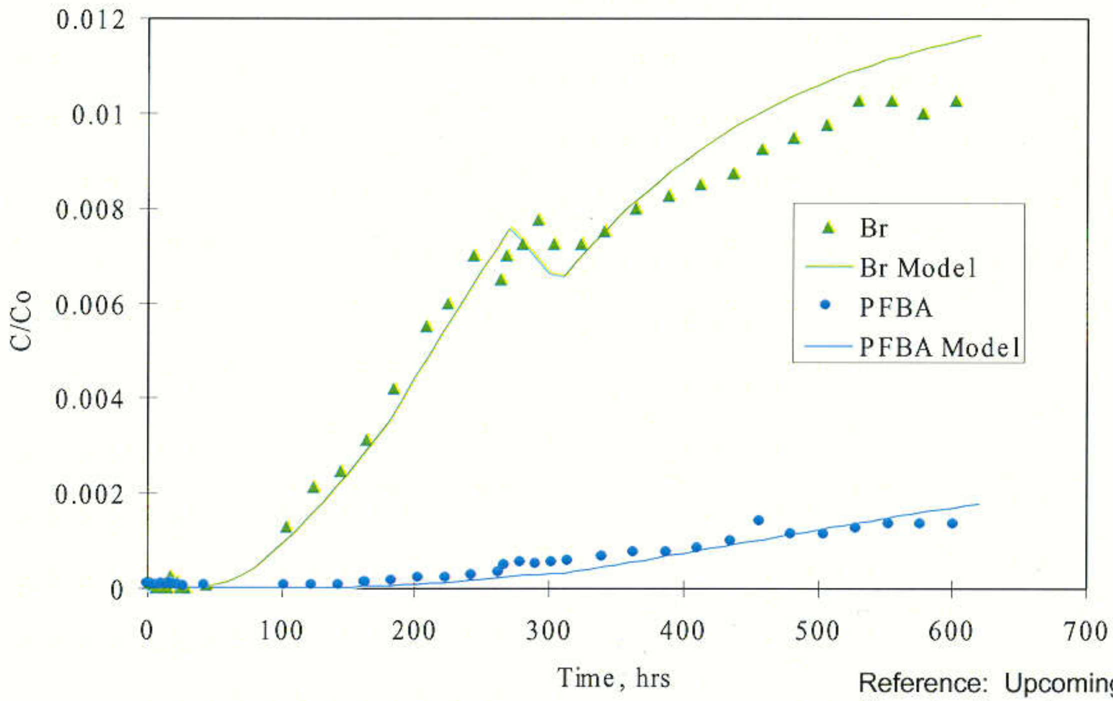
Fractured Tuff Conceptual Transport Model



Multiple Tracers with Different Physical and Chemical Properties

Tracer	Rel. Diffusivity	Sorption
PFBA	1	None
Bromide	3	None
Lithium Ion	2	Weak
Microspheres	0.001-0.002	?

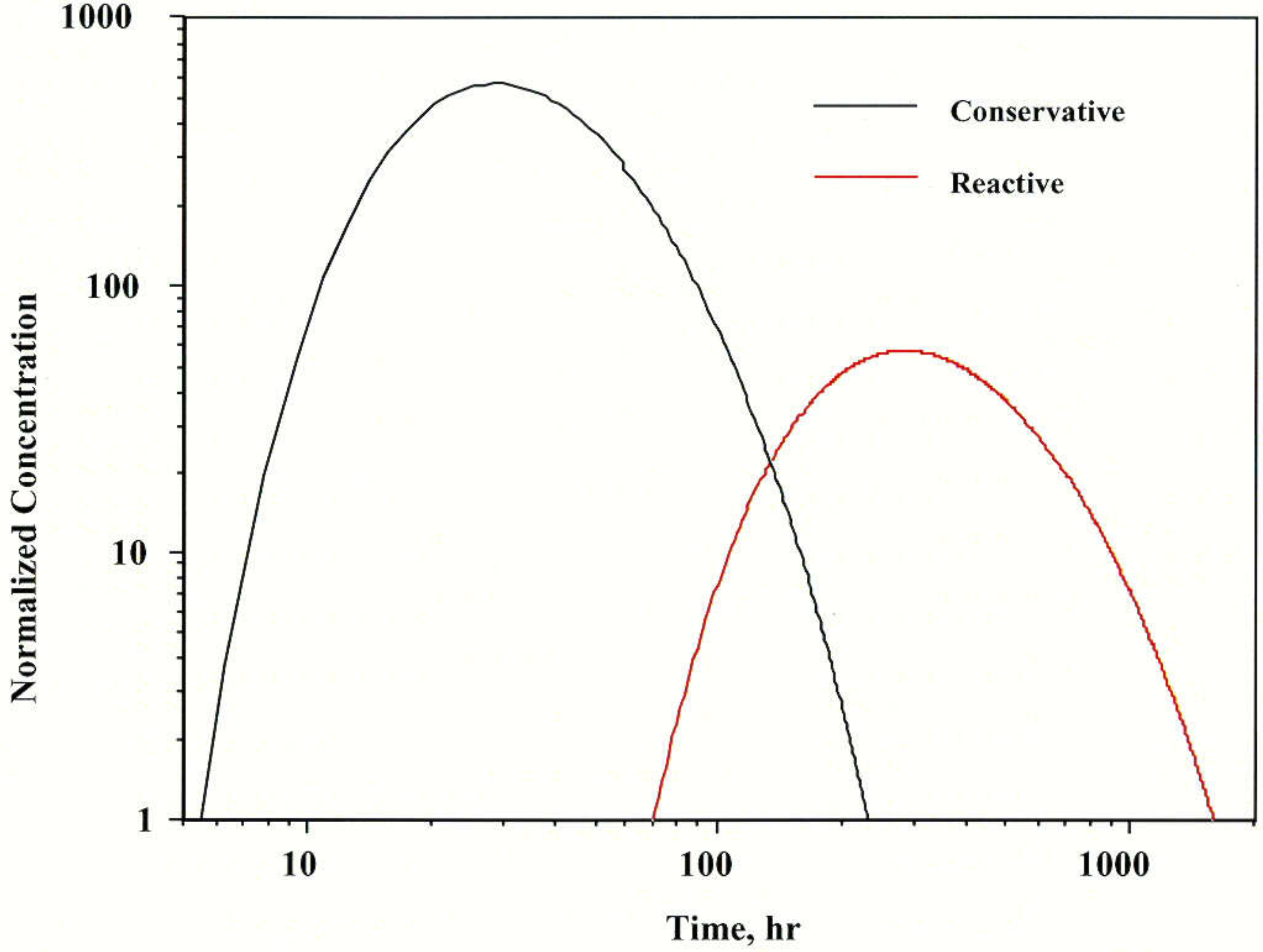
Laboratory Diffusion Cell Tests to Confirm Relative Diffusion Coefficients



Reference: Upcoming C Well Complex Report

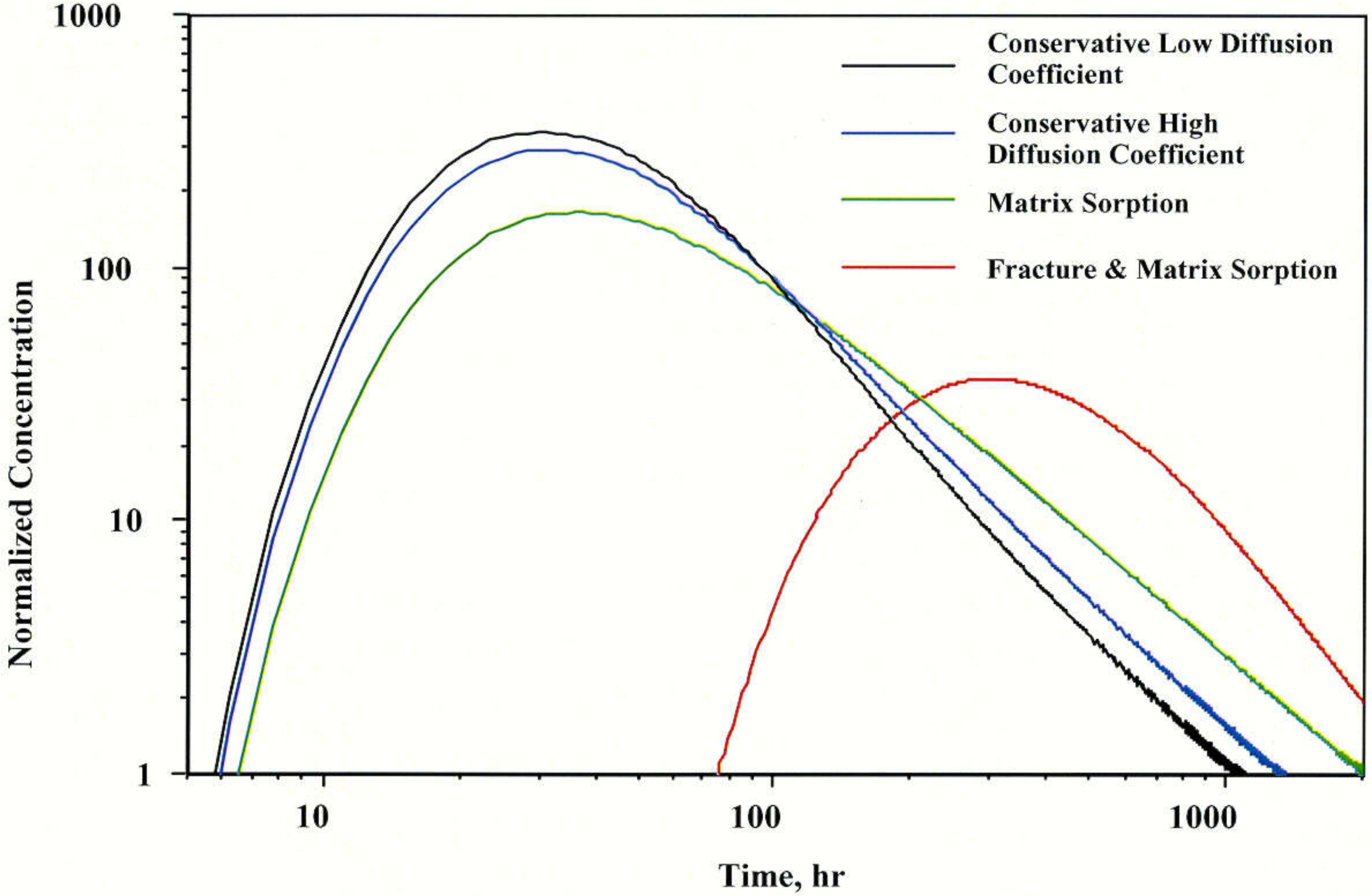
C02

Idealized Single-Porosity Responses



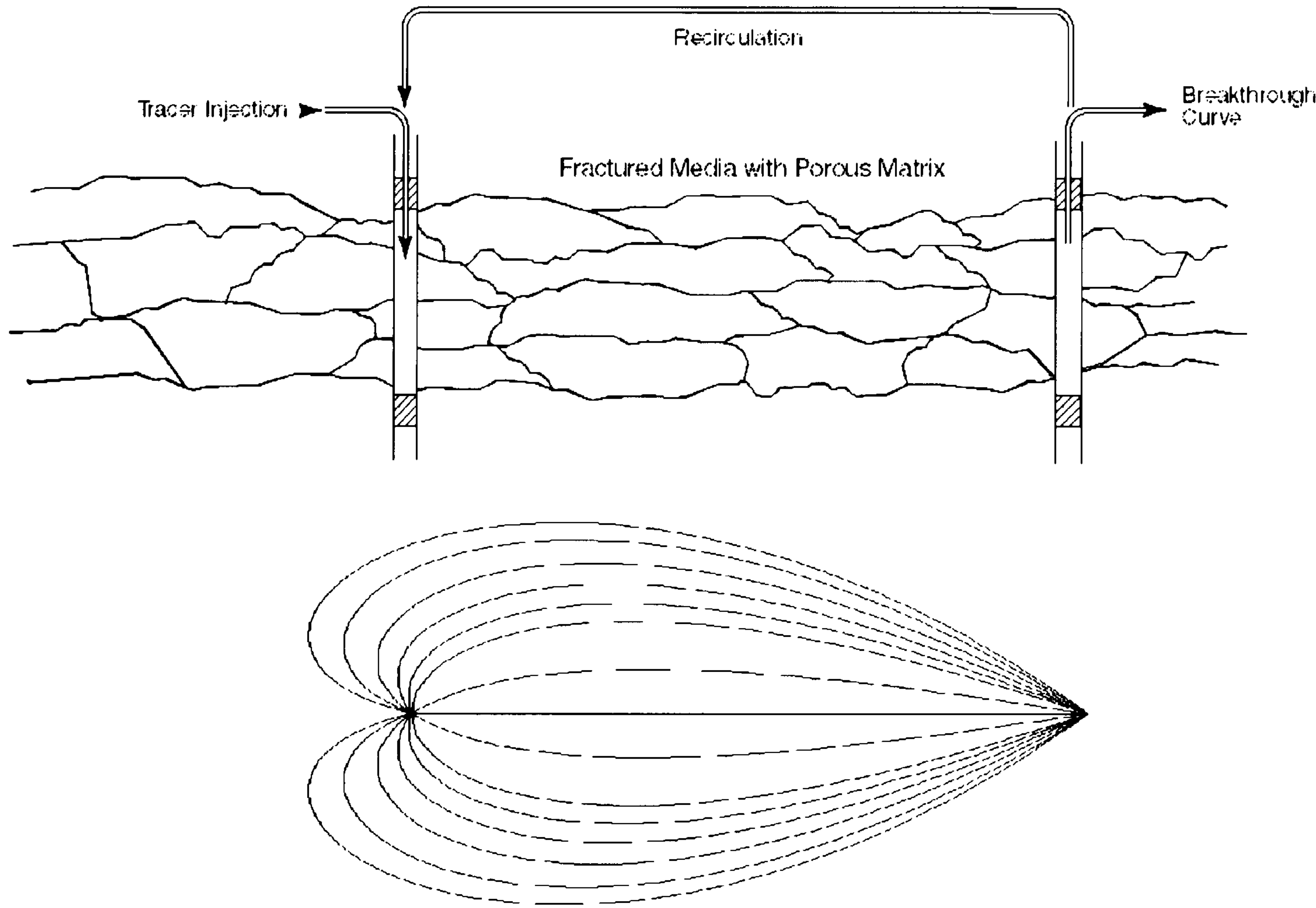
C03

Idealized Dual-Porosity Responses

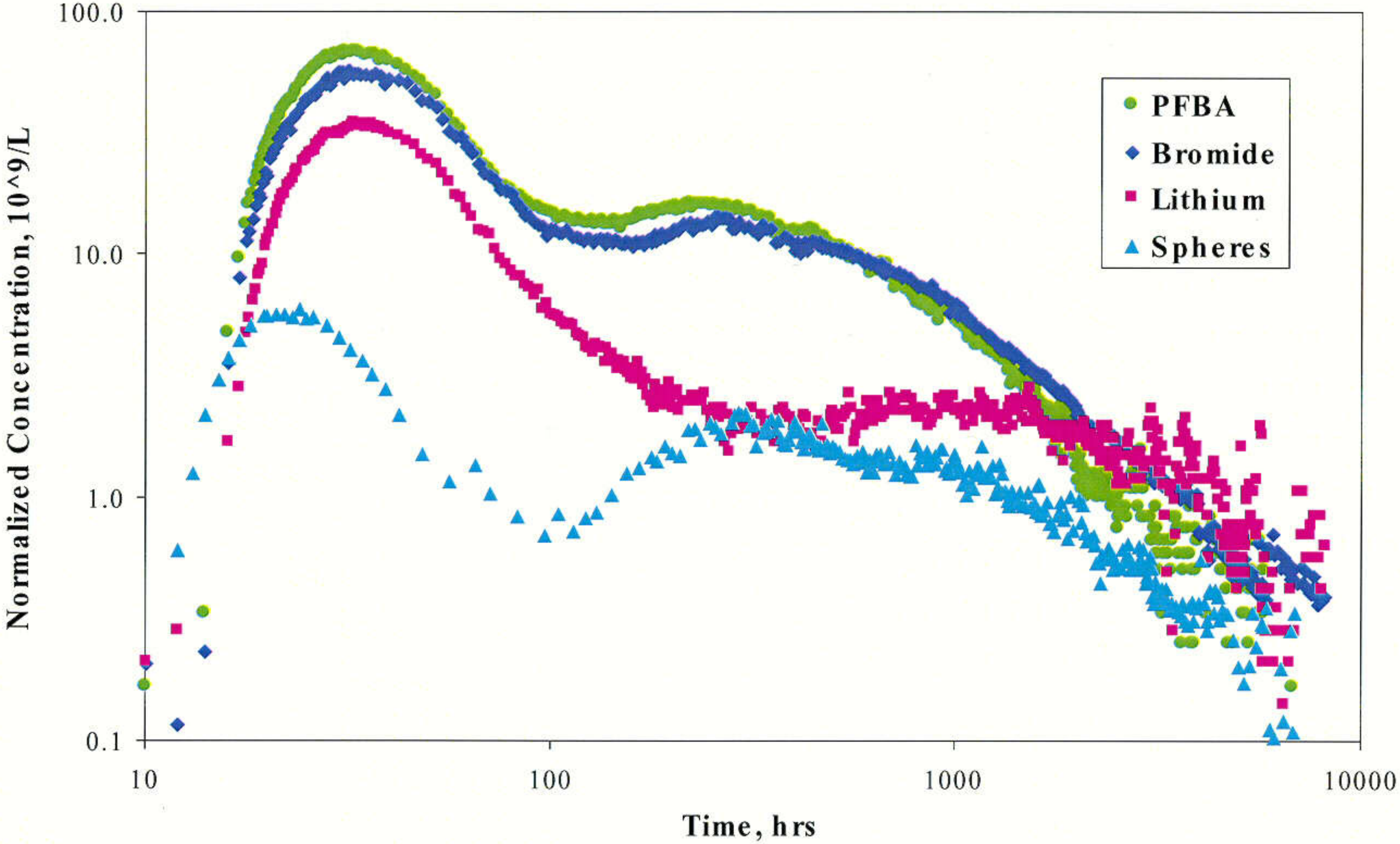


C04

C-Wells Tracer Test Configuration



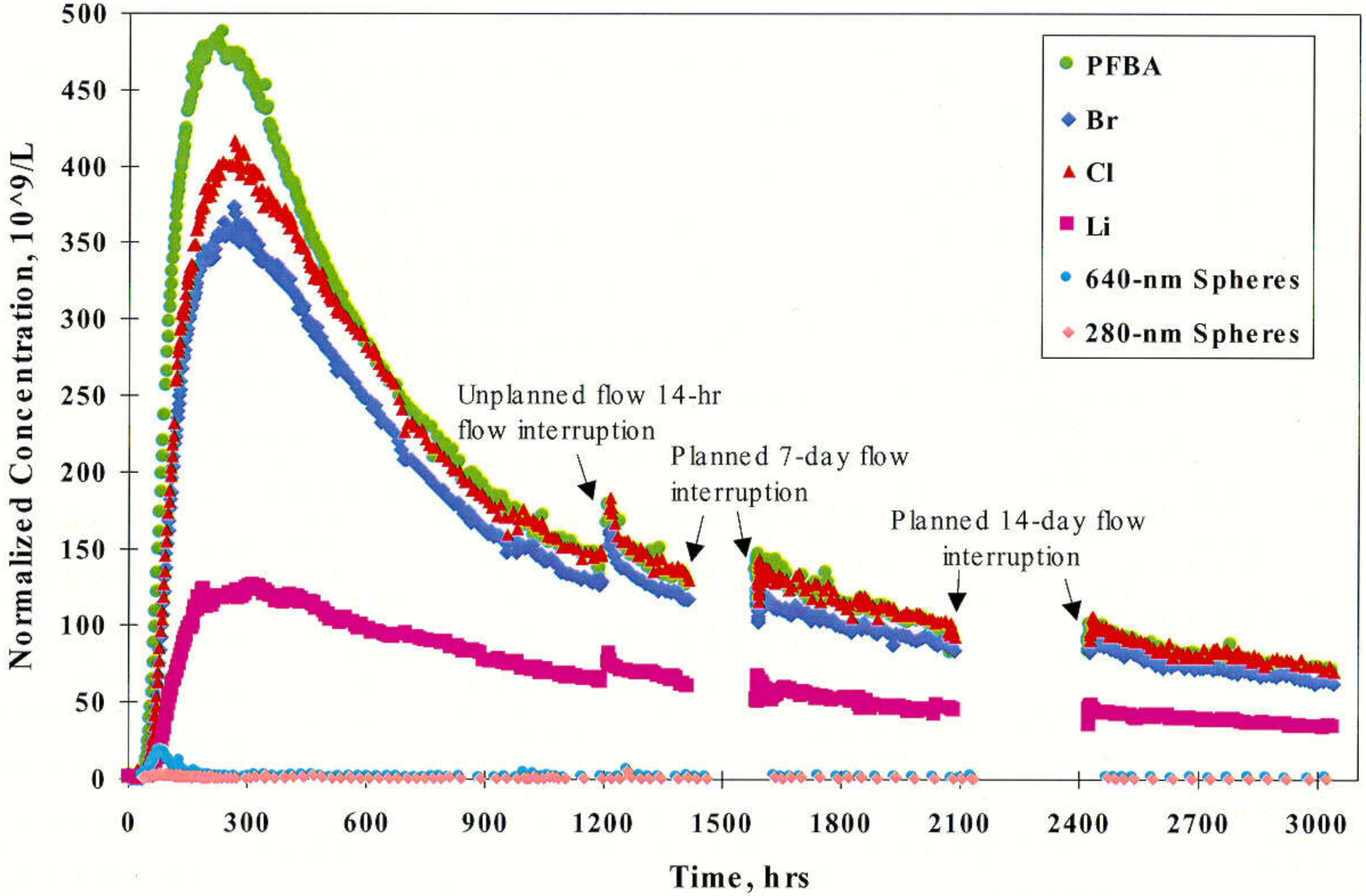
C-Wells Tracer Responses - Bullfrog Tuff



Reference: Unsaturated Zone and Saturated Zone Transport Properties (ANL-NBS-HS-000019 REV 00)

C05

C-Wells Tracer Responses - Prow Pass



Reference: Unsaturated Zone and Saturated Zone Transport Properties (ANL-NBS-HS-000019 REV 00)

C06

Technical Basis Documents

- **C-Wells Documentation Effort for FY 2001**
  - Los Alamos-Series reports on lab tests and field tests
  - Reinterpretation of lithium responses using Multicomponent Transport Model
  - Software QA, qualification of C-Wells Core
  - Journal article submittals on matrix diffusion, reactive transport, and colloid transport in fractured volcanics

Conservative Tracer Testing at C-holes

- Conservative tracer testing at the C-holes showed the presence of matrix diffusion as seen from the following two graphs comparing the breakthrough curves of a fluorinated benzoic acid and iodide
- Horizontal shifts in actual and predicted normalized breakthrough curves indicate matrix diffusion

Conservative Tracer Testing at C-holes

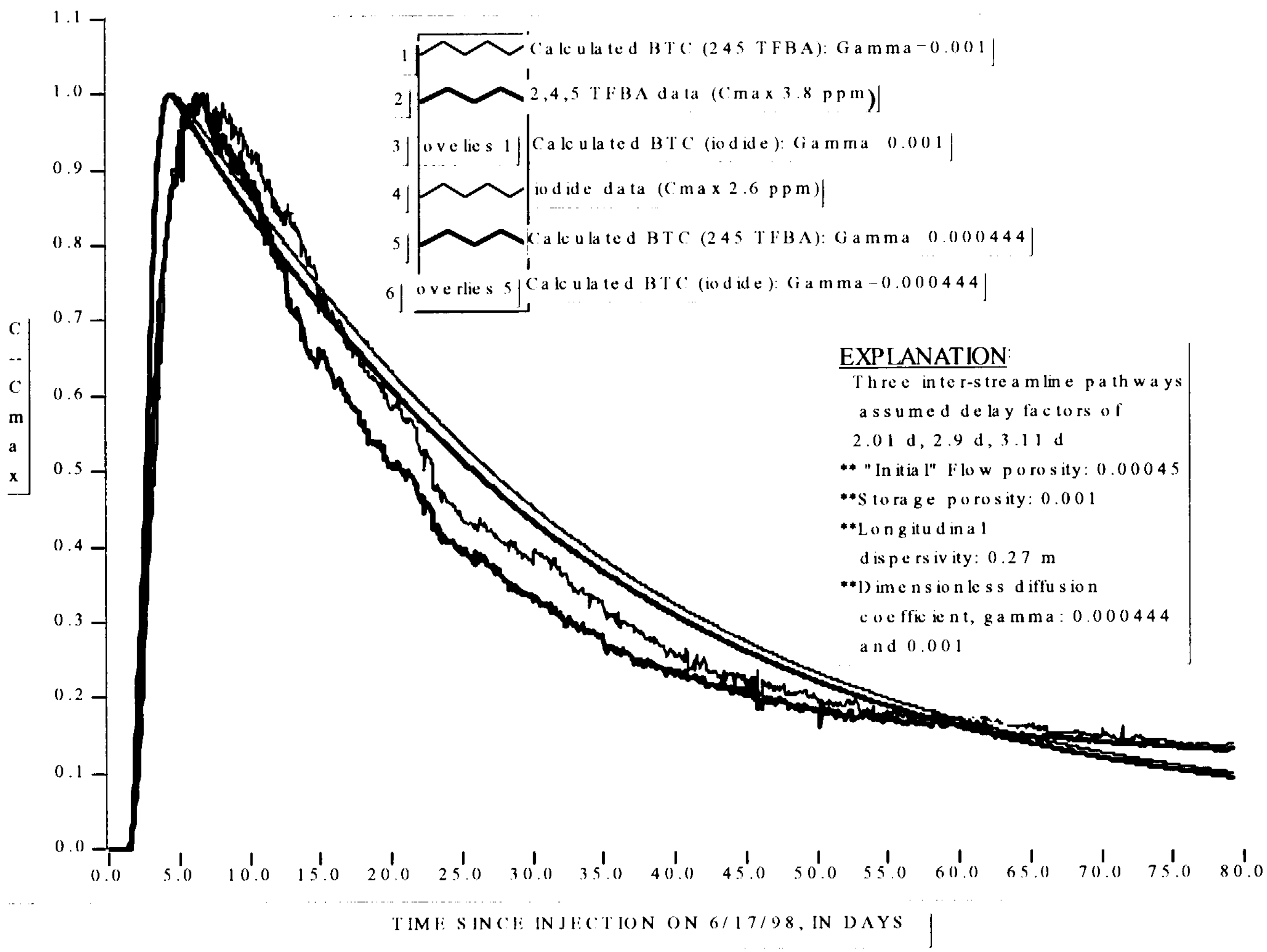


FIGURE 8. BREAKTHROUGH CURVE FOR 6/17/98 2,4,5 TFBA AND IODIDE TRACER TEST, MATCHED BY DUAL-POROSITY, PARTIAL-RECIRCULATION SOLUTION DERIVED FROM MOENCH (1995), WITH STORAGE POROSITY OF 0.001 AND DIMENSIONLESS DIFFUSION COEFFICIENTS, GAMMA, OF 0.000444 AND 0.001

Reference: Upcoming C Well Complex Report

Conservative Tracer Testing at C-holes

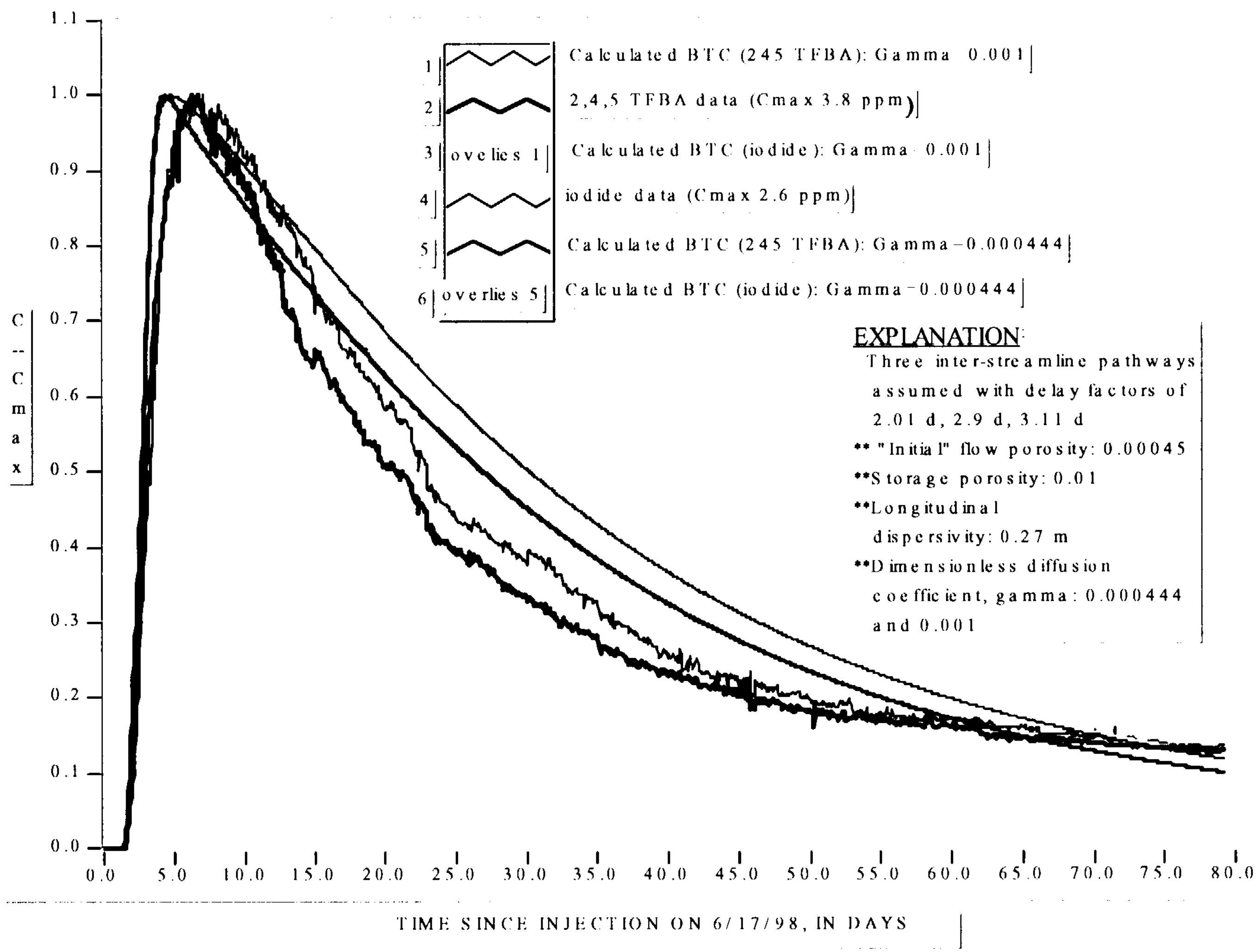


FIGURE 9. BREAKTHROUGH CURVE FOR 6/17/98 2,4,5 TFBA AND IODIDE TRACER TEST, MATCHED BY DUAL-POROSITY, PARTIAL-RECIRCULATION SOLUTION DERIVED FROM MOENCH (1995), WITH STORAGE POROSITY OF 0.01 AND DIMENSIONLESS DIFFUSION COEFFICIENTS, GAMMA, OF 0.000444 AND 0.001

Reference: Upcoming C Well Complex Report

C-Wells Testing
(Continued)

- **References**
  - C-Well Test Report scheduled for completion in September 2001
  - Update to Saturated Zone Process Model Report scheduled for completion in January 2001
  - Analysis and Model Report *Uncertainty Distributions for Stochastic Parameters* (ANL-NBS-MD-000011 REV 00)
- **Evidence of matrix diffusion has been provided in lab and field tests**
- **Uncertainty in how much credit can be taken for matrix diffusion over time and length scales that are greater than those that can be tested is addressed in Total System Performance Assessment simulations (Uncertainty Distributions for Stochastic Parameters Analysis Model Report)**

Conclusions

- **Based on the information presented today, this criterion should be closed**
  - The C-wells conservative and reactive tracer tests demonstrated that models that incorporate matrix diffusion provide more reasonable fits to the tracer-experiment data than those that assume a single continuum
  - The matrix sorption coefficient that fit the data for the lithium tracer in the C-wells reactive tracer experiment agreed well with the value determined in laboratory sorption tests. This provides confidence that the matrix-diffusion model is appropriate
  - DOE plans to complete and publish reports on C-well testing

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Subissue 5, Acceptance Criterion 1: Conceptual Flow and Data Uncertainties

Presented to:
DOE/NRC Technical Exchange on the Key Technical Issue Subissues related to Saturated Zone Flow

Presented by:

Bill W. Arnold, Ph.D.
Civilian Radioactive Waste Management System Management and Operating Contractor

October 31 - November 2, 2000
Albuquerque, NM

YUCCA MOUNTAIN PROJECT

Outline

- **Presentation Objectives**
- **Current Acceptance Criterion Status**
- **For Subissue 5, Acceptance Criterion 1, presentation will:**
  - Summarize technical basis for resolution of items
  - Identify basis documents (References)
  - Summarize technical adequacy of basis
- **Conclusions**

Note: Additional summary information is provided in the delta analysis

Presentation Objectives

- Provide the basis for resolving Acceptance Criterion 1 associated with conceptual flow and data uncertainties
- Acceptance Criterion 1: Department of Energy (DOE) has considered conceptual flow and data uncertainties. Uncertainties due to sparse data or low confidence in the data interpretations have been considered by analyzing reasonable conceptual flow models that are supported by site data, or by demonstrating through sensitivity studies that the uncertainties have little impact on repository performance

Current Acceptance Criterion Status

- Unsaturated and Saturated Flow under Isothermal Conditions Issue Resolution Status Report, Rev. 02 indicates status is open pending review of future DOE groundwater modeling reports, milestone reports, and other submittals
- April 2000 Key Technical Issue Status Technical Exchange identified the Ambient Flow and Dilution Subissue as open; did not specifically provide status of Acceptance Criterion 1

Acceptance Criterion 1

- **Action or information needs identified**
  - Discuss uncertainty in horizontal anisotropy of permeability
  - Discuss consideration of uncertainties
  - Discuss incorporation of Saturated Zone Expert Elicitation comments

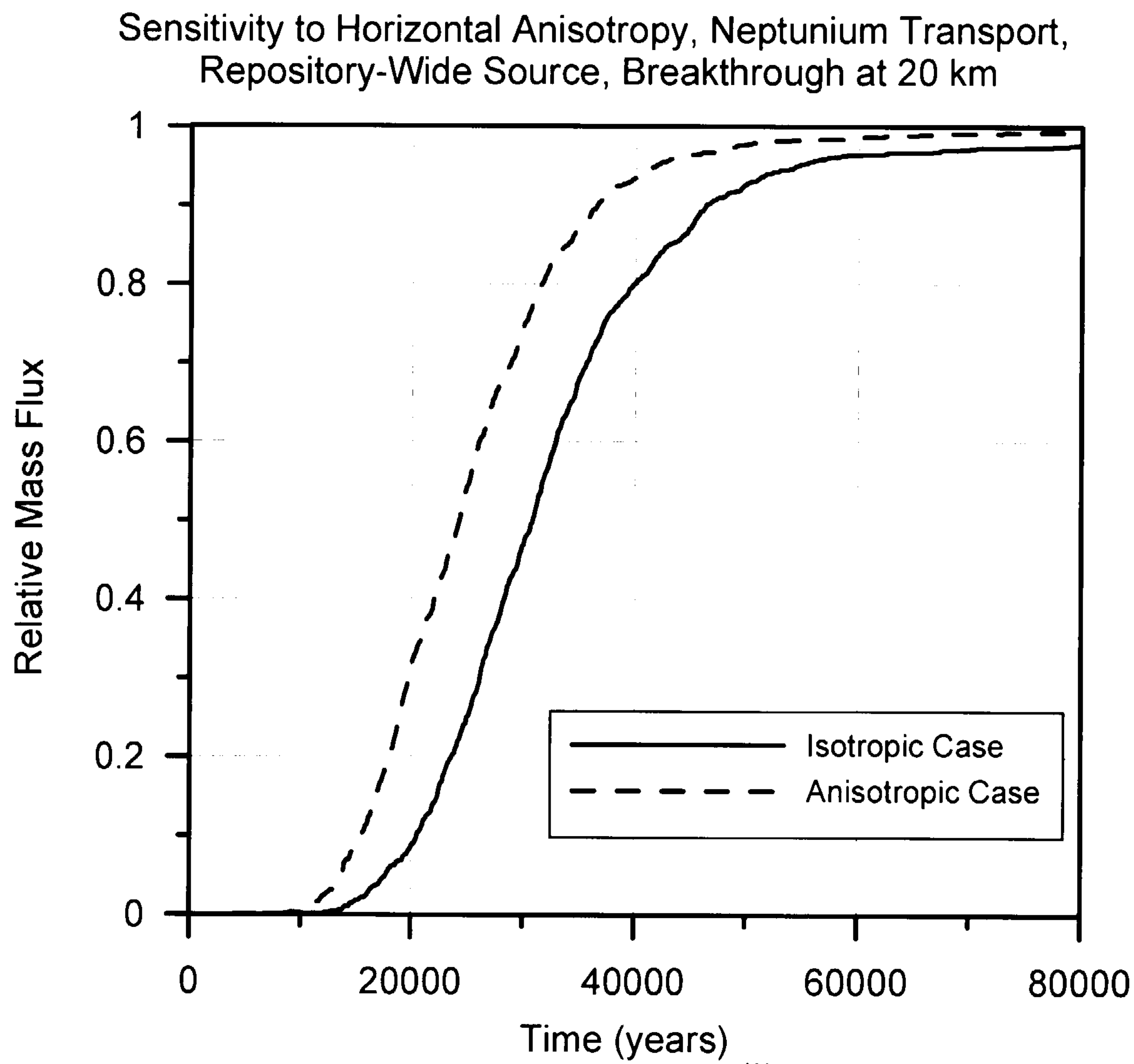
Acceptance Criterion 1

- **Basis for closure**
  - Conceptual flow and data uncertainties have been incorporated in the Total System Performance Assessment analyses
  - Uncertainties due to sparse data or low confidence in the data interpretations have been incorporated into the analyses by analyzing reasonable conceptual flow models that are supported by site data
- **This acceptance criterion has been fully addressed and should be closed**
  - DOE has incorporated uncertainty and variability into the Total System Performance Assessment

Horizontal Anisotropy

- **Basis for resolution**
  - Two discrete cases for horizontal anisotropy in permeability are defined (isotropic and 5:1 ratio)
  - Anisotropy has been applied to volcanic units south and east of Yucca Mountain
  - Anisotropy alters calibration to heads by less than 1 meter

Horizontal Anisotropy
(Continued)



***Note that breakthrough curves do not include decay**
Reference: ANL-NBS-HS-000030

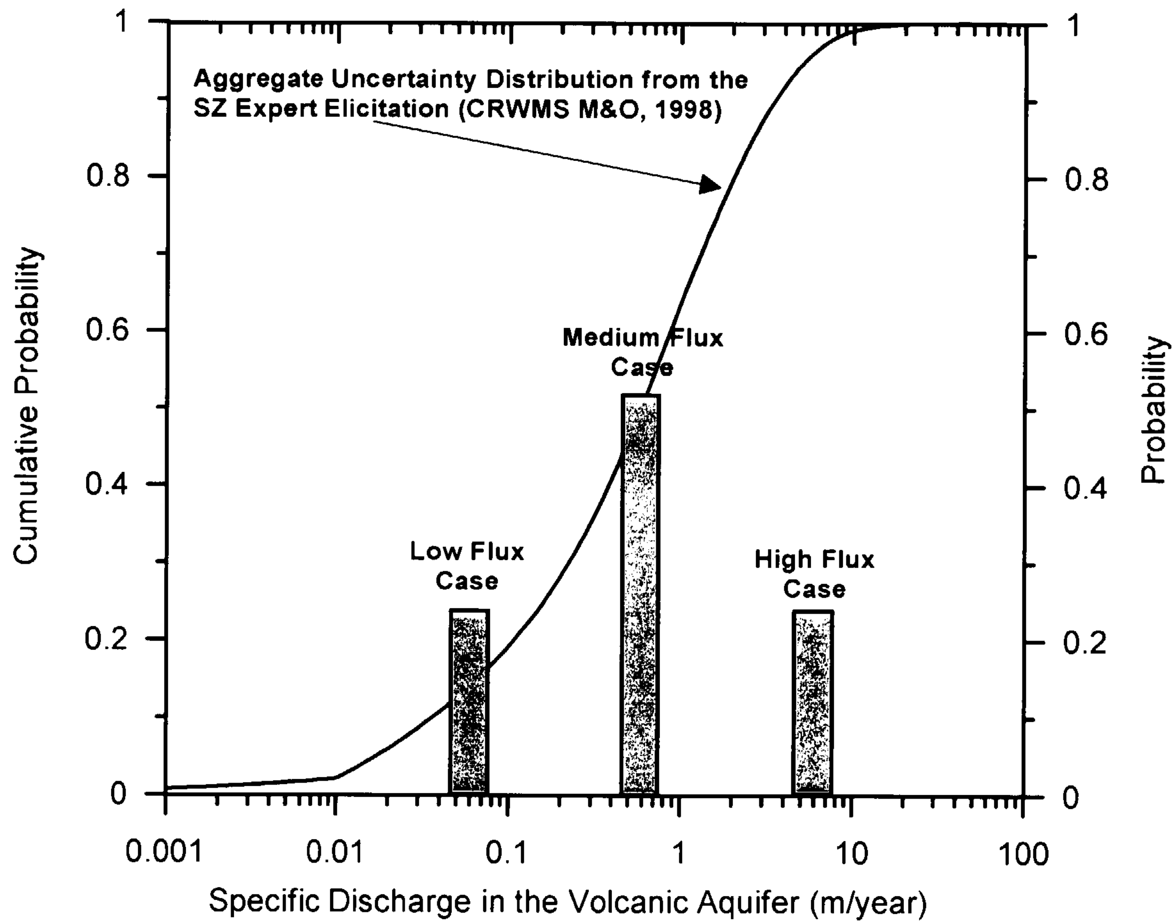
Horizontal Anisotropy
(Continued)

- **References**
  - Analysis and Model Report *Uncertainty Distributions for Stochastic Parameters* (ANL-NBS-MD-000011)
  - Analysis and Model Report *Input and Results of the Base Case Saturated Zone Flow and Transport Model for TSPA* (ANL-NBS-HS-000030)
- **Updated analyses address horizontal anisotropy. No additional work needed**

Consideration of Uncertainties (specific discharge)

- **Basis for resolution (groundwater specific discharge)**
  - Uncertainty in Saturated Zone specific discharge (groundwater flux) is based on results of the Saturated Zone expert elicitation
  - Three discrete cases (low, medium, and high flux) are defined for the Saturated Zone site-scale flow and transport model
  - Probabilities assigned to each case are derived from the aggregate uncertainty distribution for specific discharge in the volcanic aquifer from the Saturated Zone expert elicitation
  - Saturated Zone site-scale model boundary fluxes and permeabilities are scaled to preserve calibration to head

Consideration of Uncertainties (specific discharge)



Reference: ANL-NBS-MD-000011

Consideration of Uncertainties (specific discharge) (Continued)

- **References**
  - Analysis and Model Report *Uncertainty Distributions for Stochastic Parameters* (ANL-NBS-MD-000011)
  - Analysis and Model Report *Input and Results of the Base Case Saturated Zone Flow and Transport Model for TSPA* (ANL-NBS-HS-000030)
  - *Saturated Zone Flow and Transport Expert Elicitation Project* (MOL.19980825.0008)
- **Updated analyses address consideration of uncertainties. No additional work needed**

Consideration of Uncertainties (uncertain parameters)

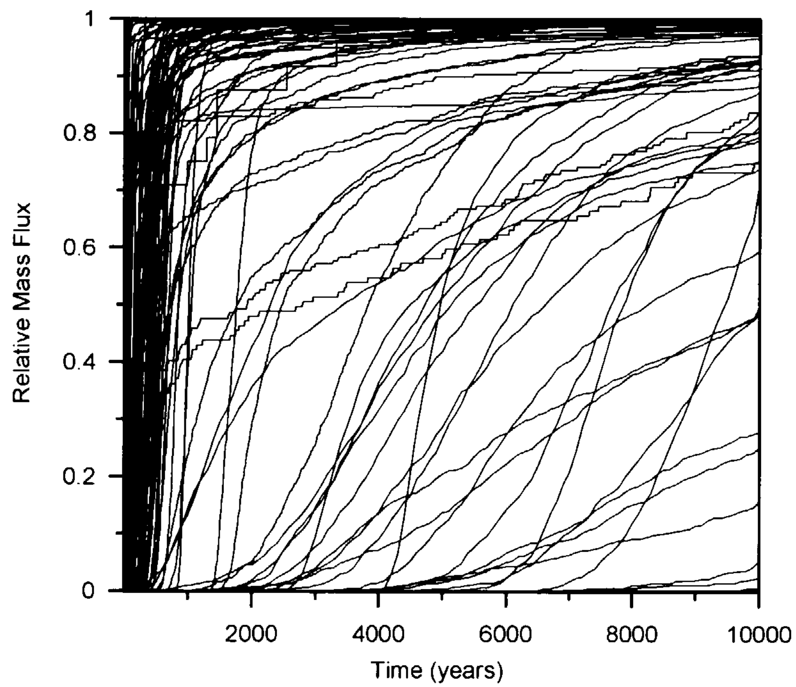
- **Basis for resolution (uncertain parameters)**
  - Conceptual flow and data uncertainties have been quantified as uncertainty distributions
  - Total System Performance Assessment-Site Recommendation incorporates key conceptual flow and data uncertainties in Saturated Zone flow and transport simulations using Monte Carlo methods

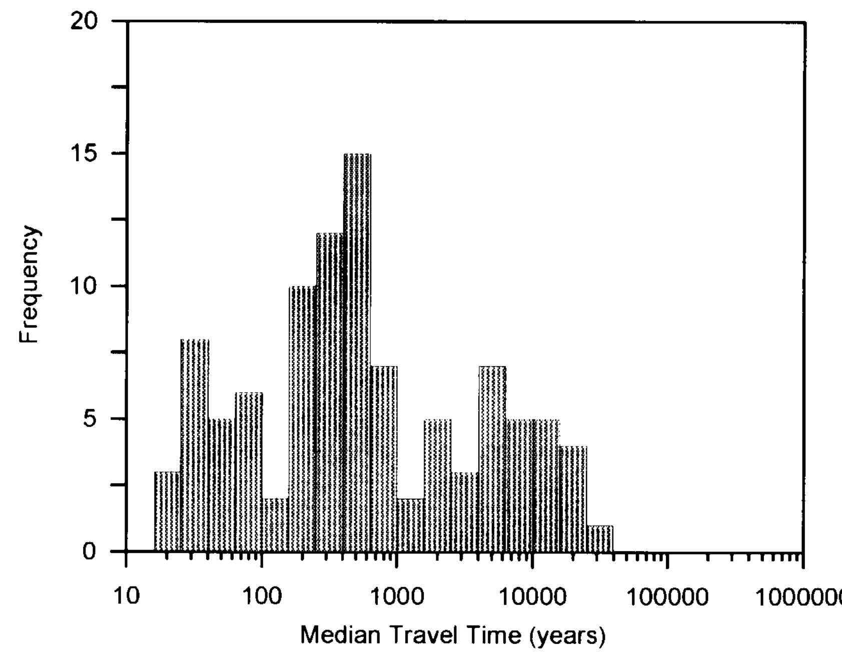
Consideration of Uncertainties (uncertain parameters) (Continued)

Parameter	Variability	Uncertainty
permeability	units, features	constant (scaled)
groundwater flux uncertainty factor	low, medium, high cases	stochastic
climate flux factor	present, monsoonal, glacial transition cases	constant
matrix porosity	units, ISM	constant
effective porosity	units	stochastic (alluvium)
flowing interval spacing	constant	stochastic
flowing interval porosity	constant	stochastic
effective diffusion coefficient	constant	stochastic
bulk density	units, ISM	constant
sorption coefficient	radionuclide, units (alluvium, volcanics)	stochastic
longitudinal dispersivity	constant	stochastic
horizontal transverse dispersivity	constant	stochastic
vertical transverse dispersivity	constant	stochastic
colloid retardation factor (volcanics)	constant	stochastic
colloid retardation factor (alluvium)	constant	stochastic
Kc parameter for actinides, Sr, and Cs	constant	stochastic
horizontal anisotropy in permeability	units (volcanics only)	stochastic
volumetric groundwater use by the critical group	N/A	stochastic

Consideration of Uncertainties (uncertain parameters) (Continued)

Mass Flux Breakthrough Curves at 20 km, Source Region 1
3-D SZ Site-Scale Transport Model, 100 Realizations C-14 Transport



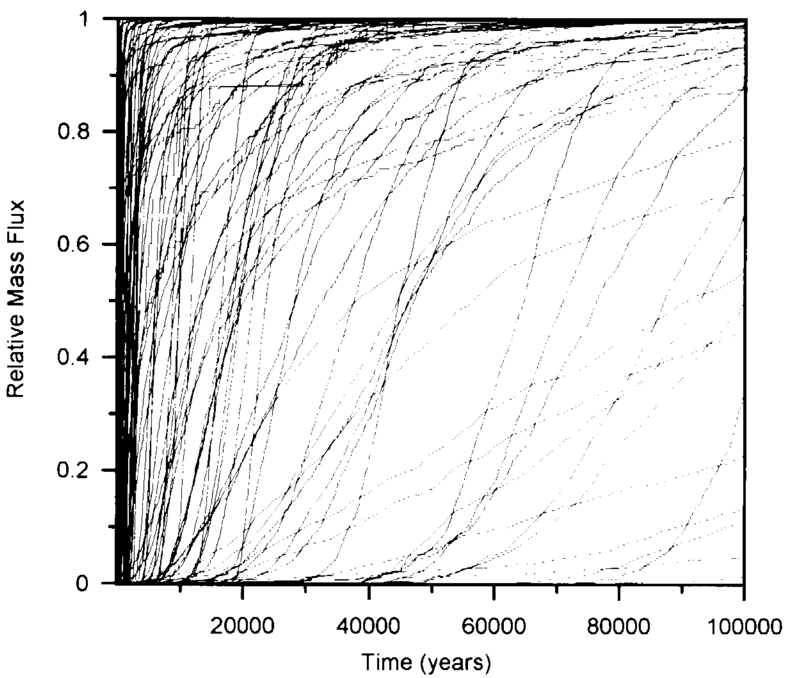


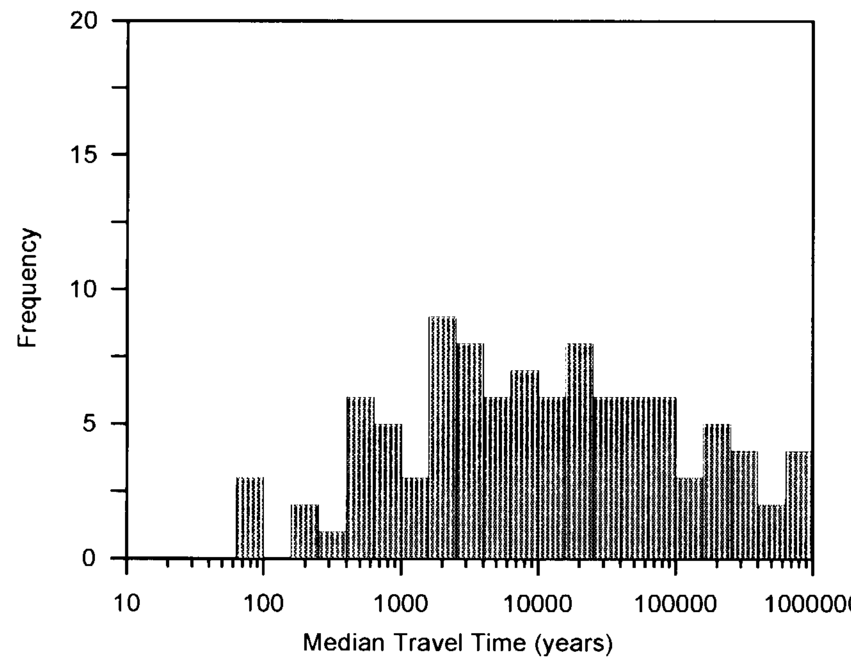
***Note that breakthrough curves do not include decay and represent transport only in the Saturated Zone**

Reference: TDR-NBS-HS-000001

Consideration of Uncertainties (uncertain parameters) (Continued)

Mass Flux Breakthrough Curves at 20 km, Source Region 1
3-D SZ Site-Scale Transport Model, 100 Realizations Np-237 Transport

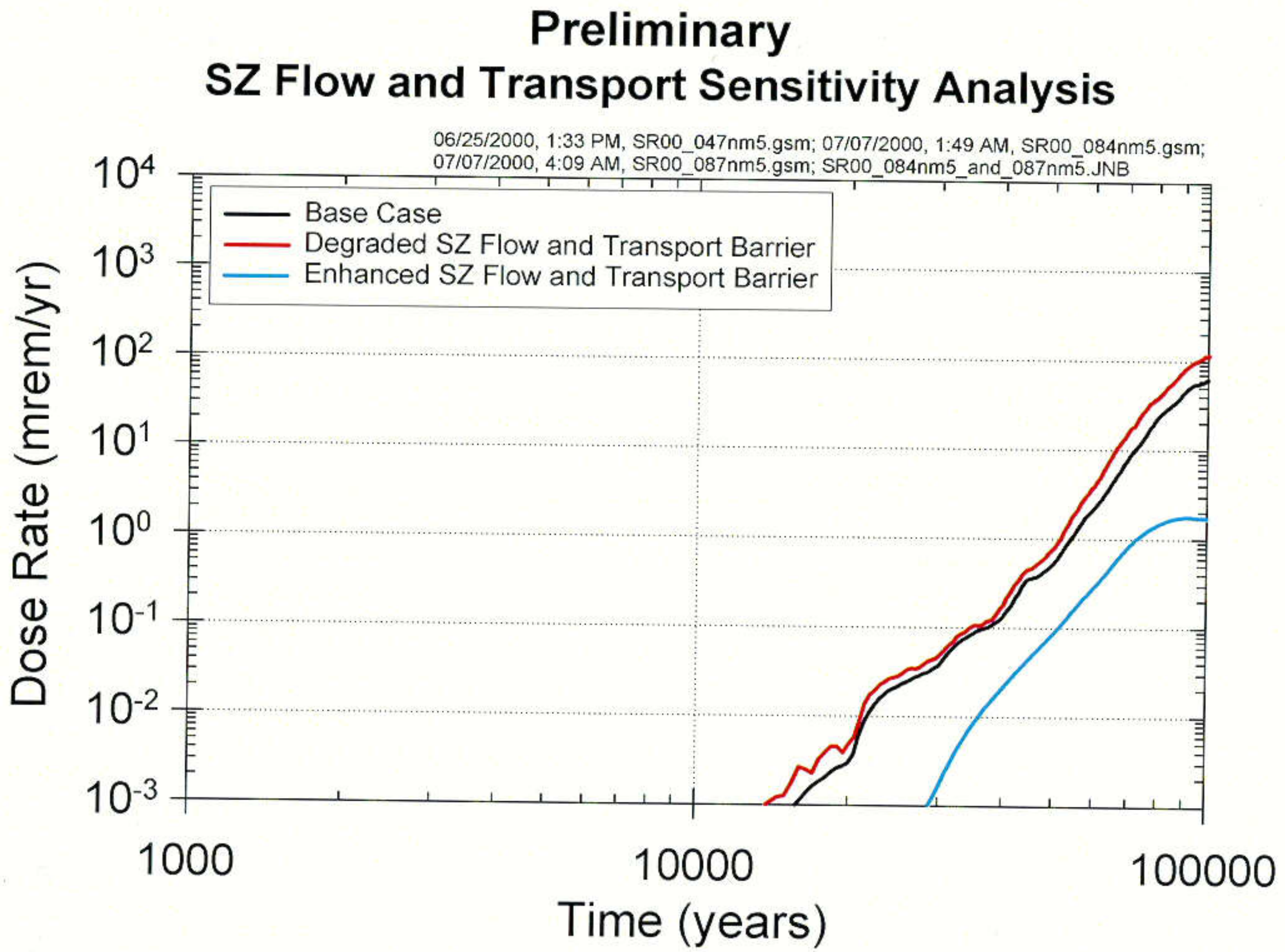




***Note that breakthrough curves do not include decay and represent transport only in the Saturated Zone**

Reference: TDR-NBS-HS-000001

Consideration of Uncertainties (uncertain parameters) (Continued)



Reference: *TSPA-SR* (work in progress)

C07

Consideration of Uncertainties (uncertain parameters) (Continued)

- **References**
  - Analysis and Model Report *Uncertainty Distributions for Stochastic Parameters* (ANL-NBS-MD-000011)
  - Analysis and Model Report *Input and Results of the Base Case Saturated Zone Flow and Transport Model for TSPA* (ANL-NBS-HS-000030)
  - *Saturated Zone Flow and Transport Process Model Report* (TDR-NBS-HS-000001 REV 00 ICN 01)
- **Updated analyses address consideration of uncertainties. No additional work needed**

Saturated Zone Expert Elicitation Comments and Recommendations

- **Basis for resolution**
  - Panel members of the Saturated Zone Expert Elicitation made comments and recommendations on several issues
  - Comments and recommendations were synthesized and tabulated for the Saturated Zone Flow/Transport and Biosphere Workshop (Feb. 17-19, 1999)
    - Kuzio, S. 1999. "Saturated Zone Flow/Transport and Biosphere Workshop Summary Document." Memorandum from S. Kuzio (SNL) to Distribution, May 25, 1999, with enclosure ACC: MOL.19991217.0096
  - Recommendations have been included as appropriate in Total System Performance Assessment-Site Recommendation modeling or are being addressed by ongoing field testing. They are discussed in Appendix A of the Saturated Zone Flow and Transport Process Model Report

Saturated Zone Expert Elicitation Comments (Continued)

- **References**
  - *Saturated Zone Flow and Transport Process Model Report.* (TDR-NBS-HS-000001 REV 00 ICN 01)
  - "Saturated Zone Flow/Transport and Biosphere Workshop Summary Document." Memorandum from S. Kuzio (SNL) to Distribution, May 25, 1999, with enclosure. ACC: MOL.19991217.0096
- **Expert Elicitation comments have been considered in planning and testing. No additional work needed**

Conclusions

- The Saturated Zone Flow and Transport Process Model Report and Supporting Analysis Model Reports provide the information required for this acceptance criterion
- Representation of conceptual and data uncertainties in Total System Performance Assessment will be refined using additional site data, when available
- The status of this acceptance criterion should be closed

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Subissue 5, Acceptance Criterion 5: Estimates of Key Hydrologic Parameters

Presented to:
DOE/NRC Technical Exchange on the Key Technical Issue Subissues Related to Saturated Zone Flow

Presented by:
Al Aziz Eddebbarh, Ph.D
Paul Reimus
Civilian Radioactive Waste Management System Management and Operating Contractor
M. J. Umari
United States Geological Survey

October 31 - November 2, 2000
Albuquerque, NM

YUCCA MOUNTAIN PROJECT

Outline

- **Presentation Objectives**
- **Current Acceptance Criterion 5 Status**
- **For Subissue 5, Acceptance Criterion 5, presentation will:**
  - Summarize technical basis for item resolution
  - Identify basis documents (References)
  - Summarize technical adequacy of basis
- **Conclusions**

Note: Additional summary information is provided in the delta analysis

Presentation Objectives

- Provide the basis for resolving Acceptance Criterion 5 associated with estimates of key hydrologic parameters
- Subissue 5, Acceptance Criterion 5: DOE estimates of key hydrologic parameters are described in the form of either probability distributions or deterministic bounding values reasonably consistent with site data. These parameters should include transmissivity, hydraulic gradient, effective flow porosity, effective immobile porosity, and effective aquifer thickness

Current Acceptance Criterion 5 Status

- **Unsaturated and Saturated Flow under Isothermal Conditions Issue Resolution Status Report, Rev. 02 indicates status is open pending review of future Nye County reports and DOE milestone reports on testing in the tuffs. DOE should continue efforts to fill in data gaps**
- **April 2000 Key Technical Issue Status Technical Exchange identified the Saturated Zone Flow and Dilution Subissue as open; did not specifically provide status of Acceptance Criterion 5**

Acceptance Criterion 5

- **Action or information needs identified**
  - At the April 2000 KTI Status Technical Exchange the NRC indicated that the need existed to obtain hydraulic conductivity and effective porosity for saturated valley fill at 20-km and in the data gaps to the south of Yucca Mountain
  - In agenda-setting telecons for this technical exchange, the NRC requested
    - a plan to fill the data gap north of the Washburn well and 19 complex
    - plans to obtain porosity data in the valley fill, using geophysical methods
    - plans for tracer tests at the Alluvium Testing Complex, along with detailed stratigraphy and results of aquifer tests in the complex

Acceptance Criterion 5
(Continued)

- **Basis for closure**
  - Values of parameters currently used for valley fill aquifer are based upon evaluation of regional values for similar type deposits and are supported by information from expert elicitation. Sufficient information is available to incorporate uncertainty and variability into the Total System Performance Assessment
  - DOE plans to complete a program of work with the Nye County Early Warning Drilling Program and at the Alluvium Testing Complex to continue to confirm these values
  - DOE continues to incorporate data gathered through the cooperative agreement with Nye County

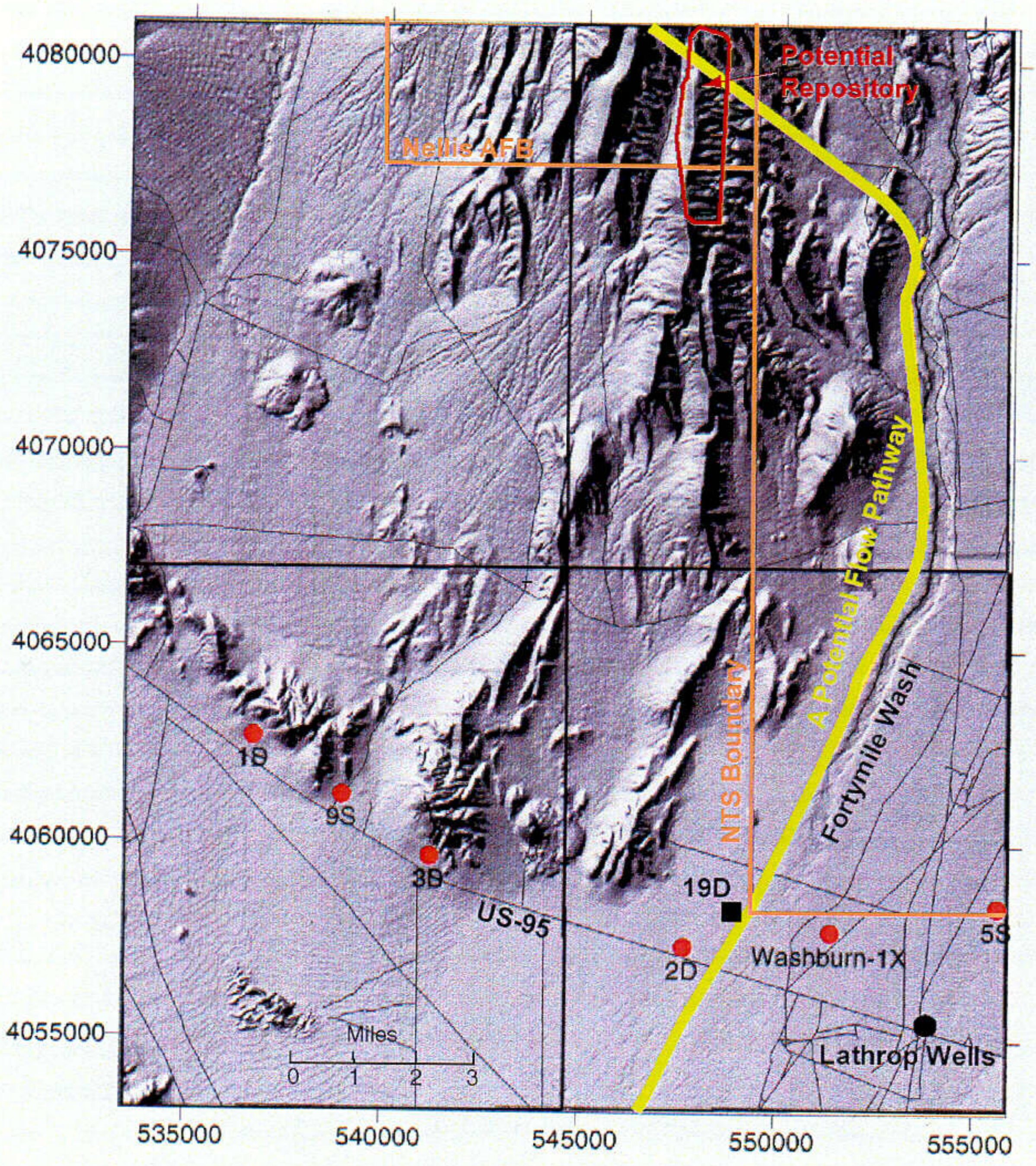
Acceptance Criterion 5
(Continued)

- DOE is providing estimates of key hydrologic parameters as described in the form of either probability distributions or deterministic bounding values that are reasonably consistent with site data

Hydraulic Conductivity and Effective Porosity of Valley Fill and Data Gap South of Yucca Mountain

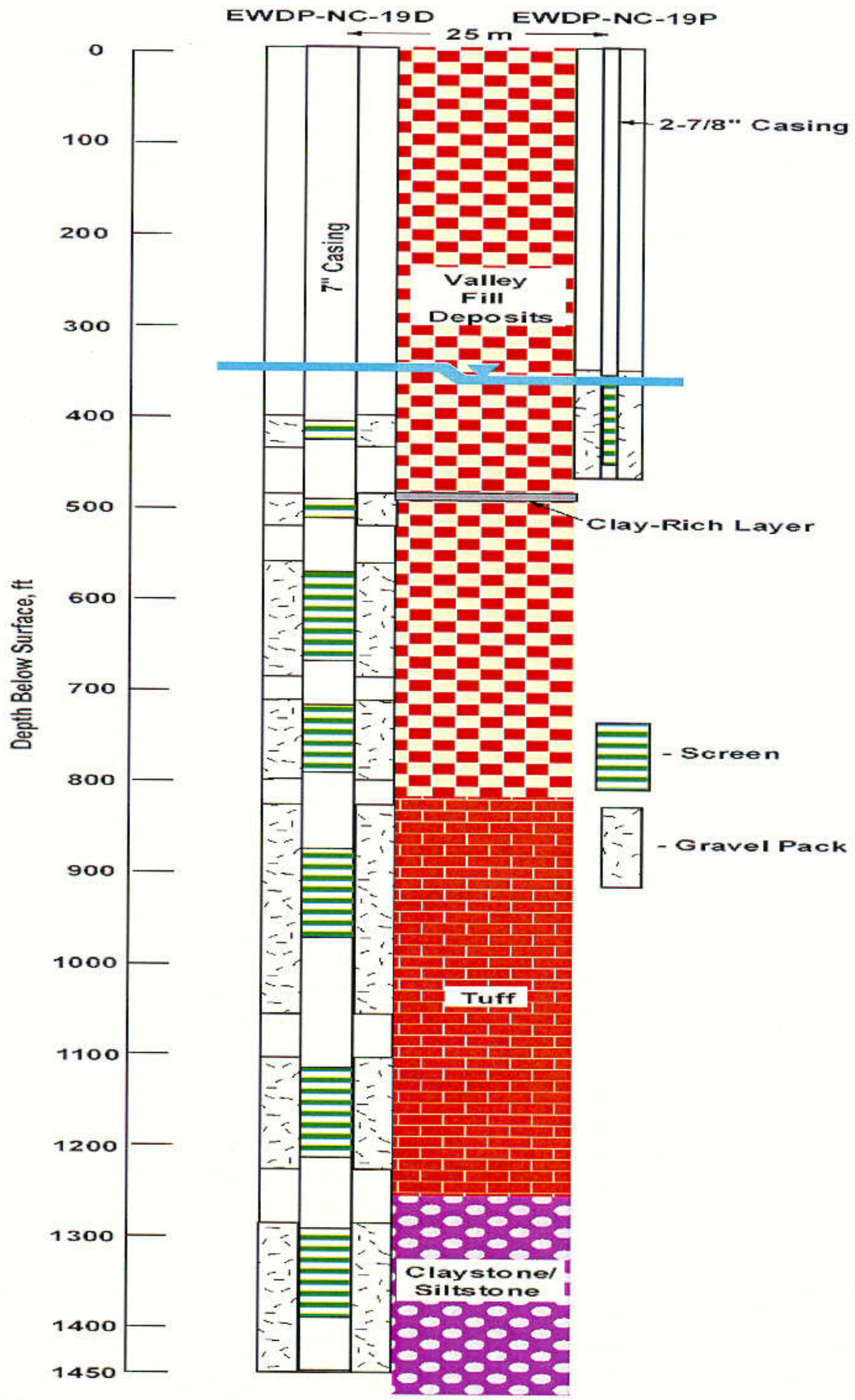
- **Basis for Resolution**
  - Hydraulic testing at Well 19-D has provided hydraulic conductivity information
  - Hydraulic testing of Nye County Phase I wells has provided additional hydraulic conductivity information
  - Grain size analysis is providing information on porosity
  - Ongoing testing at Alluvium Testing Complex and data from Nye County drilling program on hydraulic conductivity and effective porosity will add to existing data

ATC Location



Reference: work in progress

19D1/P Completions



Horizontally Exaggerated

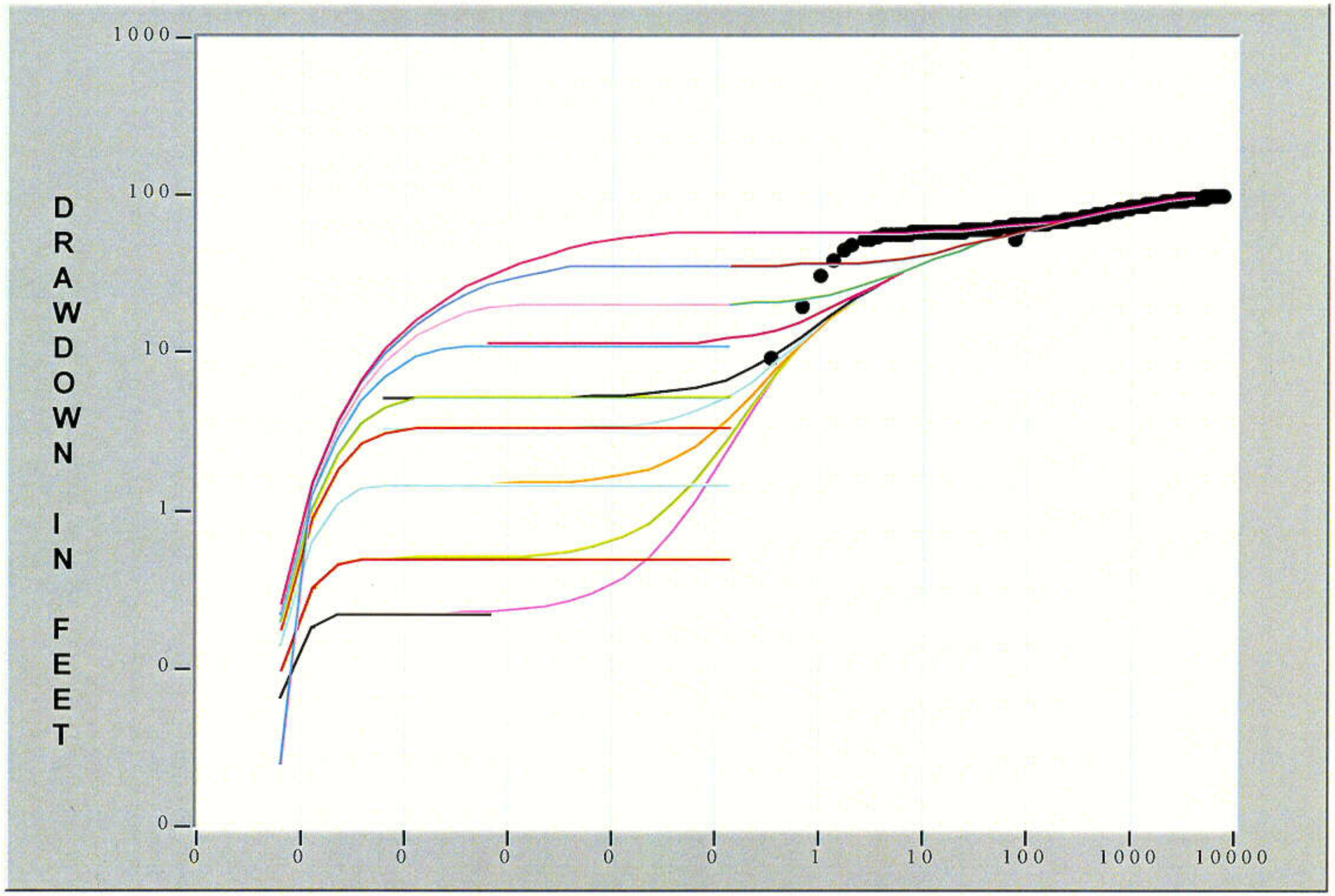
Reference: work in progress

C09

Hydraulic testing results from the Alluvium Testing Complex

- **Hydraulic testing results from the Alluvium Testing Complex:**
  - Open-hole testing produced a hydraulic conductivity, K, value of 0.5 ft/d
  - Lowest interval, screen #4, produced K= 4 ft/d
  - Interval above lowest, screen #3, produced K= 9 ft/d
  - Below are fits of the data to the Neuman unconfined aquifer type curves and to the Cooper-Jacob straight line approximation to the Theis equation

Alluvium Testing Complex EWDP-19D1 Open Hole Hydraulic Test Analysis Using Neuman's Unconfined Aquifer Analysis

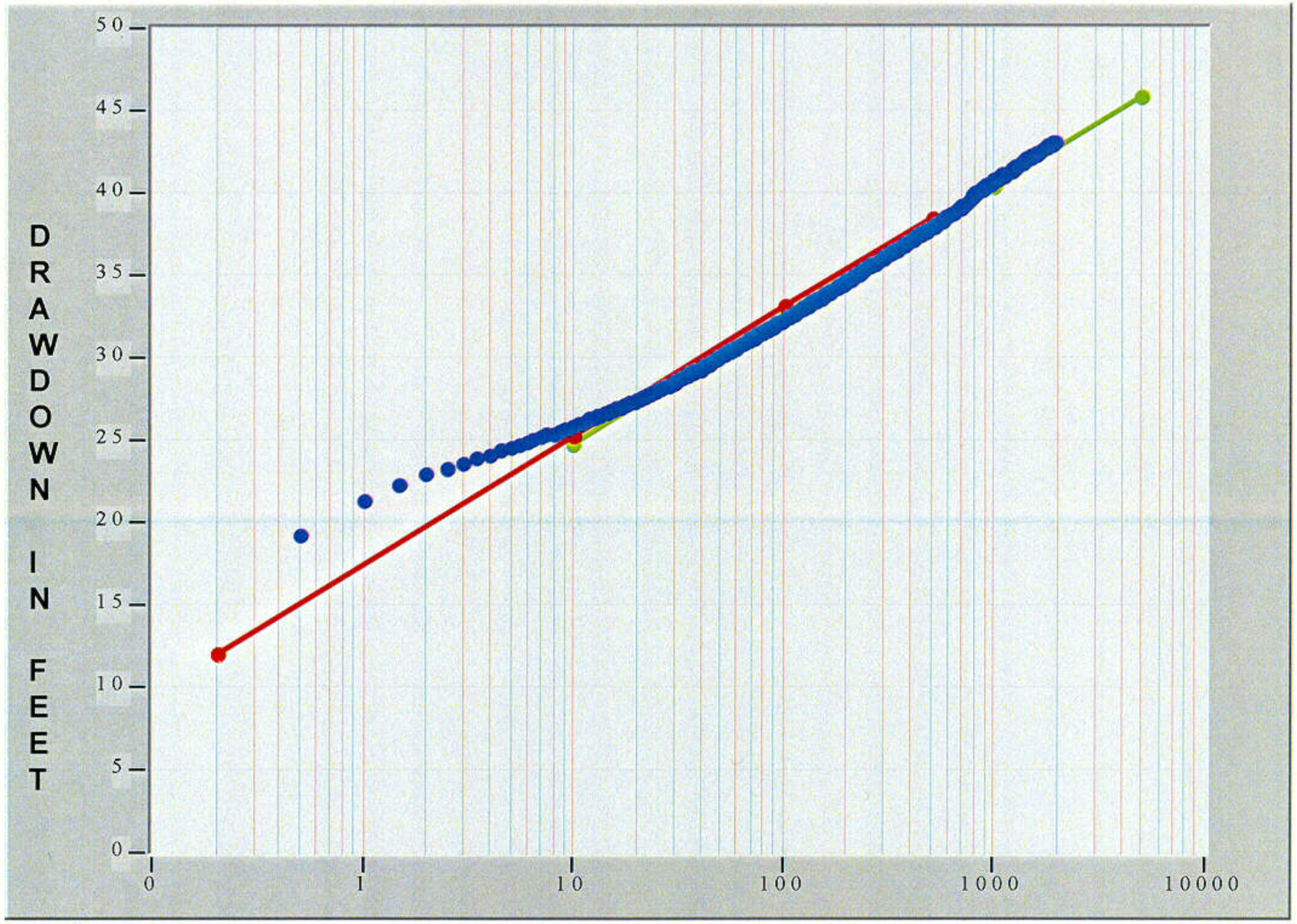


Time in Minutes

Reference: Work in Progress

C10

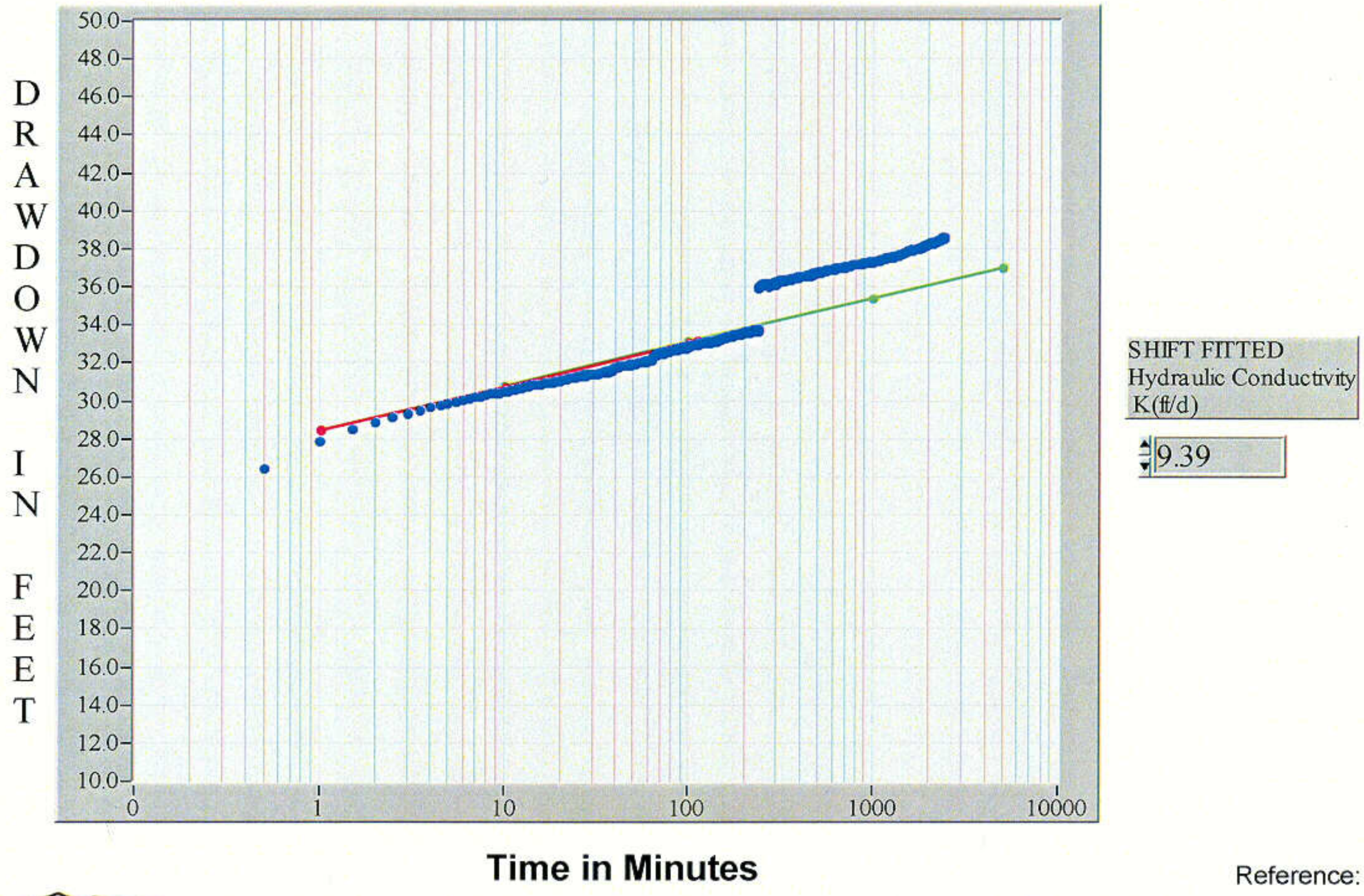
Alluvium Testing Complex
EWDP-19D1 Screen #4 Testing
Using Straight Line Method of Cooper-Jacob



Reference: Work in Progress

C11

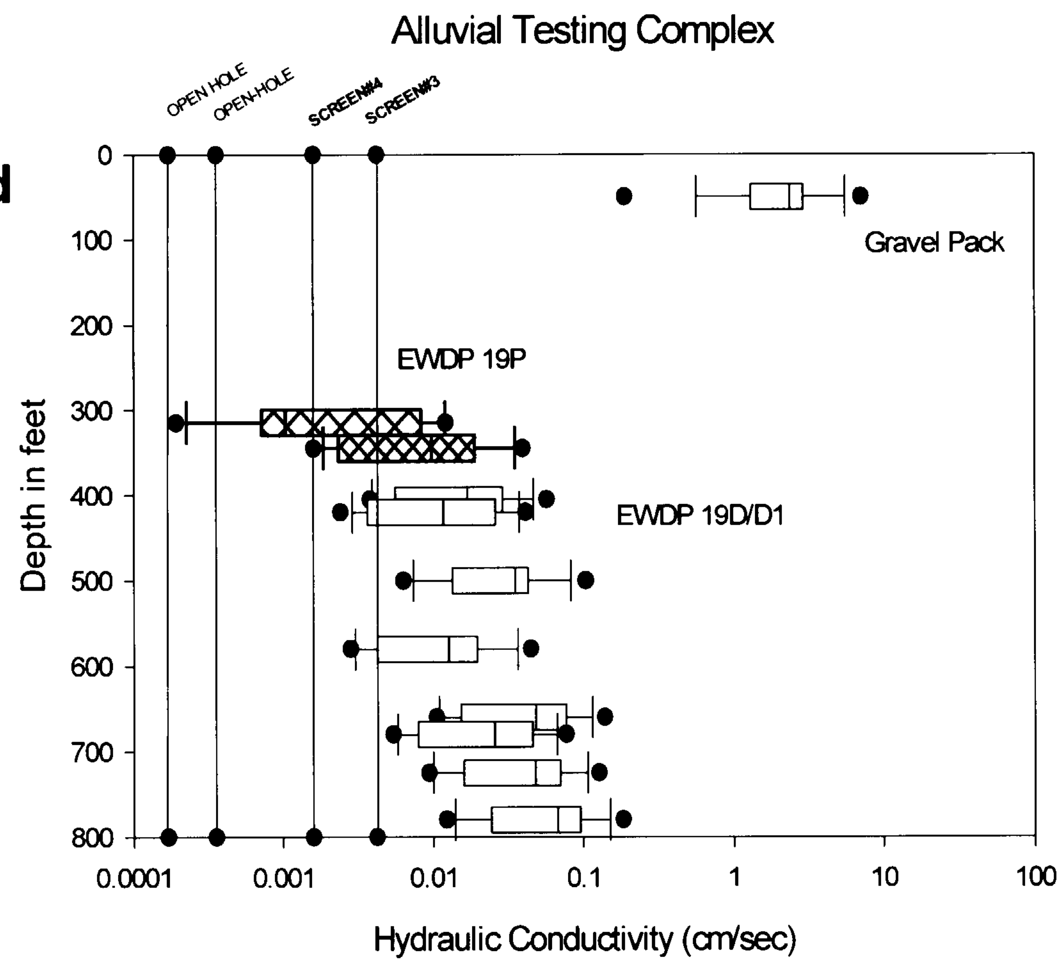
Alluvium Testing Complex
EWDP-19D1 Screen #3 Testing
Using Straight Line Method of Cooper-Jacob



Reference: Work in Progress

Hydraulic Conductivity Estimates

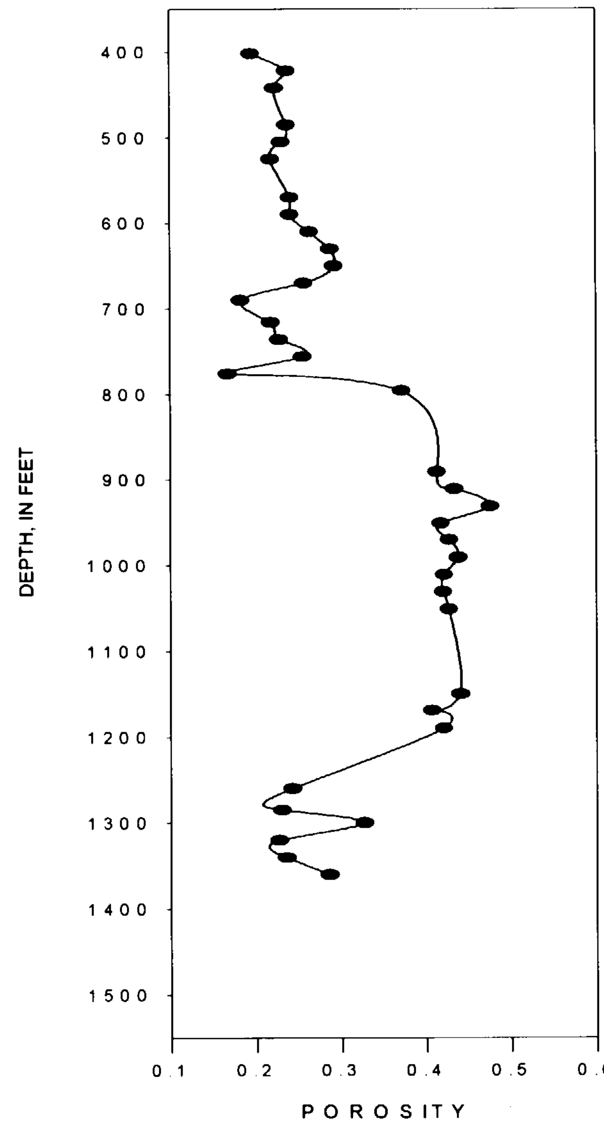
- **From Grain-Size Distributions**
- **Provides Upper Bound**
- **Compares to Aquifer Hydraulic Testing**



Reference: Work in Progress

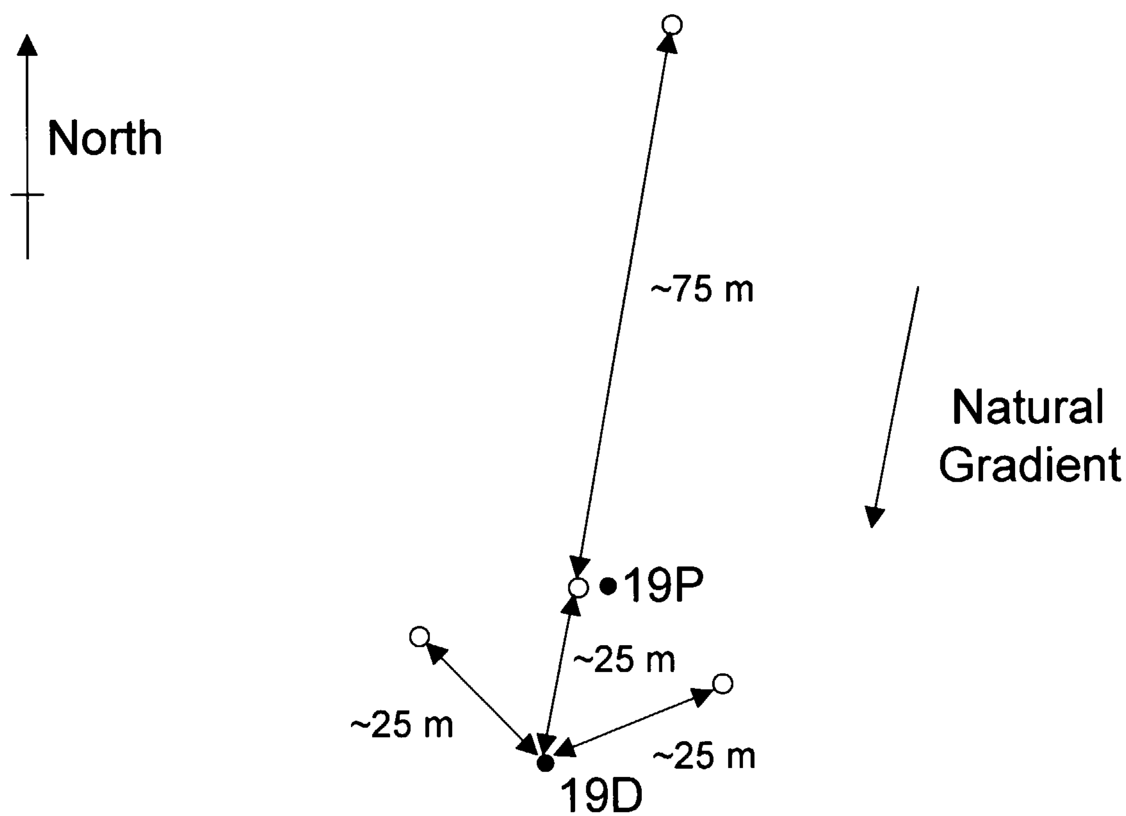
Porosity from the Borehole Gravimeter

- EWDP- 19D/D1
- EDCON BHGM
- Density Determined
- Grain Density from Adjacent Boreholes
- Porosity Estimated from Density



Reference: Work in Progress

Proposed Alluvium Testing Complex Well Layout



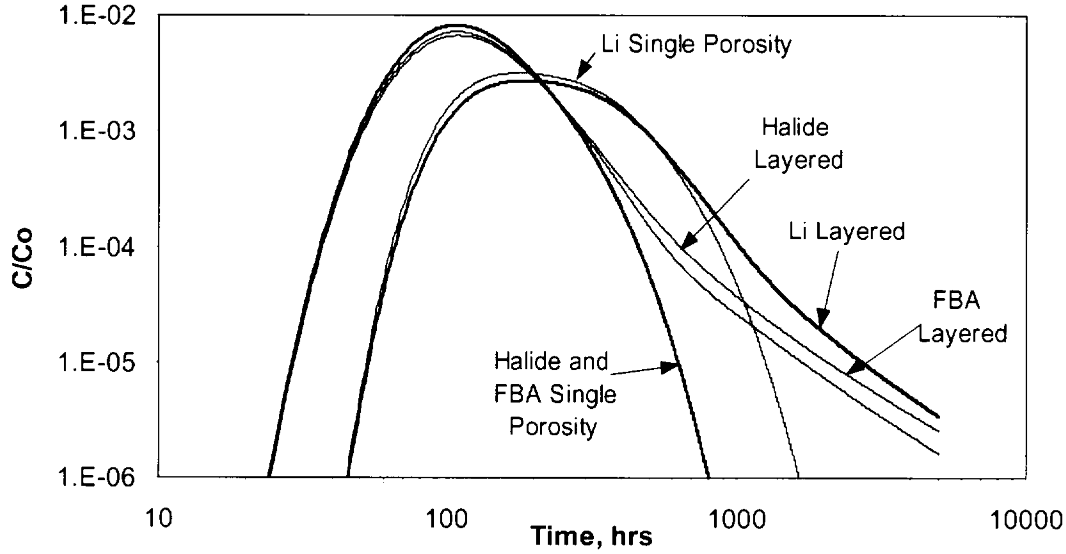
Cross-Hole Test Predictions: Planning Tool

- **Spreadsheet* that offers predictions of nonsorbing and sorbing solute travel times (both first arrival and peak arrival) as a function of:**
  - Production Rate
  - Well Separation
  - Interval Thickness (confined or unconfined)
  - Effective Flow Porosity
  - Longitudinal Dispersivity
  - Recirculation Ratio
  - Retardation Factor for Sorbing Tracer

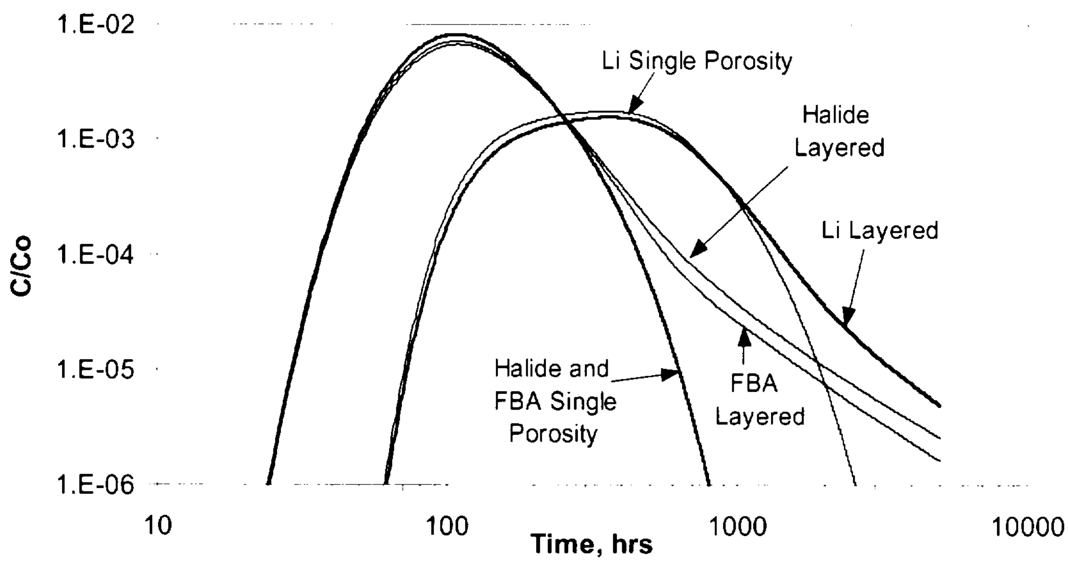
*assumes a homogeneous, isotropic medium

Cross-Hole Test Predictions

Low Lithium Sorption Case*, Advective and Layered



High Lithium Sorption Case*, Advective and Layered



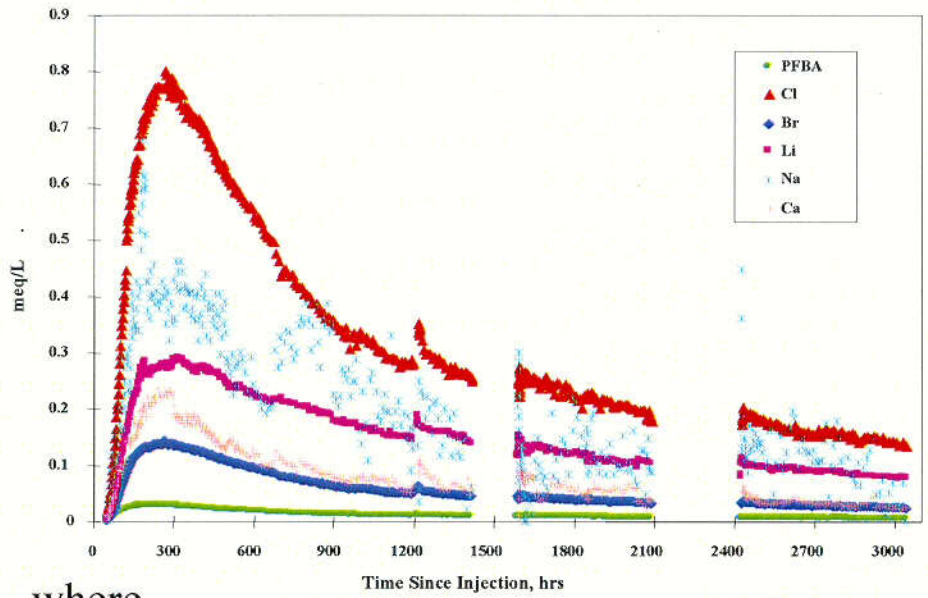
*Cases based on laboratory batch sorption data

Reference: work in progress

Three-Component Cation Exchange Model

- Clear Evidence from Prow Pass Tracer Test and Laboratory Tests:

Ion responses in Prow Pass field test



- Cation Exchange Model

$$A + BX \Rightarrow AX + B$$
$$2A + CX_2 \Rightarrow 2AX + C$$
$$2B + CX_2 \Rightarrow 2BX + C$$

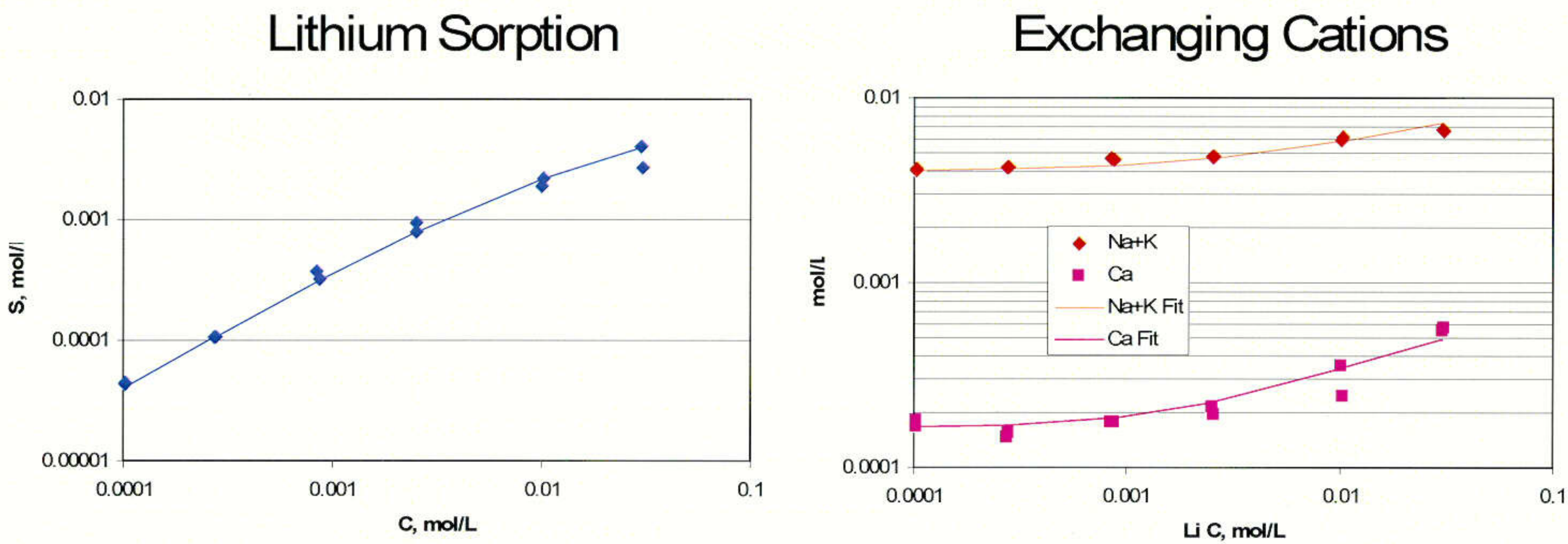
where,
$A = Li^+$
$B = Na^+ + K^+$
$C = Ca^{++}$
X = Negatively-Charged Surface Site

Reference: Analysis and Model Report *Unsaturated Zone and Saturated Zone Transport Properties* (ANL-NBS-HS-000019 REV 00)

C13

Three-Component Cation Exchange Model: Application to Alluvium Batch Sorption Data

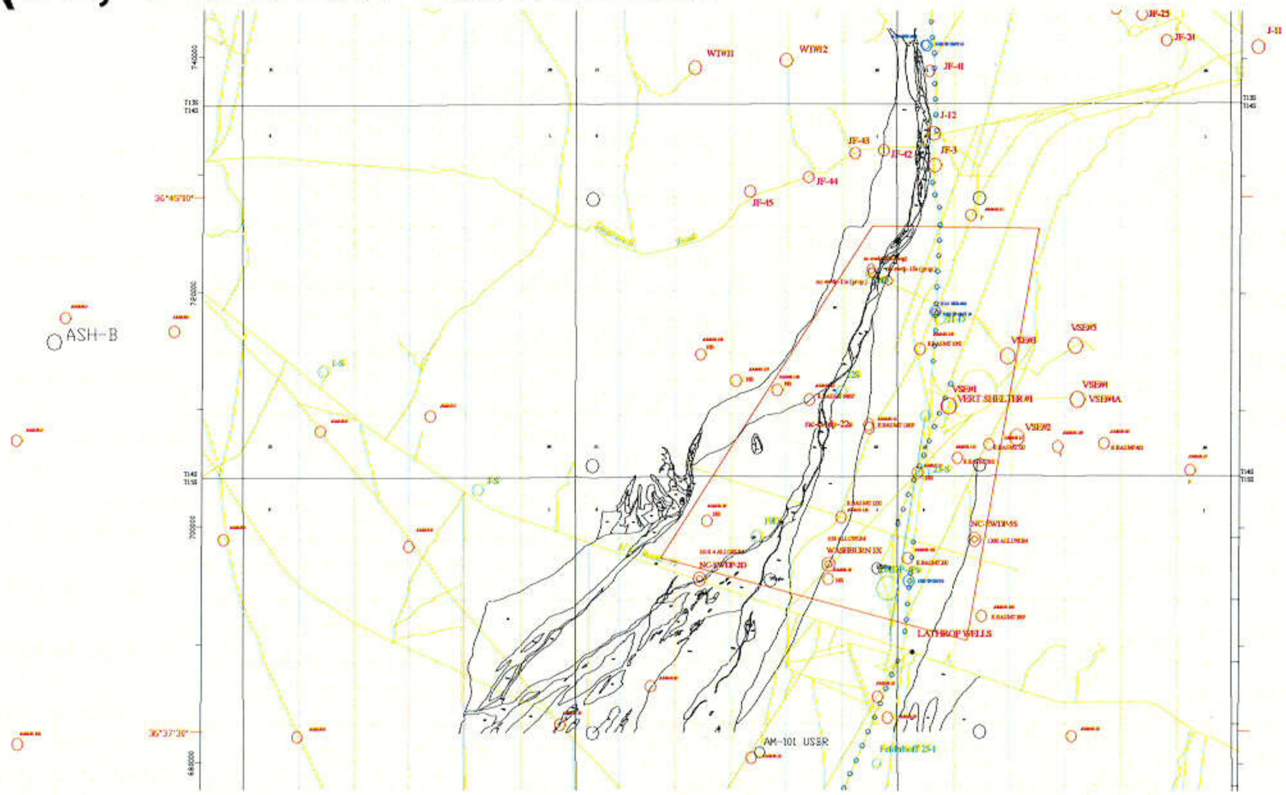
Cation Exchange for Material from EWDP-19P, 410 ft



C114

Data Gap South of Yucca Mountain

- **Data available in addition to Boreholes**
- **Seismic Refraction**
- **Electric-bores (i.e, Vertical Electrical Soundwaves)**
- **Gravity**
- **Magnetics**
- **Geology**



Reference: work in progress

C15

Hydraulic Conductivity and Effective Porosity of Valley Fill and Data Gap South of Yucca Mountain
(Continued)

- **References**
  - Update to Analysis and Model Report *Transport Properties,* scheduled for the Site Recommendation and License Application
  - Update to *Saturated Zone Flow and Transport Process Model Report,* scheduled for the Site Recommendation and License Application
  - Alluvium Testing Complex Work Plan
  - Saturated Zone Technical Work Plan
- **The combination of hydraulic conductivity information obtained to date and the additional information to be obtained from the Alluvium Testing Complex and from Nye County drilling program on hydraulic conductivity and effective porosity will fully address this information need. No additional work needed**

Data Gap North of Washburn Well and 19-D Complex

- **Basis for Resolution**
  - Nye County drilling program phases II and III plan wells north of Washburn Well and 19-D Complex will add to existing data
- **References**
  - Nye County Cooperative Agreement
- **DOE continues to collect additional information for this area. No additional work needed**

Plans for Tracer Tests at Alluvium Testing Complex and Detailed Stratigraphy and Results of Aquifer Tests in the complex

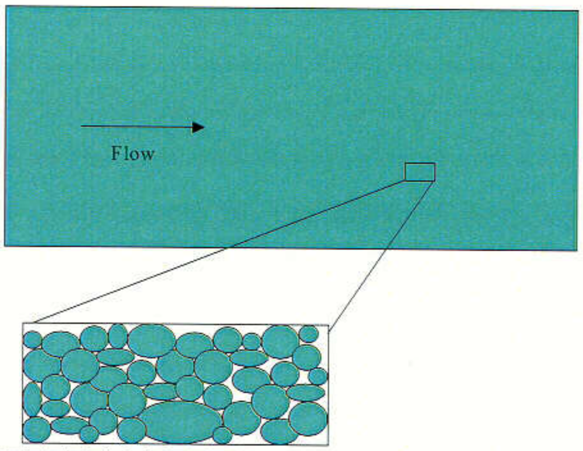
- **Basis for Resolution**
  - Testing has begun at the Alluvium Testing Complex. Results will be incorporated into Saturated Zone Flow and Transport Process Model Report and associated Analysis Model Reports and will be included in Total System Performance Assessment - Site Recommendation, as available

Tracer Testing at Alluvium Testing Complex

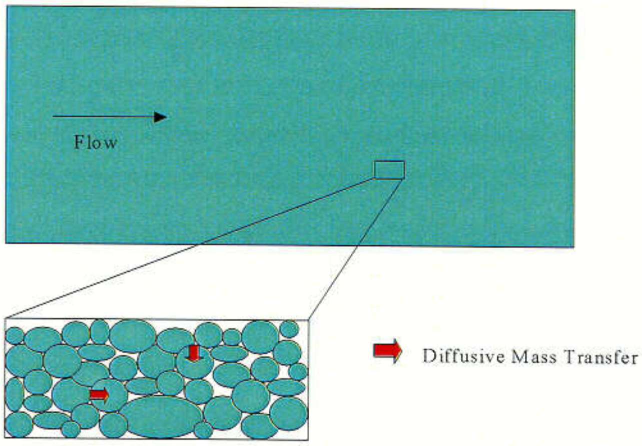
- **Single-well tests in FY 01**
  - Appropriate Conceptual Transport Model (Extent of Mass Transfer Between Flowing and Stagnant Water)
- **Cross-hole tests in FY 02**
  - Further Verification of Conceptual Transport Model
  - Effective Flow Porosity
  - Longitudinal Dispersivity
  - Sorption Parameters (comparison to lab values)
  - Colloid Transport Parameters
- **Supporting Laboratory Transport Tests**
  - Sieve Analysis of Alluvium Material
  - Batch Sorption (Lithium and Radionuclides)
  - Column Transport Studies (Sorption and Diffusion)

Conceptual Transport Models

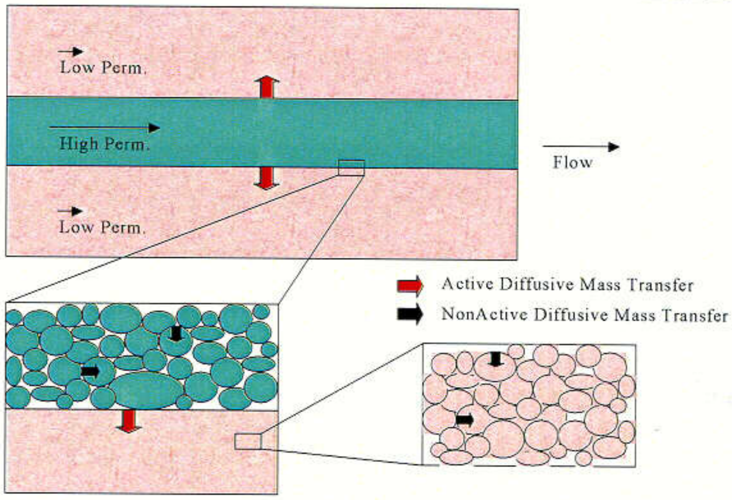
Advection Only



Advection with Diffusion into Grains



High and Low Perm. Layered System with Interlayer Diffusion

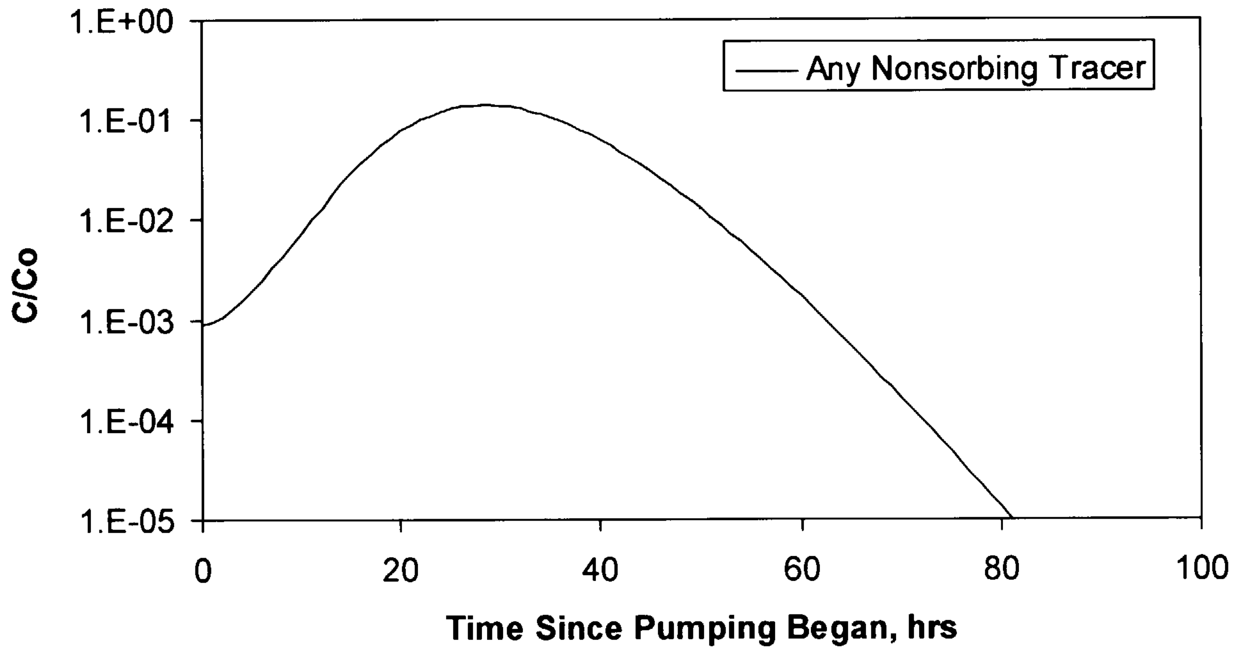


Reference: work in progress

Plans for Tracer Tests at Alluvium Testing Complex

- **Single-Well Tests - Three different tracer injections and withdrawals in the same interval**
  - 2,4 DFBA and Microspheres with Zero Rest Period
  - 2,6 DFBA and Iodide with 2-Day Rest Period
  - PFBA and Bromide with 30-Day Rest Period
  - Flow interruptions may be introduced
- **Cross-Hole Tests**
  - One interval to be selected (may be different from single-well tests)
  - Possibly two different injection wells, with reactive tracer mix injected into one well

Single-Well Tracer Responses for Advection-Only Model

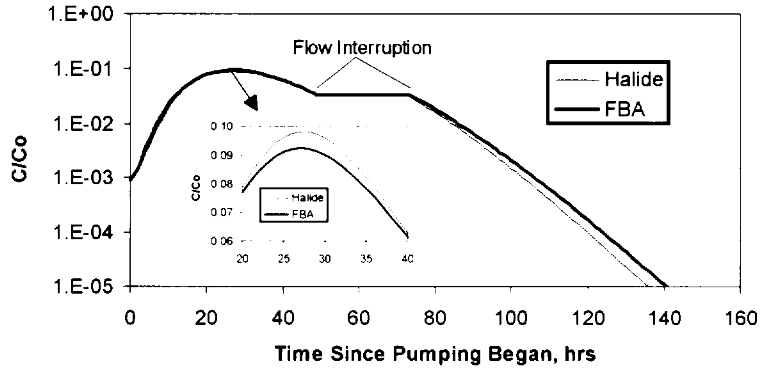


- Tracer responses independent of tracer diffusion coefficient or rest period (assuming no drift or density effects)

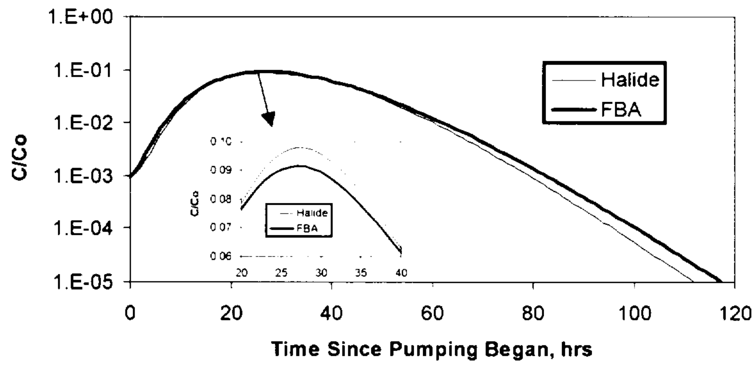
Reference: Work in Progress

Single-Well Tracer Responses for Diffusion Into Grains Model

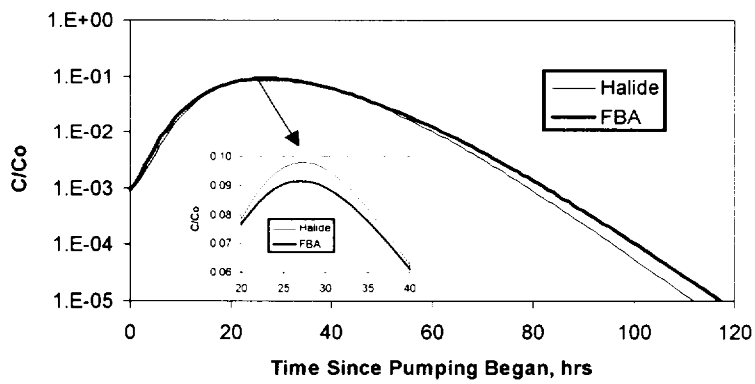
Zero Rest



2-Day Rest



30-Day Rest

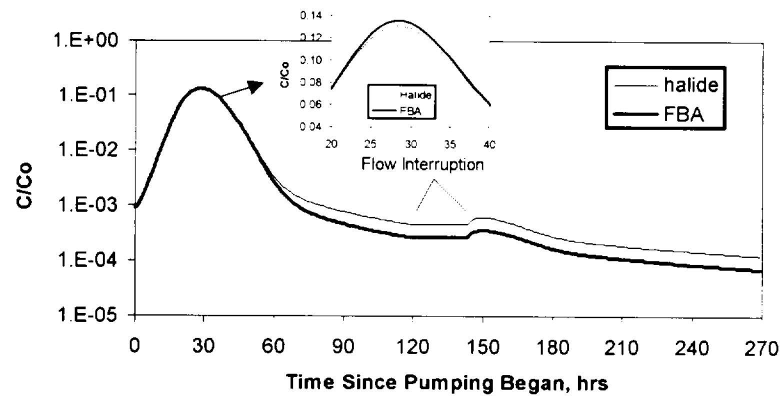


- Relatively short diffusion distances and narrow flow pathways
- Tracers with different diffusion coefficients have different responses (less diffusive tracer has lower peak and longer tail)
- Very little difference in individual tracer responses at different rest periods

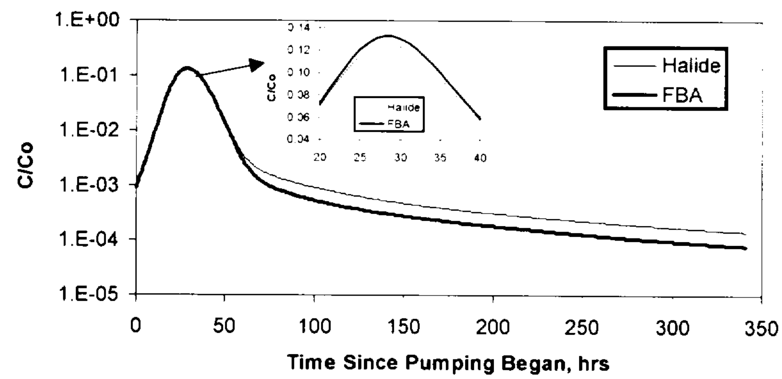
Reference: work in progress

Single-Well Tracer Responses for Layered Model

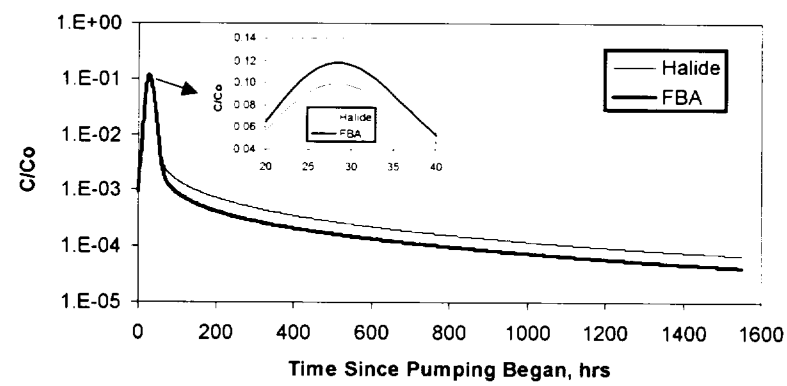
Zero Rest



2-Day Rest



30-Day Rest

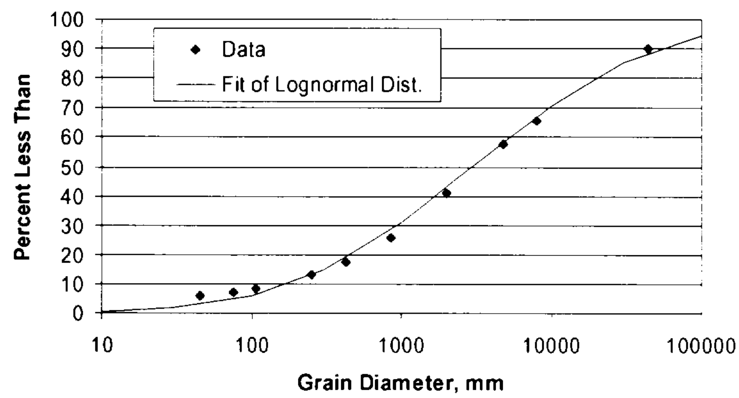


- Relatively long diffusion distances and wide flow pathways
- Tracers with different diffusion coefficients have different responses (less diffusive tracer has higher peak and lower tail)
- Significant differences in individual tracer responses at different rest periods

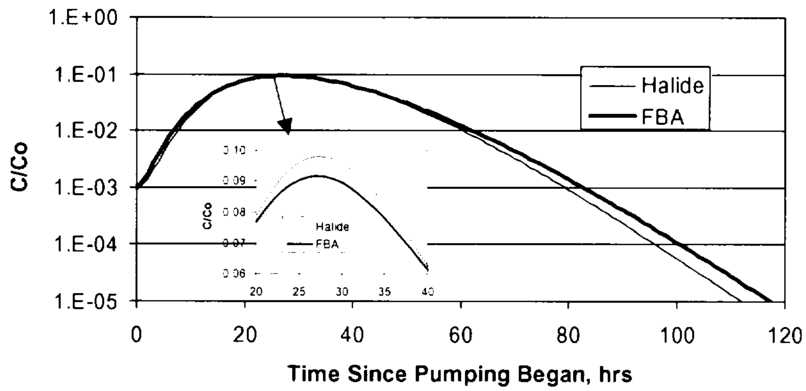
Reference: work in progress

Diffusion into Grains Model: Effect of Grain Size Distribution

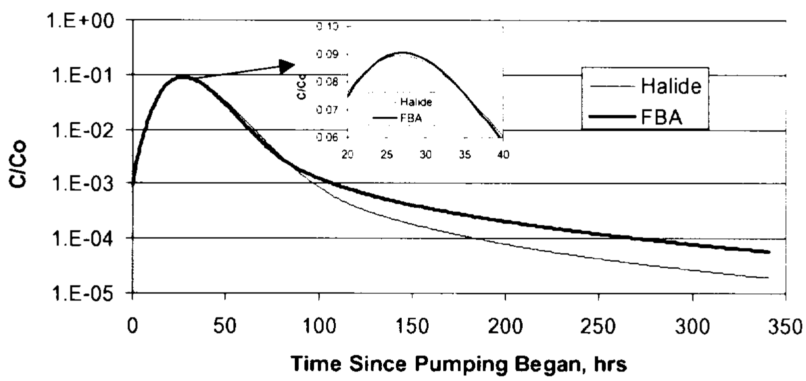
Actual 19P Grain Size Distribution



Assuming only Average Grain Size



Assuming Entire Grain Size Distribution



Reference: work in progress

Plans for Tracer Tests at Alluvium Testing Complex and Detailed Stratigraphy and Results of Aquifer Tests in the complex
(Continued)

- **References**
  - *Saturated Zone Flow and Transport Process Model Report* (TDR-NBS-HS-000001 REV 00 ICN 01)
  - Analysis and Model Report *Unsaturated Zone and Saturated Zone Transport Properties* (ANL-NBS-HS-000019 REV 00)
- **Testing in progress fully addresses this information need. No additional work needed**

Conclusions

- **This criterion should be closed**
  - Values of parameters currently used for valley fill aquifer are based upon evaluation of regional values for similar type deposits and are supported by information from expert elicitation. Sufficient information is available to incorporate the uncertainty and variability into the Total System Performance Assessment
  - DOE plans to complete a program of work with the Nye County Early Warning Drilling Program and at the Alluvium Testing Complex to confirm these values
  - DOE continues to incorporate data gathered through the cooperative agreement with Nye County

DOE – NRC Technical Exchange Meeting

Unsaturated Flow and Saturated Flow Under Isothermal Conditions

Acceptance Criteria 2

Delineation of Flow Paths

Nye County
Early Warning Drilling Program

Delineation of Flow Paths

Phase II Progress

Preliminary Findings

Phase III Plans

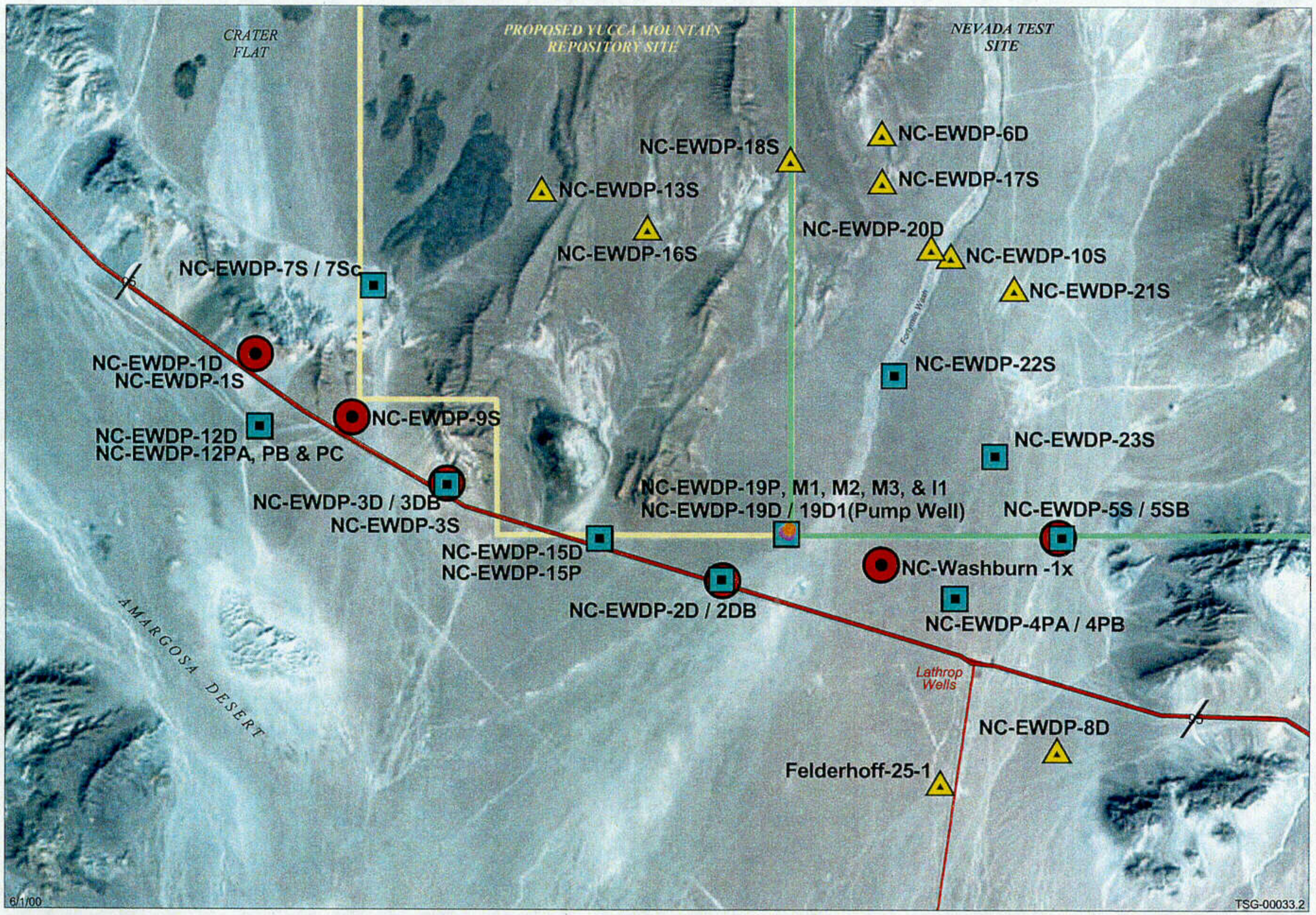
In Memory

Presented by:

Thomas S Buqo
Consulting Hydrogeologist

Nye County
Nuclear Waste Repository Office
Pahrump, Nevada

1 November 2000



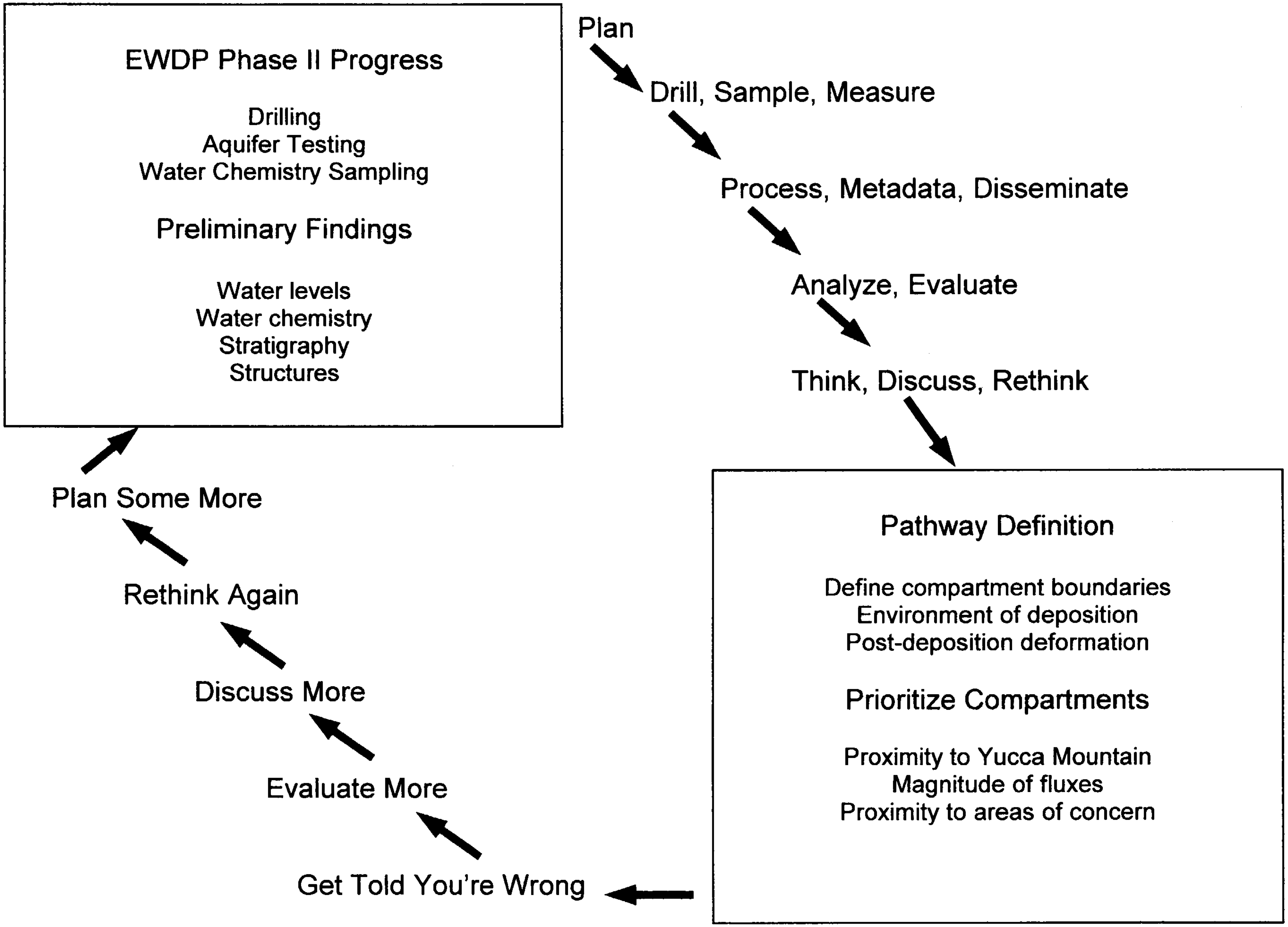
NYE COUNTY, NEVADA

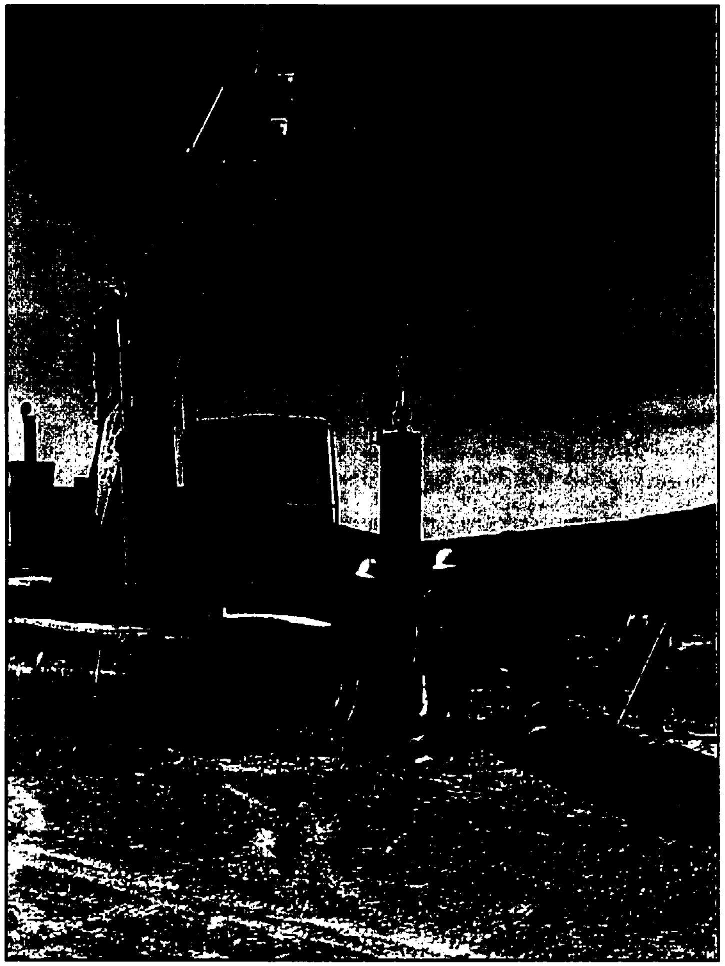
EARLY WARNING DRILLING PROGRAM
DRILLHOLE LOCATIONS

5 0 5
Miles

- Phase I Drillholes
- Phase II Drillholes
- Phase II Monitoring Wells
- Phase II Injection Well
- Phase III Drillholes

C17


EWDP Phase II Progress
Drilling
Aquifer Testing
Water Chemistry Sampling
Preliminary Findings
Water levels
Water chemistry
Stratigraphy
Structures
Plan
Drill, Sample, Measure
Process, Metadata, Disseminate
Analyze, Evaluate
Think, Discuss, Rethink
Pathway Definition
Define compartment boundaries
Environment of deposition
Post-deposition deformation
Prioritize Compartments
Proximity to Yucca Mountain
Magnitude of fluxes
Proximity to areas of concern
Get Told You're Wrong
Evaluate More
Discuss More
Rethink Again
Plan Some More



EWDP Phase 2 Progress

Ten wells/six sites alluvial, volcanic, paleospring & carbonate
Conductors casings at three more sites for deeper drilling
Six first water samples from four site
Sampling underway now
One pump spinner test and one 48-hour pumping test
Alluvial Tracer Complex

Completed Wells and Piezometers

Completed

NC-EWDP-2DB	3075' well with open completion at Tertiary/Paleozoic contact
NC-EWDP-4PA,B	500' and 800' piezometers in alluvium and uppermost Tertiary(?)
NC-EWDP-5SB	500' piezometer in alluvium
NC-EWDP-7S	53' piezometer in paleospring deposits
NC-EWDP-12PA,B,C	390', 400', and 250' for test well observation
NC-EWDP-19D, 19P	1438' ATC Test Well and 500' piezometer

In Progress

NC-EWDP-3DB	505' conductor
NC-EWDP-7SC	778' borehole to be completed as multiple completion shallow well.
NC-EWDP-12D	68' conductor for test well
NC-EWDP-15D	607' conductor

PHASE 2 EWDP PRELIMINARY FINDINGS

WATER LEVELS ARE LOOKING UP

DEPTH TO GROUNDWATER SHALLOWER THAN EXPECTED

LOCATION	DEPTH TO WATER (FT) EXPECTED	ACTUAL
NC-EWDP-7S	200±	22±
NC-EWDP-12	200±	170±
NC-EWDP-15P	300±	200±

UPWARD GRADIENTS

LOCATION	WELL DEPTH	DEPTH TO WATER
NC-EWDP-2D	1,600 ft	312± ft
NC-EWDO-2DB	3,075 ft	292± ft
NC-EWDP-4PA	500 ft	345± ft
NC-EWDP-4PB	800 ft	326± ft
NC-EWDP-12PA	390 ft	170± ft
NC-EWDP-12PB	400 ft	170± ft
NC-EWDP-12PC	250 ft	179± ft
NC-EWDP-19P	500 ft	365± ft
NC-EWDP-19D	1,438 ft	348± ft

Accomplished to Date

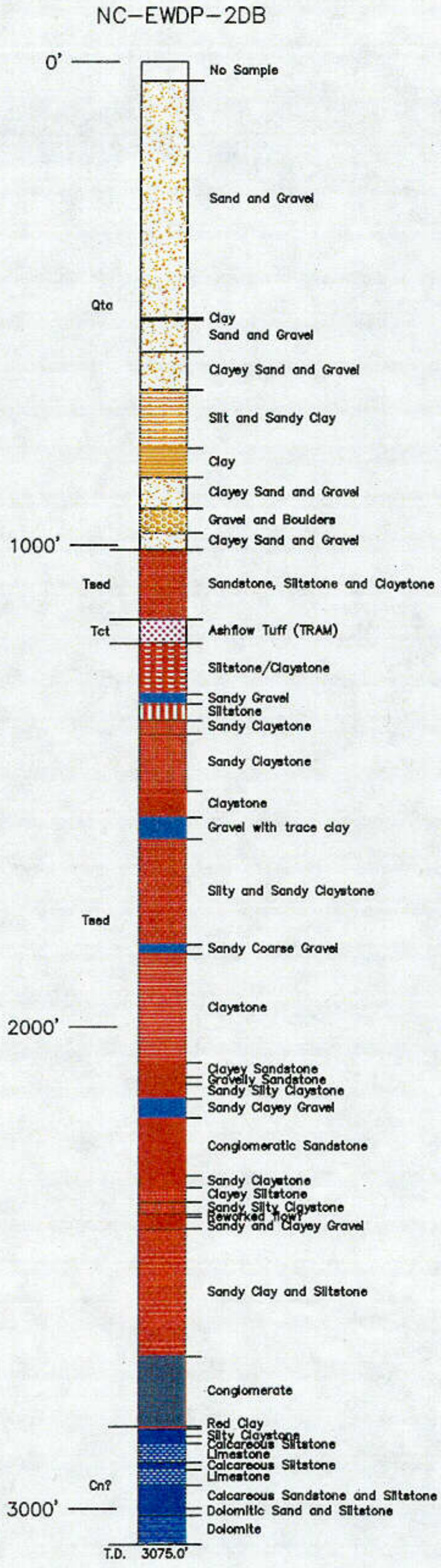
Conductor to 500 ft
Drill/Sample to 3,075 ft
Reamed to 2,690 ft
Set inner conductor to 2,685 ft
Began development
Temperature log to 2,770 ft

Planned Activities

Finish developing with air
Full suite of geophysical logs
Pump spinner log
Forty-eight hour pump test
Sampling & chemical analysis
Evaluate need to core deeper
Evaluate packer testing
Plug stuck casing at 2D
Drill intermediate well

Findings

Tagged Paleozoics
Probably Cambrian
Hot water (72oC) at 2,770 ft
Upward hydraulic gradient
Permeable zone near basal Tertiary
Possible fault gouge
Knowledge of Tertiary lacking
Analogs not applicable



Drilled on western edge of Fortymile Wash

Drilled on pre-Tertiary ridge dividing Fortymile Wash and Amargosa Desert Tertiary basins.

Alluvium is more fine-grained than alluvium at NC-EWDP-19P

"Package" of thin pre-Tram volcanics may be present

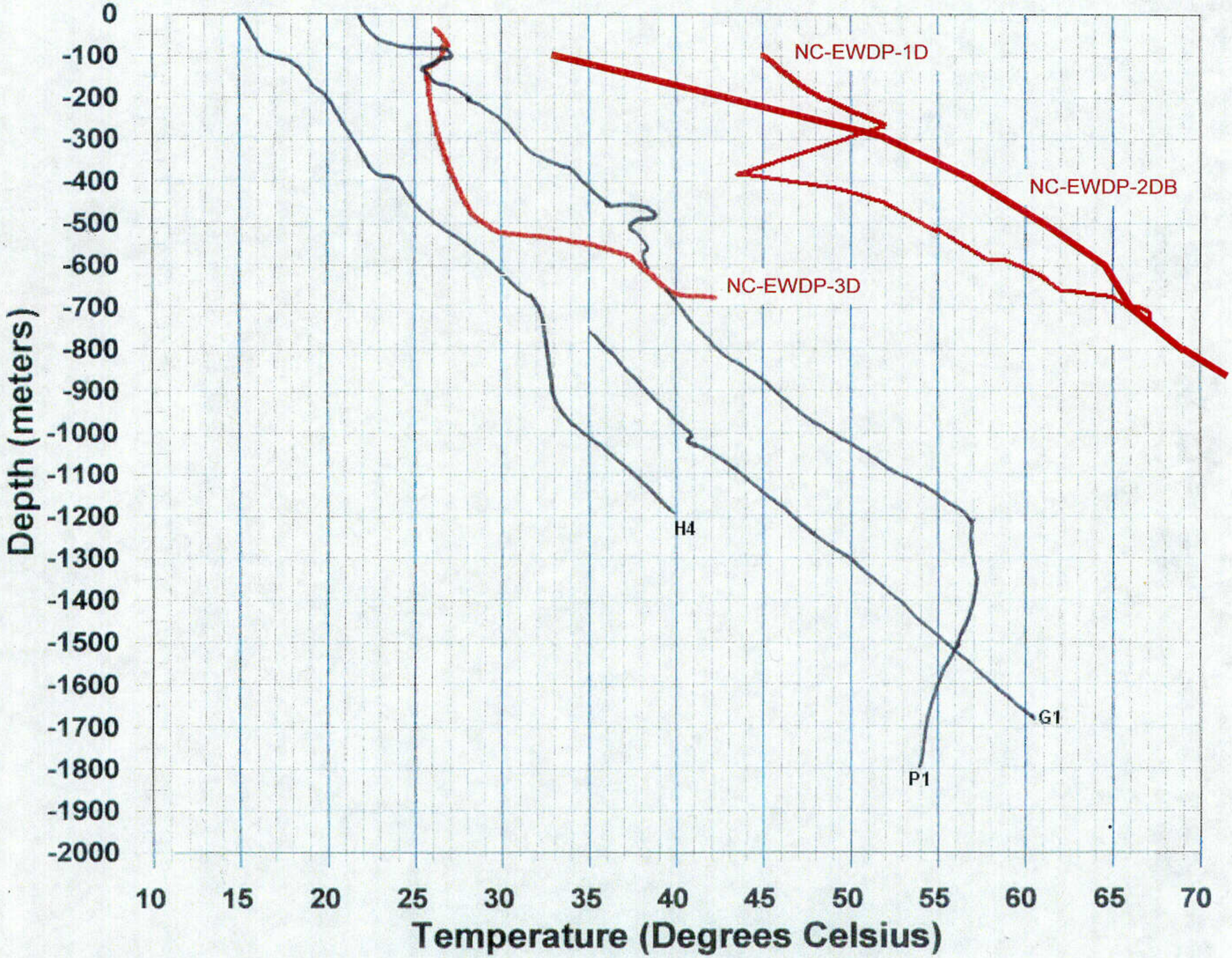
Tram Tuff is predominant volcanic unit present

Sandy gravels and gravel units within Tertiary sediments may be channel deposits. Whatever their origin, these coarse grained units likely are preferential pathways for groundwater flow.

Lost circulation zone in conglometrate is likely a very transmissive zone.

Red clay has been mapped in outcrops in Furneral Range as a detachment.

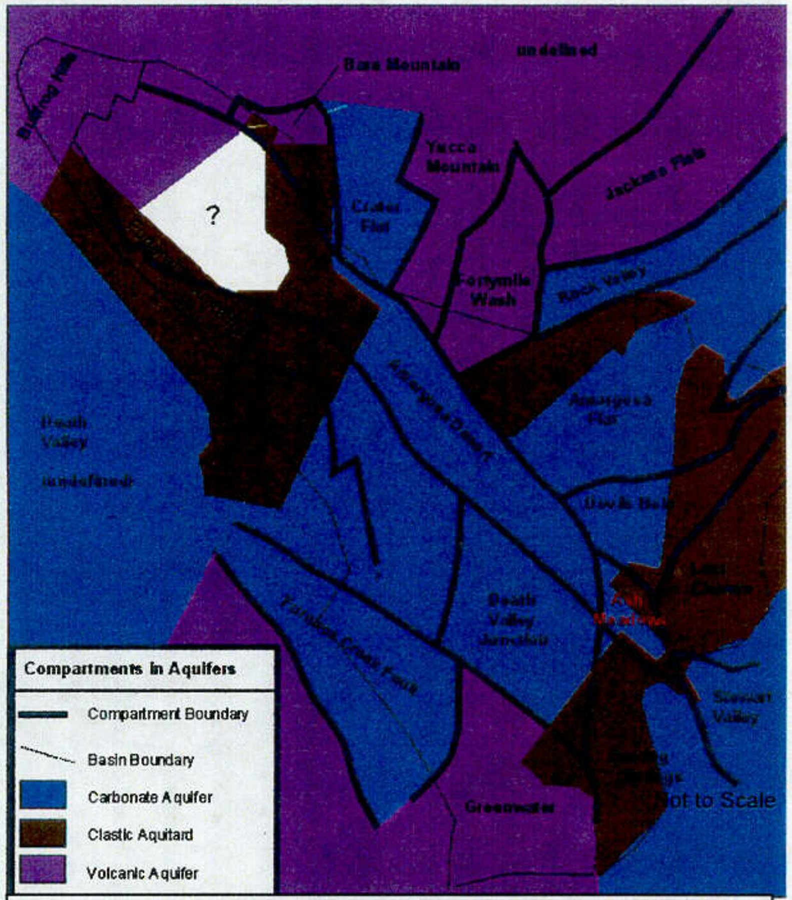
Top of Paleozoic uncertain pending study of calcareous units between red clay and dolomitic limestones.



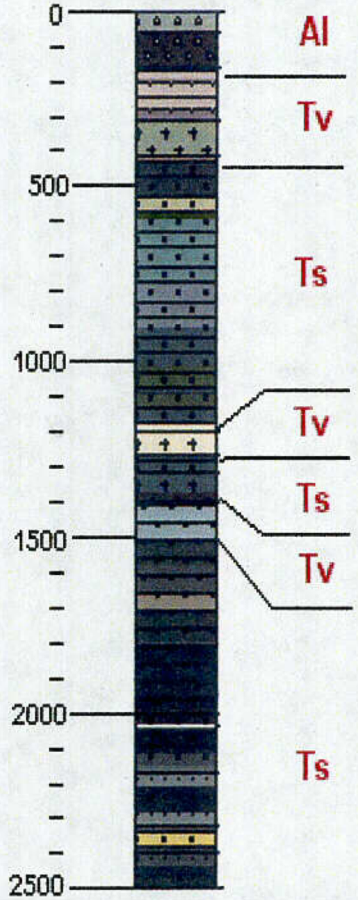
NC-EWDP-1D
NC-EWDP-2DB
NC-EWDP-3D
H4
G1
P1
Depth (meters)
Temperature (Degrees Celsius)
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-1100
-1200
-1300
-1400
-1500
-1600
-1700
-1800
-1900
-2000
10
15
20
25
30
35
40
45
50
55
60
65
70

C19

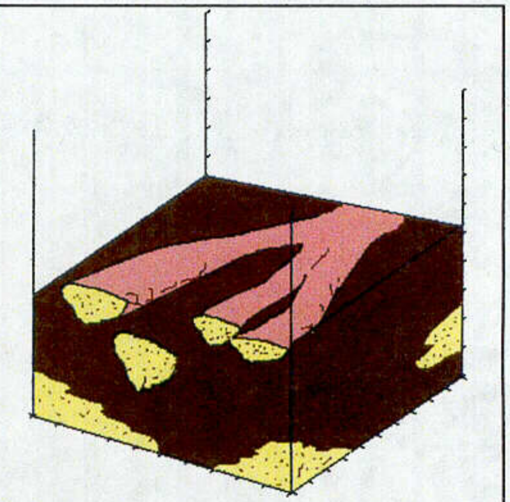
Caldera comlex



Conceptual compartments in pre-Tertiary units



Tertiary sequence NC-EWDP-1D



Conceptual distributary sand channels in Lathrop Wells area

CONCEPTUAL COMPARTMENTS IN AMARGOSA DESERT

C 20

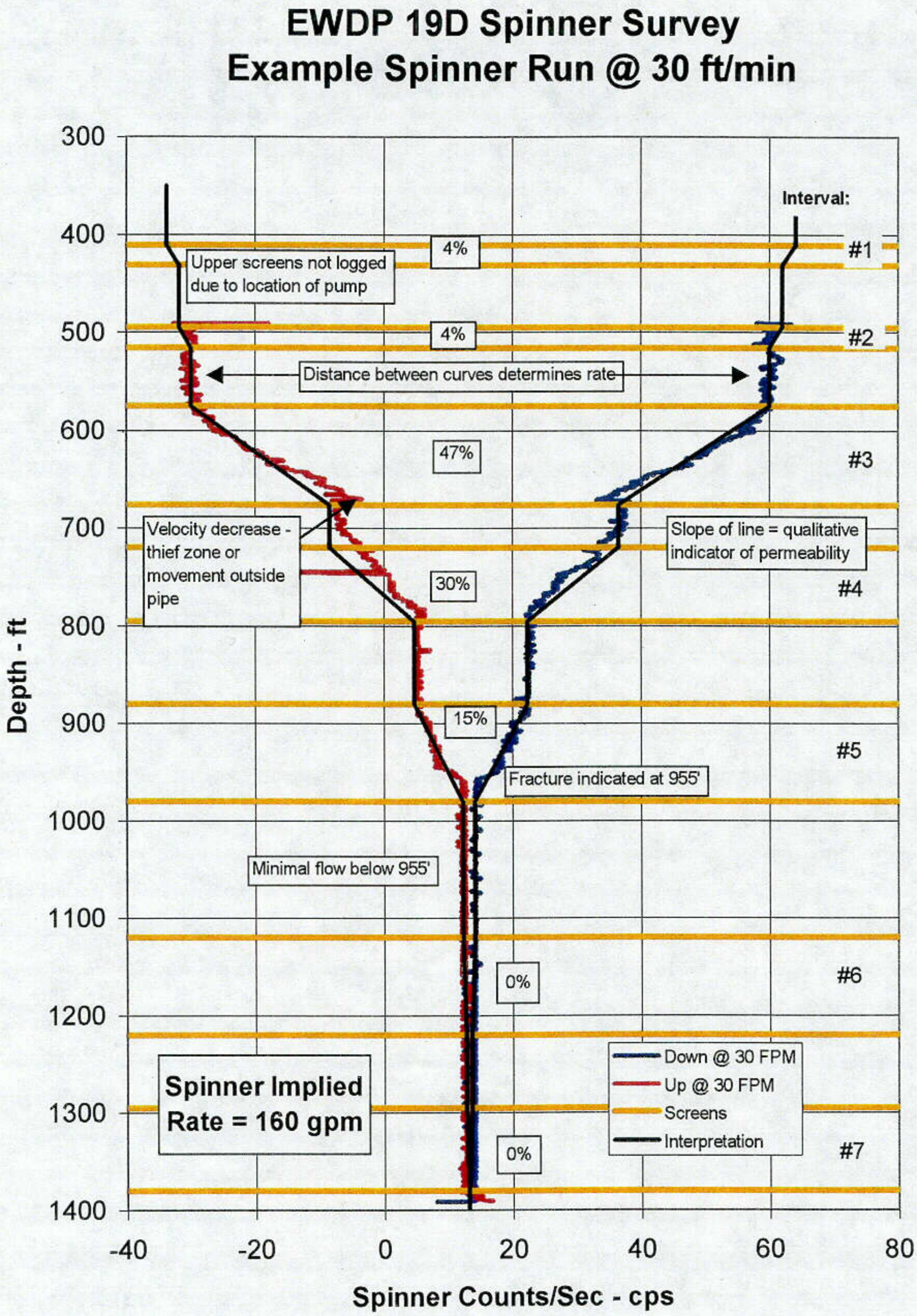
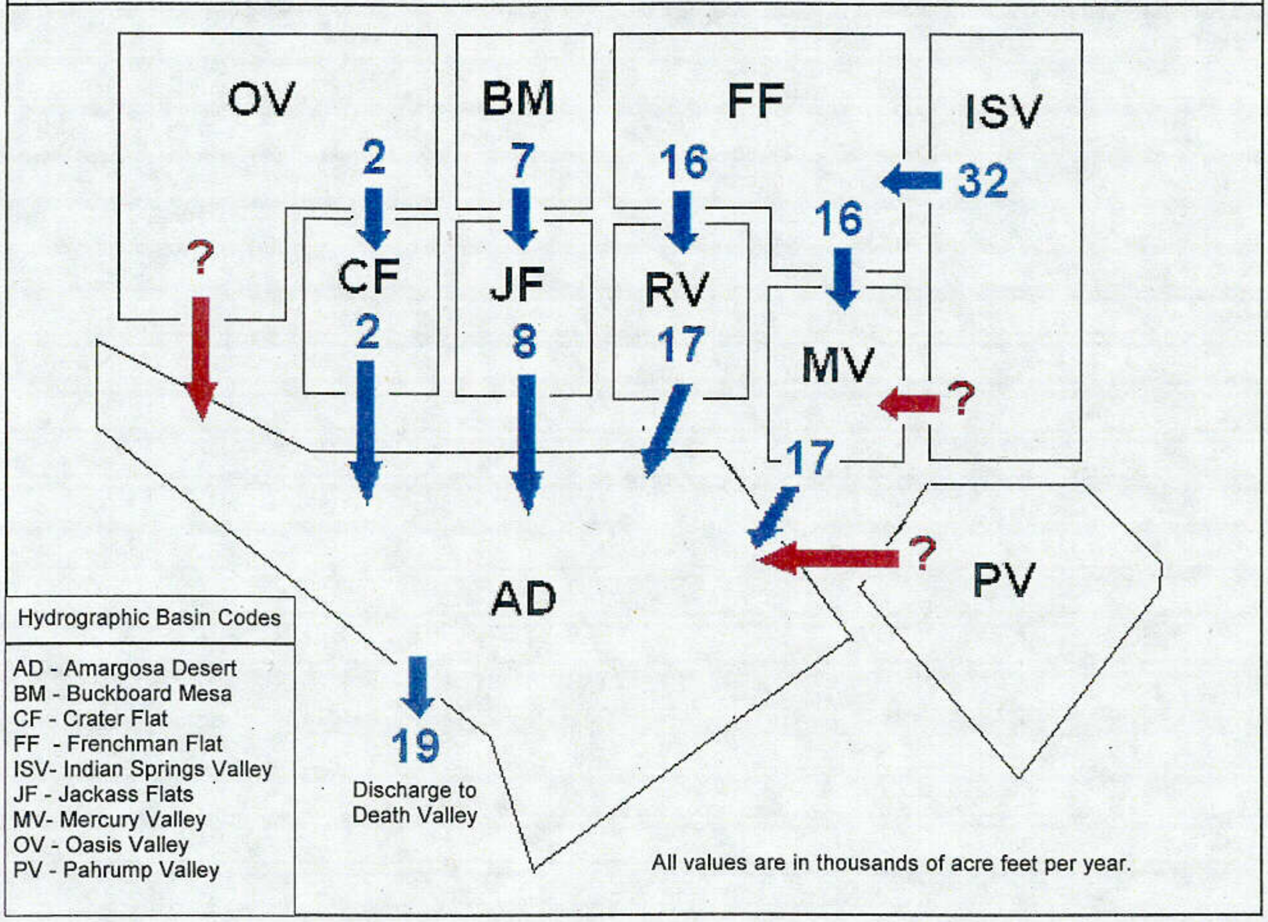

EWDP 19D Spinner Survey
Example Spinner Run @ 30 ft/min
Interval:
#1
#2
#3
#4
#5
#6
#7
4%
4%
47%
30%
15%
0%
0%
Upper screens not logged due to location of pump
Distance between curves determines rate
Velocity decrease - thief zone or movement outside pipe
Slope of line = qualitative indicator of permeability
Fracture indicated at 955'
Minimal flow below 955'
Spinner Implied Rate = 160 gpm
Down @ 30 FPM
Up @ 30 FPM
Screens
Interpretation
Depth - ft
Spinner Counts/Sec - cps
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
-40
-20
0
20
40
60
80

Figure 4

C21

Published estimates of groundwater flows from basins tributary to Amargosa Desert.

Sources: Scott et al (1971 and 1971a), Rush (1970), and Walker and Eakin (1963).



PRIORITIZING THE COMPARMENTS

Depends on proximity to Yucca Mountain, magnitude of fluxes across model boundaries, and proximity to receptor populations in Amargsoa Valley now and in the future.

Priority 1 - Jackass Flats, Amargosa Desert, Crater Flat (Proximity)

- **hydrostratigraphy within Tertiary basin and bounding Paleozoic highs**
- **structures within these three basins and along boundaries**
- **potentiometrics in each major compartment**

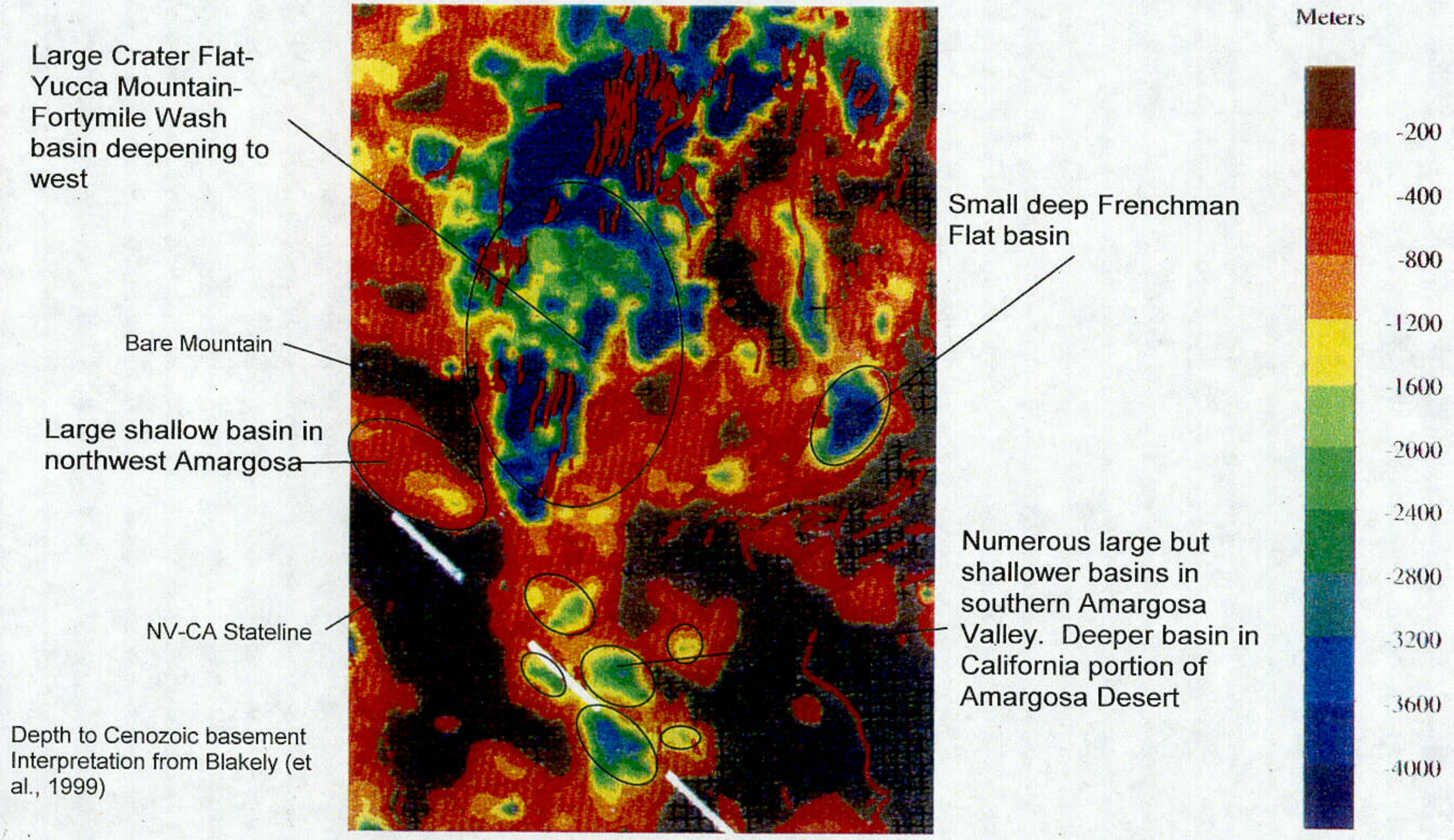
Priority 2 - Rock Valley, Buckboard Mesa, Frenchman Flat, Mercury Valley, Oasis Valley (Fluxes)

- **quantify fluxes across compartment boundaries tributary to Priority 1**

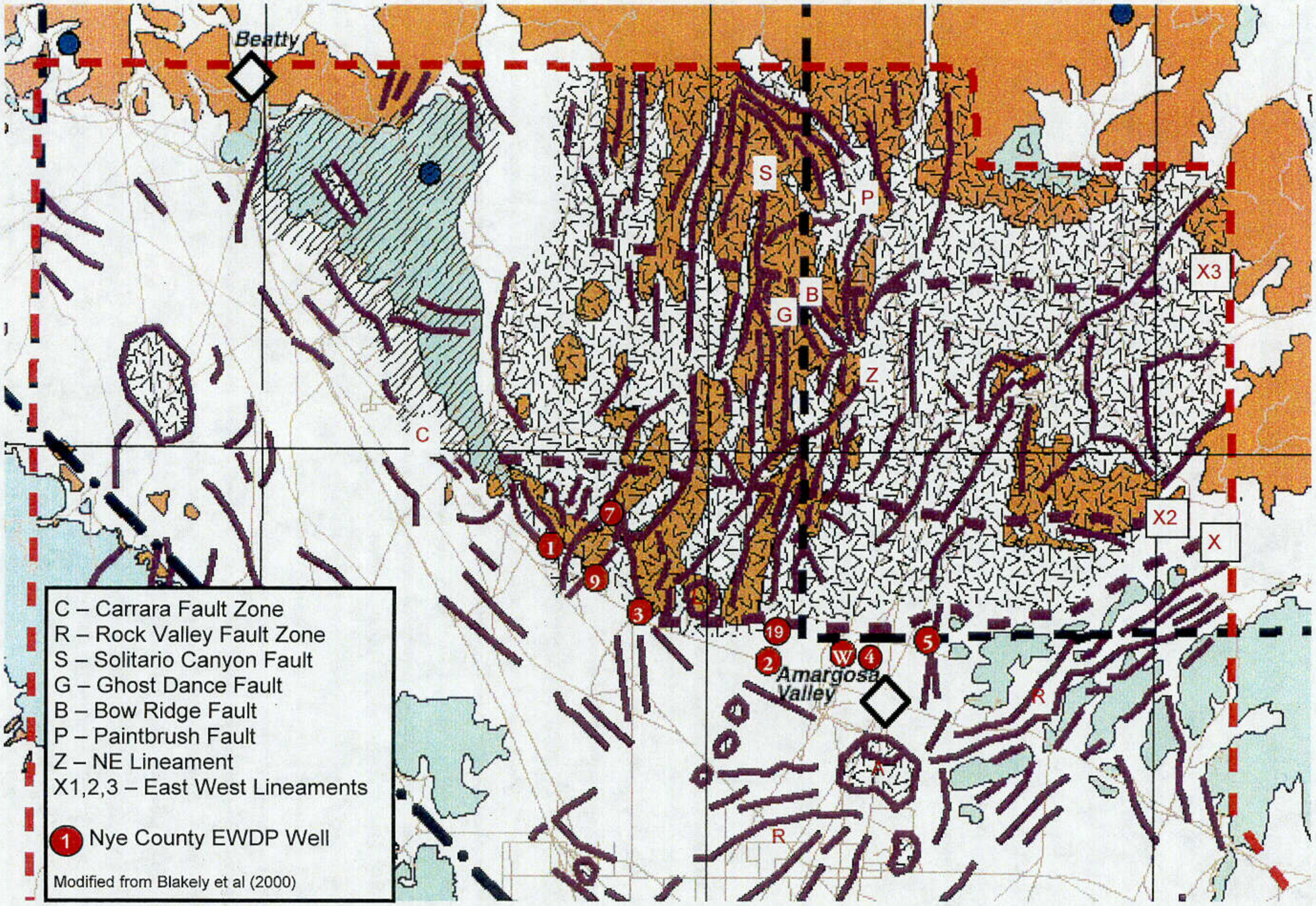
C22

Structural Complexities and Compartmentalization

Separate Early Tertiary Basins



C23


Beatty
Amargosa Valley
S
P
B
G
Z
C
X3
X2
X
R
A
7
1
9
3
19
2
W
4
5
C – Carrara Fault Zone
R – Rock Valley Fault Zone
S – Solitario Canyon Fault
G – Ghost Dance Fault
B – Bow Ridge Fault
P – Paintbrush Fault
Z – NE Lineament
X1,2,3 – East West Lineaments
1 Nye County EWDP Well
Modified from Blakely et al (2000)

C24

Structural Complexities and Compartmentalization

Although the alluvial sediments in NC-EWDP-2DB and NC-EWDP-19DB are consistent with each other, the Tertiary stratigraphy in the two wells is quite different. This difference suggests Miocene and later faulting and /or folding between the two wells.

These differences can be explained by the structural model of detachment faulting described by Fridrich (1999) but other interpretations should also be considered. The Early Tertiary basins predate the detachment faulting.

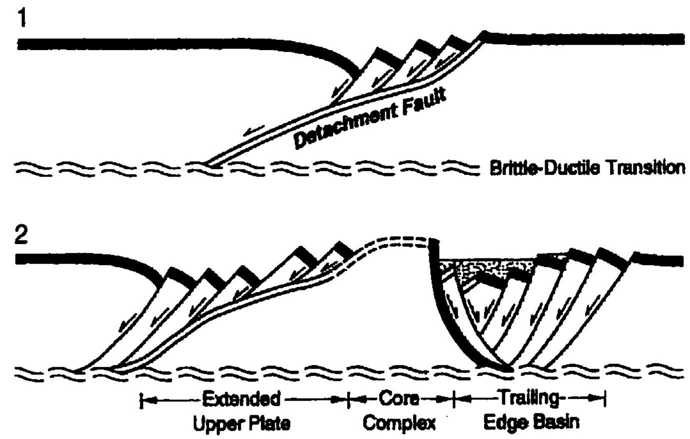
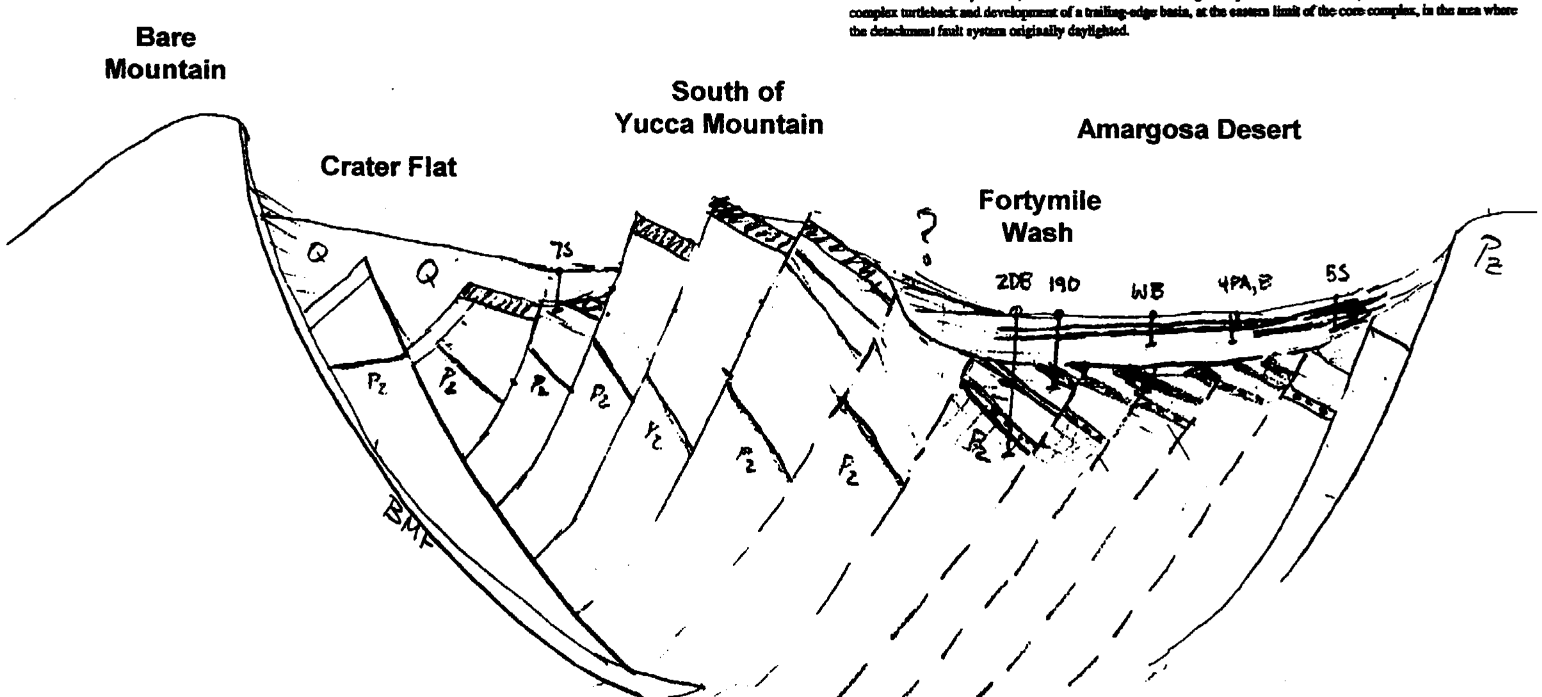
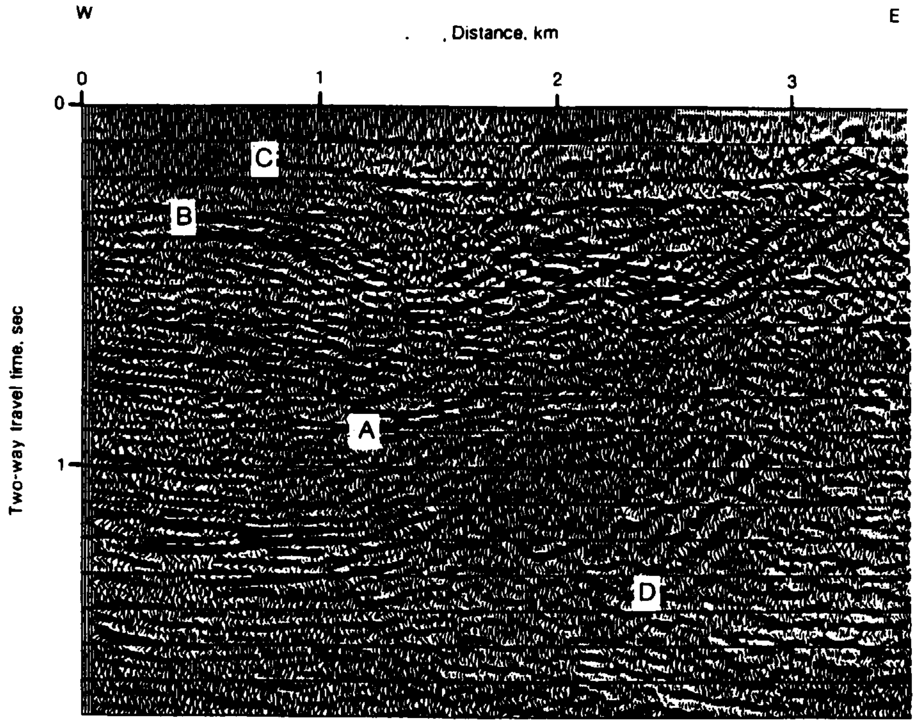
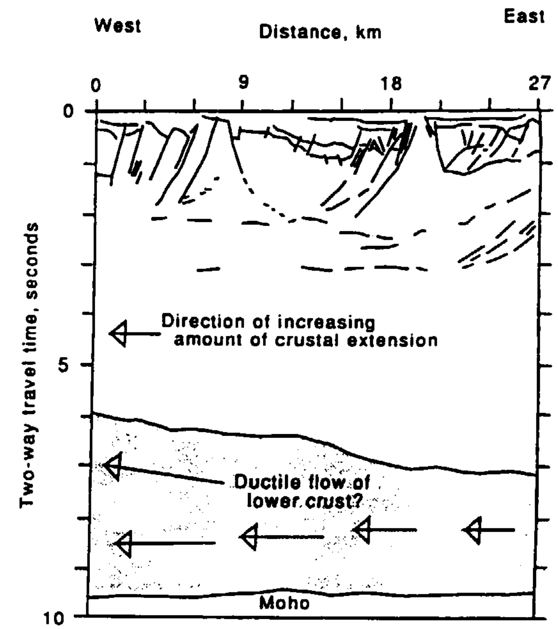
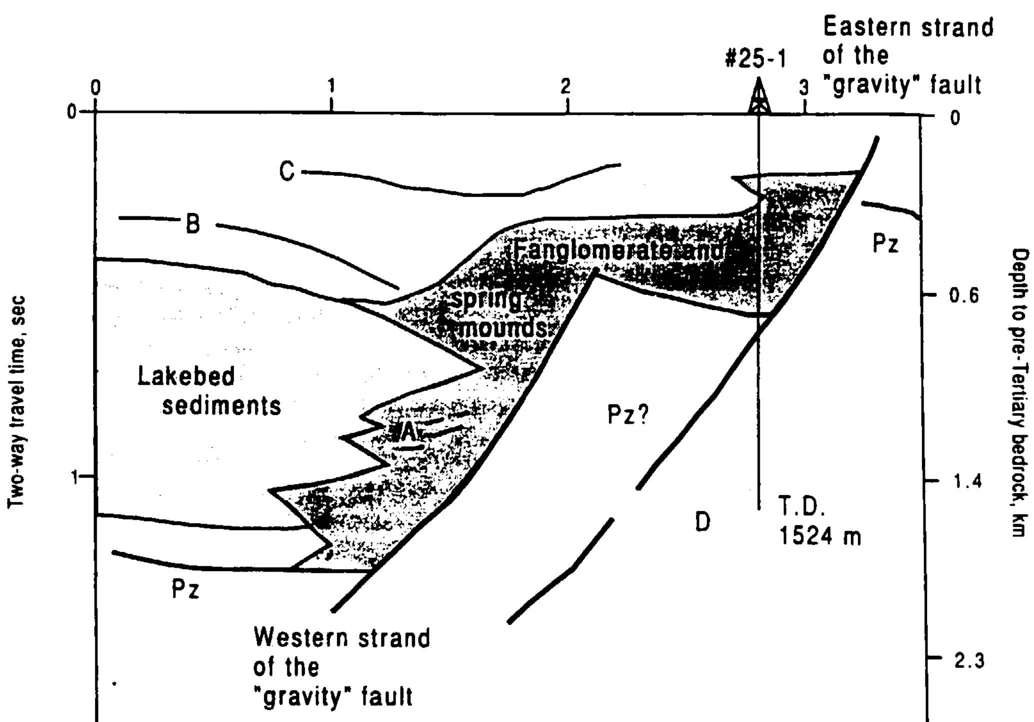


Figure 4. Schematic cross sections drawn in the major direction of extension, showing two stages in the evolution of the detachment fault system: 1, initiation of detachment faulting; 2, exposure of a tectonically denuded metamorphic core complex turtleback and development of a trailing-edge basin, at the eastern limit of the core complex, in the area where the detachment fault system originally daylighted.









How about more Geophysics?

Seismic reflection

Tertiary - Paleozoic contact

Variability in valley-fill seds.

How many lines? Where?

Gravity

More stations? Where

Modified from Brocher et al. (1993)

Alternative Infiltration Scenarios for Yucca Mountain

State of Nevada Sponsored Research

Presented by:
Linda L. Lehman
L. Lehman & Associates, Inc.

To the DOE/NRC Technical Exchange Meeting on Groundwater Flow and Travel Time, Denver CO, Nov. 29 - Dec. 1, 1994

Saturated Zone Model

- Highly Structure Controlled and Compartmentalized
- Self Similar
- Interbasin Transfer
- Temperature is a good indicator of pathways
- Accurate potentiometric surface is also an indicator of pathways

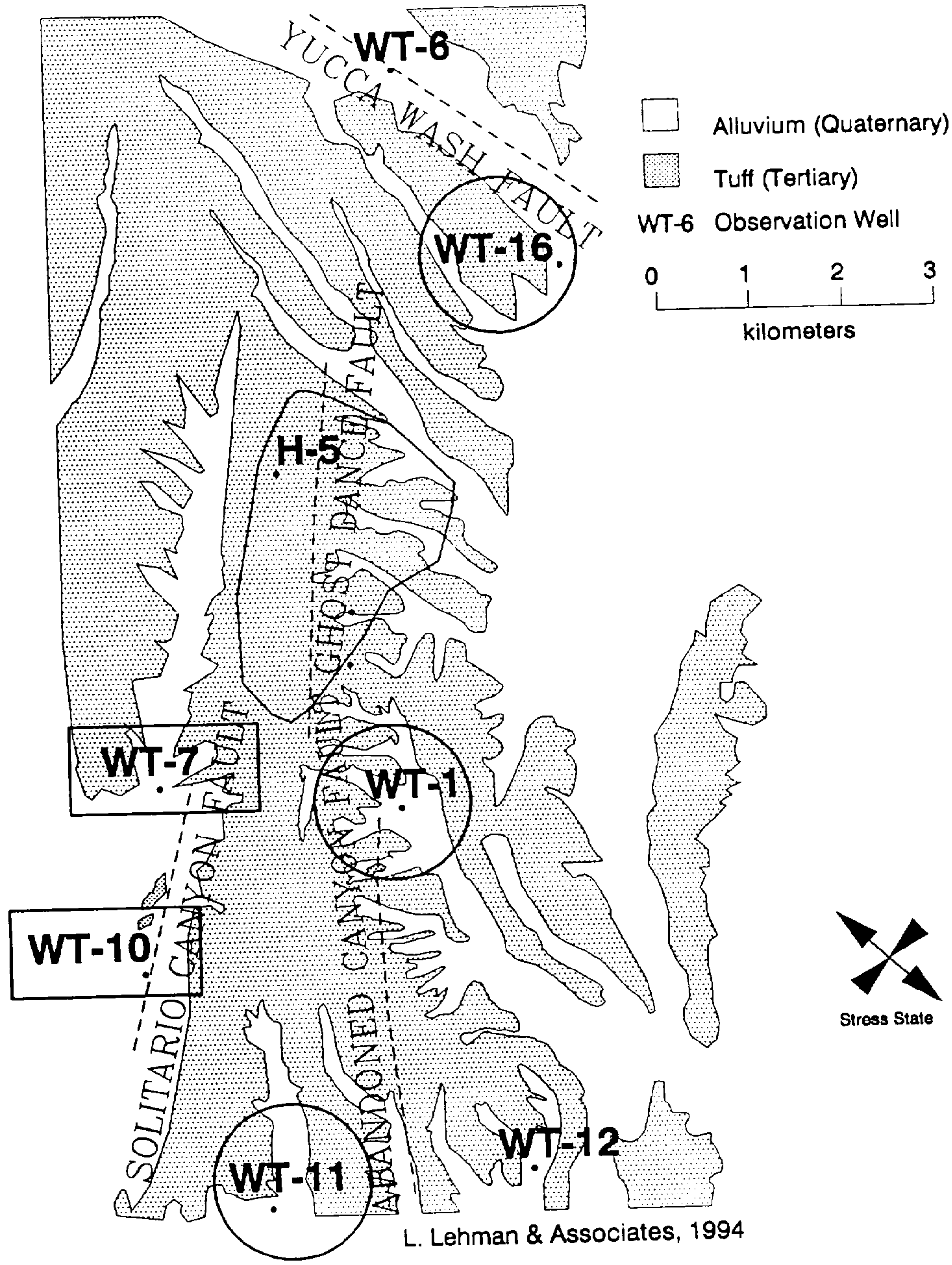


Figure 1. **Location of wells that exhibited different fitted periodicity at Yucca Mountain with circles indicating periods of 870 days and squares indicating periods near 1000 days.**

TABLE I

WATER-LEVEL DATA SET RESULTS

Well #	Period	Phase Shift	Amplitude	r^2	Slope	Cycles
WT-7	1012.2	177.7	0.09	0.47	0.000107	1⅓ cycle
WT-10	925.4	182.4	0.7	0.22	0.000074	~ 2 cycles
WT-12	1240.0	169.8	0.7	0.35	0.000101	~ 1¼ cycles
WT-1	889.2	249.5	0.1	0.44	.000191	almost 2 cycles
WT-11	887.7	253.4	0.115	0.58	0.000100	~ 1¼ cycles
WT-16	860.6	266.9	0.11	0.68	0.000240	~ 1¼ cycles
WT-6	2975.2	738.1	1.3	0.75	.00323	~ ⅓ cycle
H-5	1936.8	416.6	0.54	0.45	-0.000044	< ⅓ cycle
H-5	1888.4	417.9	0.31	0.28	-0.00033	~ ⅓ cycle

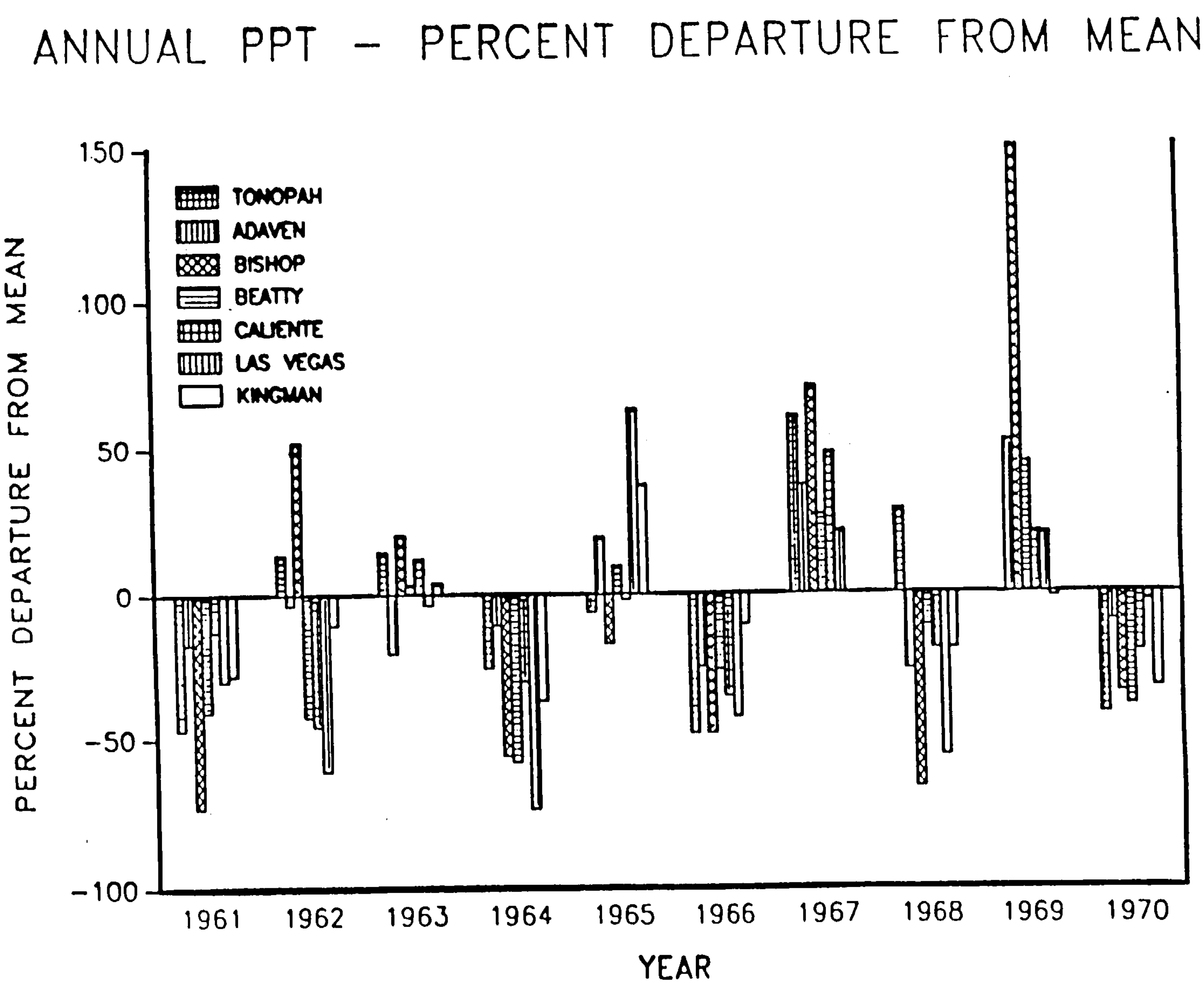


Fig. 5.
Annual Precipitation Totals During Years 1961-1970
From Cochran et al.

Frequency Analysis

- Linearity - structure controlled
- Frequency and phase shift different on each side of the block
- 2.5 year Deviation from mean average annual rainfall

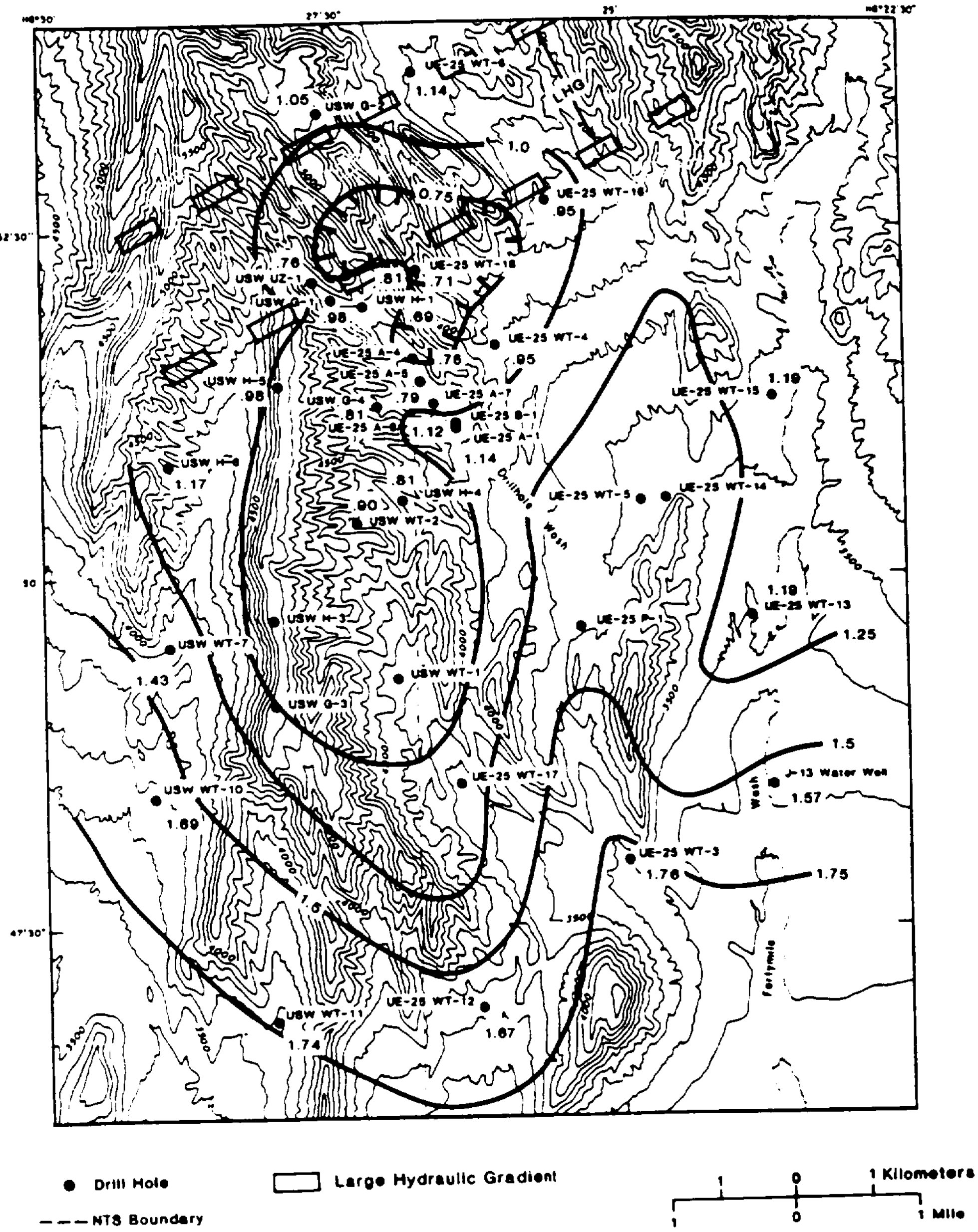


Fig. 7. Map showing lines of equal heat flow in heat-flow units (1 Hfu = 10^{-6} cal cm^{-2} s^{-1}) measured in the unsaturated zone under Yucca Mountain, modified from Sass et al. (1988).

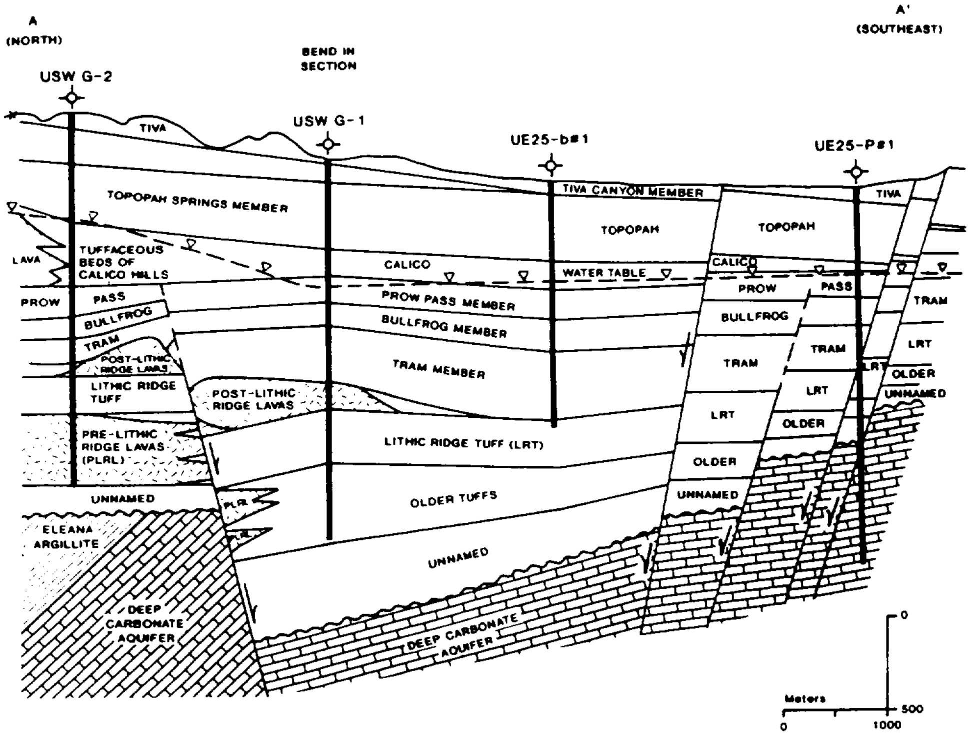


Fig. 11. North-to- southeast geologic section across Yucca Mountain showing the interpreted buried graben. Line of section shown in Fig. 5. Constructed using data from the full suite of lithology logs, cited in the caption of Fig. 4.

the zone of the large gradient; the lowermost part of the volcanic sequence between these two drill holes probably consists largely of lava flow fronts, brittle rocks that typically are brecciated during emplacement and, therefore, may be permeable. The second change is an alignment of lavas (post-Lithic Ridge lavas) beneath the Crater Flat Tuffs along the zone of large gradient, and extending about 1–2 km to either side of the large gradient (Fig. 4). Spengler and Fox (1989) suggested that these lavas were fed by vents localized along the buried fault zone; this hypothesis is supported by the existing data on their distribution.

10. Summary of the geologic interpretation

In summary, the six lines of evidence discussed above, along with the hydrostratigraphic analysis of the volcanic rocks and the analysis of the

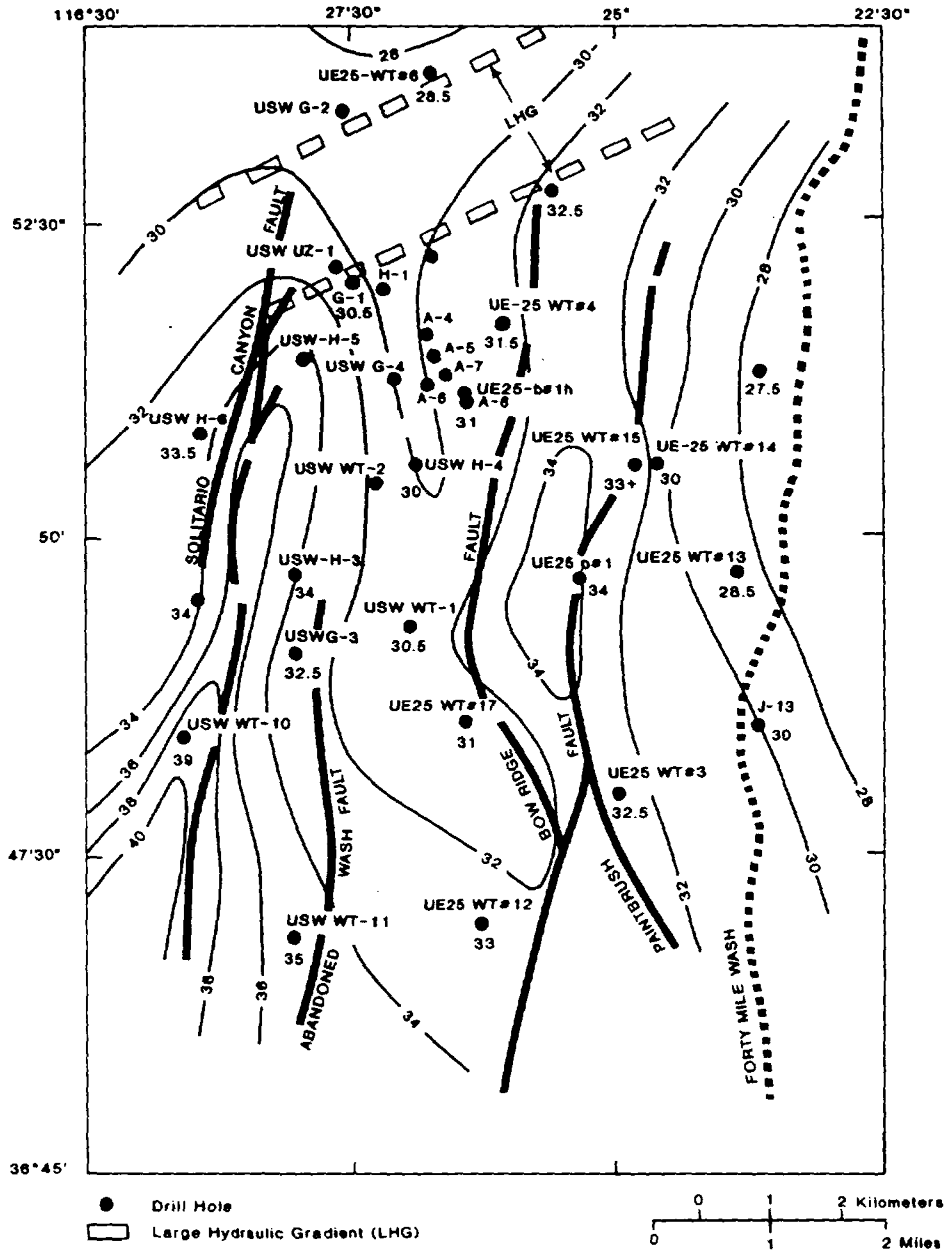


Fig. 8. Map showing isotherms at the water table under Yucca Mountain, contoured with an interval of 2°C, based on data from Sass et al. (1988), and repeating the pattern of major normal faults at the water table from Fig. 5, along with the trace of Forty-Mile wash.

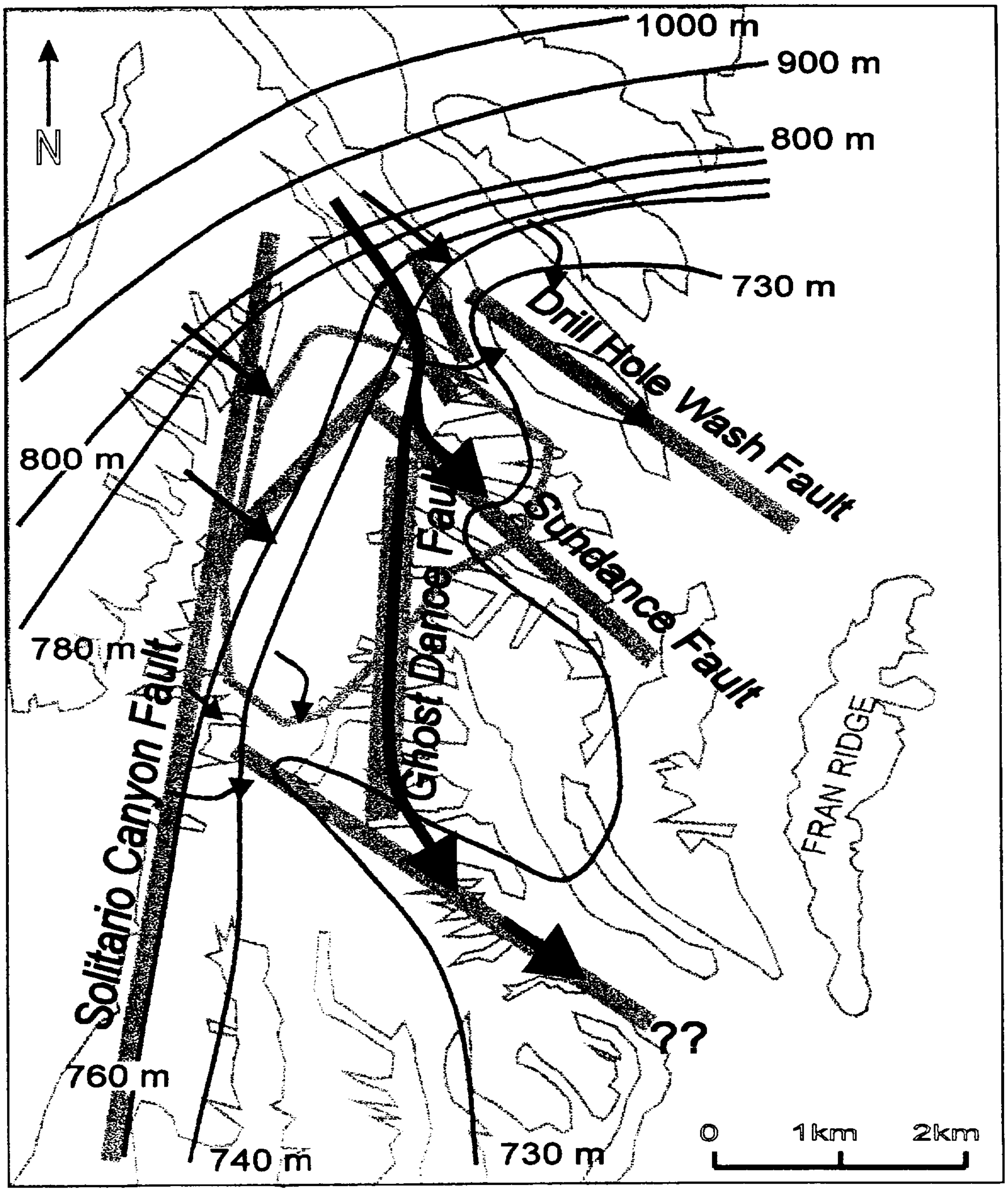


Figure 4. Alternative potentiometric surface with fault locartions and resulting flow pathways.

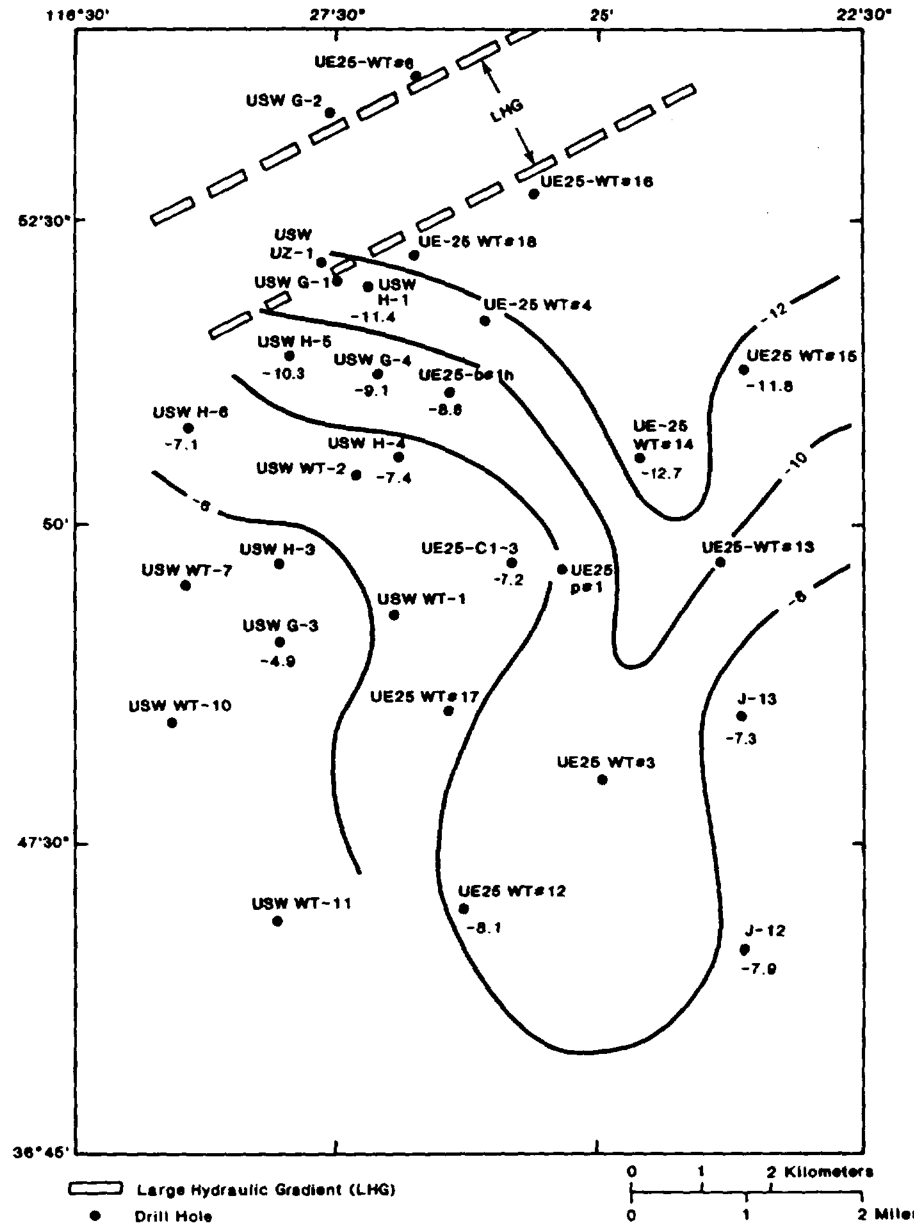


Fig. 9. Values of $\delta^{13}C$ (in units of ‰) of ground waters sampled from drill holes through Yucca Mountai[n]. Data from Stuckless et al. (1991).

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Subissue 5, Acceptance Criterion 2: Delineation of Flow Paths

Presented to:
DOE/NRC Technical Exchange on the Key Technical Issue Subissues Related to Saturated Zone Flow

Presented by:
Al Aziz Eddebbarh
Civilian Radioactive Waste Management System Management and Operating Contractor
Richard W. Spengler
United States Geological Survey

October 31 - November 2, 2000
Albuquerque, NM

YUCCA MOUNTAIN PROJECT

Outline

- **Presentation Objectives**
- **Current Acceptance Criterion Status**
- **For Subissue 5, Acceptance Criterion 2, presentation will:**
  - Summarize technical basis for item resolution
  - Identify basis documents (References)
  - Summarize technical adequacy of basis
- **Conclusions**

Note: Additional summary information is provided in the delta analysis

Presentation Objectives

- **Provide the basis for resolving Acceptance Criterion 2 associated with delineation of flow paths**
- **Subissue 5, Acceptance Criterion 2: Department of Energy (DOE) has reasonably delineated possible flow paths from beneath the repository to potential receptor locations based on data sufficient to elucidate**
  - (i) the relative travel distances through aquifers of differing hydrologic and geochemical properties
  - (ii) in fractured-rock aquifers, the portions of flow through rock matrix and fractures
  - (iii) flow directions with respect to the hydraulic gradient, considering the potential effects of horizontal anisotropy
  - (iv) approximate volume fluxes and pore velocities

Presentation Objectives
(Continued)

- **Subissue 5, Acceptance Criterion 2: Department of Energy (DOE) has reasonably delineated possible flow paths from beneath the repository to potential receptor locations based on data that is sufficient to elucidate (Continued)**
  - (v) vertical hydraulic gradients, including the potential for flow between the Paleozoic carbonate aquifer and the volcanic tuff aquifer. A sufficient number of wells and exploratory holes should be drilled, and an adequate number of tests conducted, to reasonably bound the hydraulic and transport properties of the units downgradient from the proposed repository

Current Acceptance Criterion 2 Status

- Unsaturated and Saturated Flow under Isothermal Conditions Issue Resolution Status Report, Rev. 02 indicates that status is partly resolved: flow paths from the proposed repository to a 20-km distance appear to be bounded within a relatively narrow arc
- April 2000 Key Technical Issue Status Technical Exchange identified the Saturated Zone Flow and Dilution Subissue as open; did not specifically provide status of Acceptance Criterion 2

Acceptance Criterion 2

- **Action or information needs identified**
  - At the April 2000 Key Technical Issue Status Technical Exchange, the NRC indicated:
    - The need existed to show where the water table transitions from the tuffs to the valley fill or conservatively use the shortest lengths of alluvial transport paths that can be justified
    - DOE should do Carbon-14 dating of organic carbon in ground-water from the saturated zone to estimate residence time
  - In agenda-setting telecons for this technical exchange, the NRC requested information on stratigraphy and cross sections from Nye County wells

Acceptance Criterion 2
(Continued)

- **Basis for closure**
  - Flow paths from beneath the repository to potential receptor locations have been delineated based upon multiple lines of evidence including areal distributions of chemical and isotopic data, and gradients of measured head
  - Flow is conservatively assumed to be through the fractures in the fractured-rock aquifer and not in the matrix
  - Uncertainties in hydraulic and transport properties downgradient are incorporated into Total System Performance Assessment
  - Horizontal anisotropy of permeability in fractured tuff units has been included in Saturated Zone flow and transport simulations for Total System Performance Assessment-Site Recommendation as an alternative conceptual model
  - The upward gradient, as observed at well UE-25 p#1, is simulated in the Saturated Zone site-scale flow and transport model

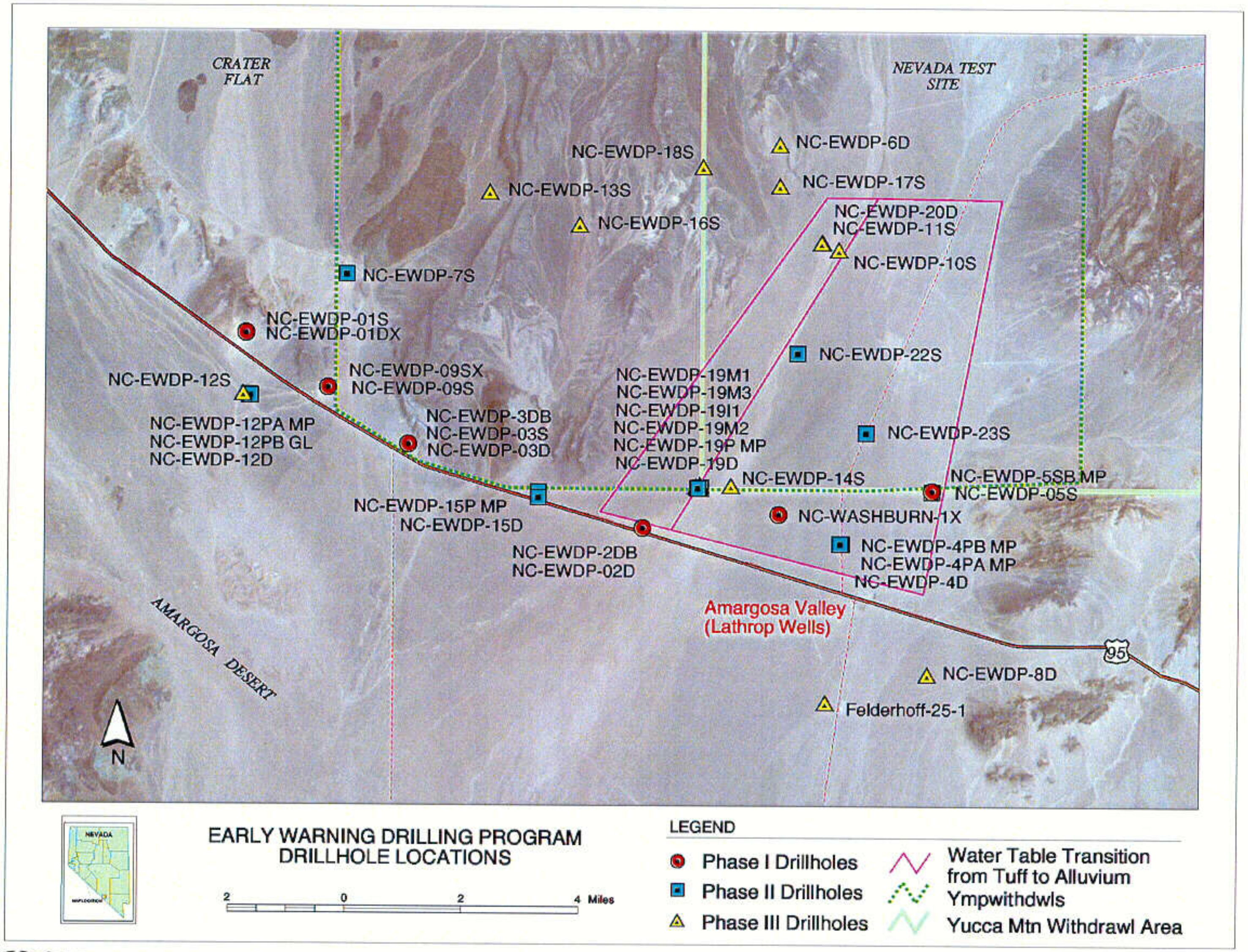
Acceptance Criterion 2
(Continued)

- **Basis for closure** **(Continued)**
  - The uncertainty in the extent of alluvium in the site-scale flow and transport model is abstracted as a polygonal region. The dimensions of the polygonal region are stochastically varied in the Saturated Zone flow and transport simulations for Total System Performance Assessment calculations. Planned Nye County wells will help reduce the uncertainty
  - DOE plans to perform Carbon-14 dating of organic carbon in ground-water from the Saturated Zone
  - Information on stratigraphy and correlation diagrams from Nye County wells is provided in presentation
- **This acceptance criterion should be closed**
  - DOE has appropriately delineated saturated zone flow paths and is further refining the flow path delineation through additional Fiscal Year 2001 work

Water Table Transition

- **Basis for Resolution**
  - DOE, in cooperation with Nye County, is conducting an extensive investigation of the stratigraphy of the saturated zone to define the transition of the water table from tuff to valley fill. Existing uncertainty is incorporated in the performance assessment

Water Table Transition Zone and Planned Nye County Wells



C25

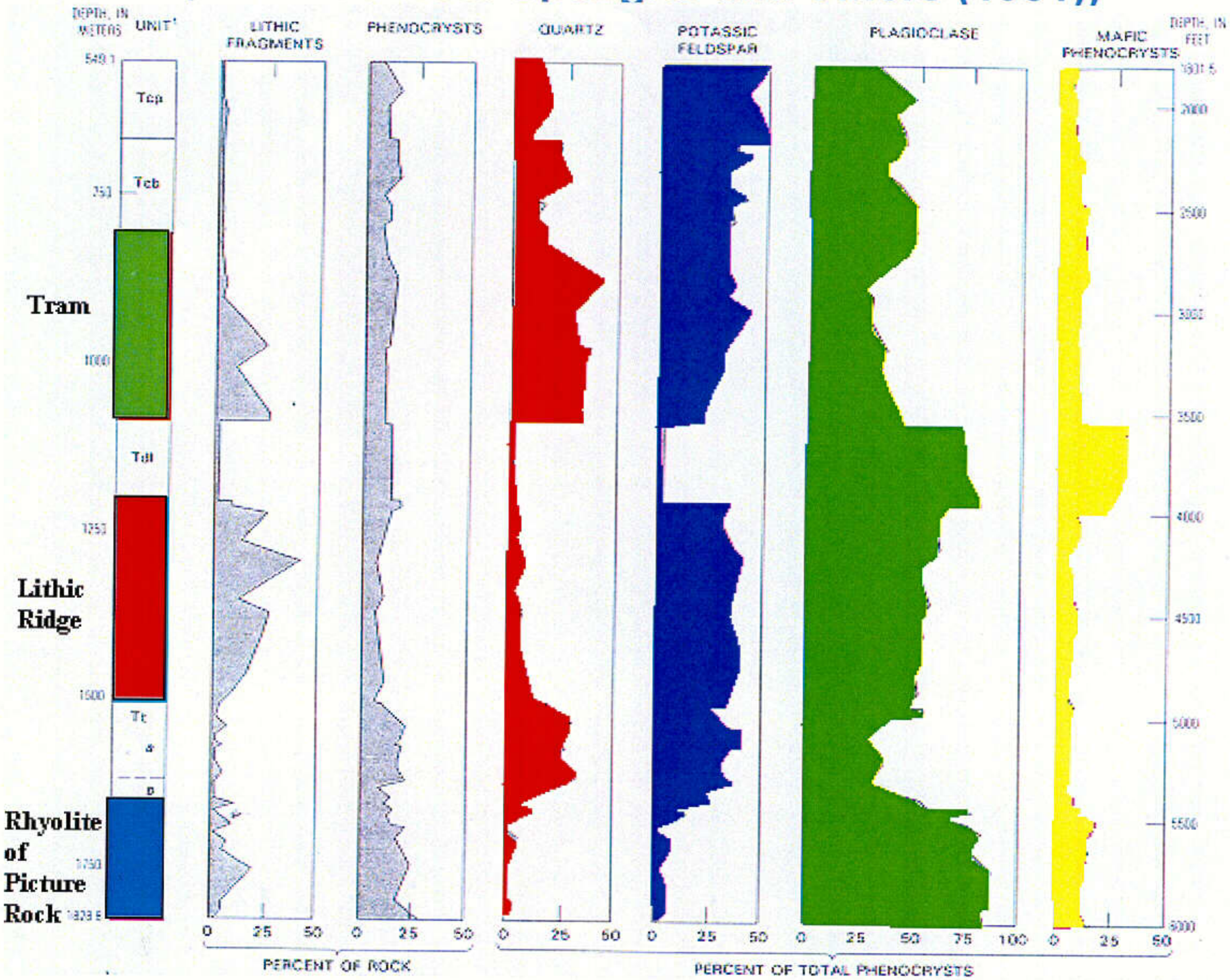
Water Table Transition
(Continued)

- **References**
  - *Saturated Zone Flow and Transport Process Model Report* (TDR-NBS-HS-000001 REV 00 ICN 01)
  - *Analysis and Model Report Uncertainty Distribution for Stochastic Parameters* (ANL-NBS-MD-000011 REV 00)
  - *Analysis and Model Report Input and Results of the Base Case Saturated Zone Flow and Transport Model for TSPA* (ANL-NBS-HS-000030 REV 00)
- **This information need has been fully addressed through saturated zone investigations. No additional work is needed**

Stratigraphy and Cross Sections from Nye County Wells

- **Basis for Resolution**
  - DOE has, in cooperation with Nye County, obtained stratigraphic information
  - DOE will develop cross sections and will incorporate new data as they become available

Review of Petrographic Characteristics USW G-1 (modified from Spengler and others (1981))



C26

Volcanic Stratigraphic Units likely to be Encountered in Southern Yucca Mountain

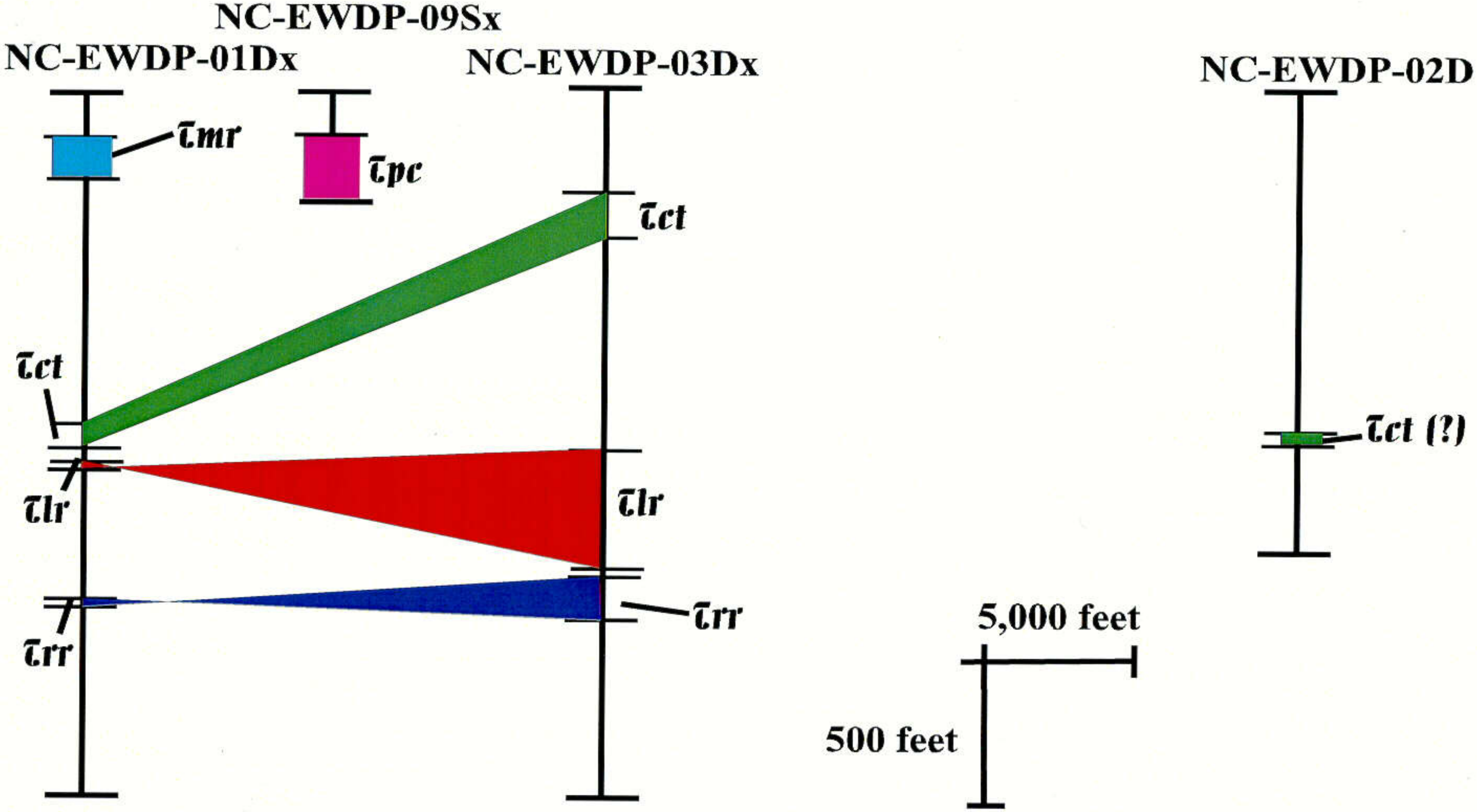
Stratigraphic Unit	Age	Thickness (maximum)**	Symbol
Timber Mtn Group	12.60*	150	Tm
(Rainier Mesa Tuff)			
Paintbrush Group	12.80	?	Tp
(Tiva Canyon Tuff)			
Wahmonie Formation	13.08	?	Tw
Prow Pass Tuff	13.13	?	Tcp
Bullfrog Tuff	13.31	?	Tcb
Tram	13.35	167	Tct
Lithic Ridge Tuff	14.00	425	Tlr
Rhyolite of Picture Rock	14.14	137	Trr

*age data from Sawyer and others (1994) and Warren and others (2000)

**Thickness in feet.

C27

Correlation Diagram of Select Boreholes along Highway 95



Reference: work in progress

Salient Features

- **Unlike the central part of Yucca Mountain, where major pyroclastic flow deposits are separated by several feet of pyroclastic fall deposits, pyroclastic flow deposits in the vicinity of Highway 95 are separated by tens to hundreds of feet of either:**
  - A combination of pyroclastic fall deposits, reworked tuff, siltstone, and claystone, or
  - Siltstone and claystone with no indication of pyroclastic fall material

Stratigraphy and Cross Sections from Nye County Wells (Continued)

- **References**
  - Cross section information will be included in revised *Analysis and Model Report Hydrogeologic Framework for the Saturated-zone Site-scale Flow and Transport Model*
- **This information need is being addressed by work to be completed in FY 2001. No additional work needed**

Carbon-14 Dating

- **Basis for Resolution**
  - DOE plans to perform Carbon-14 dating but believes it is not necessary for closure of this acceptance criterion because DOE has used stratigraphic data, hydraulic information, and hydrochemistry data to adequately delineate flow paths
- **References**
  - *Saturated Zone Flow and Transport Process Model Report* (TDR-NBS-HS-000001 REV 00 ICN 01)
  - *Analysis and Model Report Calibration of the Site-Scale Saturated Zone Flow Model* (MDL-NBS-HS-000011 REV 00)
  - *Analysis and Model Report Geochemical and Isotopic Constraints on Groundwater Flow Directions, Mixing, and Recharge at Yucca Mountain, Nevada* (ANL-NBS-HS-000021 REV 00)
- **Sufficient information exists on the Saturated Zone Flow network to support acceptance criterion closure**

Conclusions

- **This criterion should be closed**
  - Flow paths from beneath the repository to potential receptor locations have been delineated based upon multiple lines of evidence including areal distributions of chemical and isotopic data, and gradients of measured head. There is sufficient information available to incorporate uncertainty into the Total System Performance Assessment
  - Hydraulic and transport properties downgradient have been bounded, and additional testing is ongoing to reduce uncertainty
  - Carbon-14 dating of organic carbon in groundwater is expected to confirm residence time estimates

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Subissue 5, Acceptance Criterion 3: Moderate and Large Hydraulic Gradient

Presented to:
DOE/NRC Technical Exchange on the Key Technical Issue Subissues related to Saturated Zone Flow

Presented by:
Al Aziz Eddebbarh, Ph.D
Civilian Radioactive Waste Management System Management and Operating Contractor
Pat Tucci
United States Geological Survey

October 31 - November 2, 2000
Albuquerque, NM

YUCCA MOUNTAIN PROJECT

Outline

- **Presentation Objectives**
- **Current Acceptance Criterion Status**
- **For Subissue 5, Acceptance Criterion 3, presentation will:**
  - Summarize technical basis for item resolution
  - Identify basis documents (References)
  - Summarize technical adequacy of basis
- **Conclusions**

Note: Additional summary information is provided in the delta analysis

Presentation Objectives

- Provide the basis for resolving Acceptance Criterion 3 associated with the moderate and large hydraulic gradients
- Subissue 5, Acceptance Criterion 3: Department of Energy (DOE) has provided a hydrologic assessment to describe likely causes of the "moderate hydraulic gradient" and the "large hydraulic gradient"

Current Acceptance Criterion 3 Status

- Unsaturated and Saturated Flow under Isothermal Conditions Issue Resolution Status Report, Rev. 02 indicates status is open, pending submission and staff review of DOE reports on the drilling and testing of wells WT-24 and SD-6
- April 2000 Key Technical Issue Status Technical Exchange identified the Saturated Zone Flow and Dilution Subissue as open; did not specifically provide status of Acceptance Criterion 3

Acceptance Criterion 3 Moderate and Large Hydraulic Gradient

- **Action or information needs identified**
  - At the April 2000 Key Technical Issue Status Technical Exchange, the NRC indicated data from WT-24 and SD-6 should be provided and analyzed
  - Information submitted regarding agenda-setting telecons indicated the NRC wanted DOE to publish reports on SD-6 and WT-24 for staff review

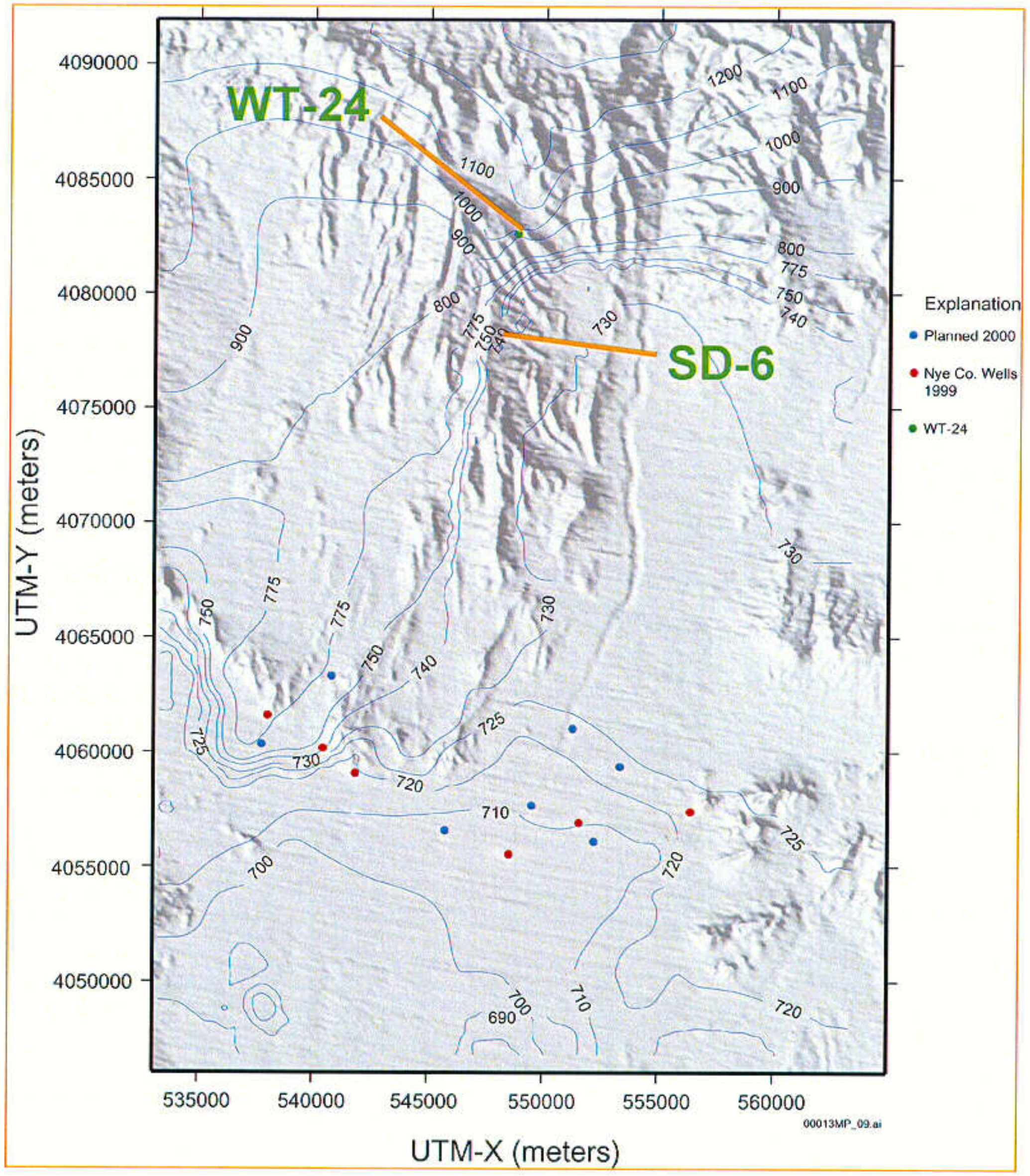
Acceptance Criterion 3

- **Basis for closure**
  - Regardless of the cause of these hydraulic features, they are represented in the Saturated Zone Flow and Transport Model
  - An expert elicitation panel on Saturated Zone flow and transport convened by DOE addressed the issue of the cause of the large hydraulic gradient. The panel narrowed the theories to the two most credible hypotheses:
    - Flow through the upper volcanic confining unit or semi-perched water; the consensus of the panel slightly favored semi-perched water.
    - The experts agreed the issue was mainly one of technical credibility, that the probability of any large transient change in the configuration of the large gradient was low, and that the probability of long-term transient readjustment of gradients was low
- **This acceptance criterion has been fully addressed**
  - DOE has appropriately assessed the likely causes of "moderate hydraulic gradient" and "large hydraulic gradient"

Data from WT-24 and SD-6

- **Basis for Resolution**
  - Additional information on boreholes USW SD-6 and USW WT-24 is provided in the *Integrated Site Model Process Model Report* and its supporting documents and the *Saturated Zone Process Model Report* and its supporting documents. Activities related to these boreholes have improved understanding of the cause of the large and moderate hydraulic gradients
  - The Saturated Zone Site-scale Model incorporates the effect of those hydraulic features on flow and transport

Location of WT-24 and SD-6



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Data from WT-24 and SD-6
(Continued)

- **WT-24 Facts**
  - Perched water encountered in lower Topopah Spring Tuff and pre-Topopah bedded tuff
  - Perched water depth - 507 m below land surface (987 m above sea level)
  - Perched zone hydraulic tests 10/97
  - Perched zone sealed off 538 - 542 m below land surface (true base of zone unknown)
  - Water-bearing fracture encountered at 760 m below land surface (734 m above sea level) in Calico Hills Formation

Data from WT-24 and SD-6
(Continued)

- **WT-24 Facts**
  - Water rose to 654 m below land surface (840 m above sea level), and remained at that level as well was deepened to TD (864 m below land surface)
  - Lower saturated interval produces little water
- **WT-24 Hydrologic Implications**
  - Still some question as to whether 840-m potentiometric level is regional water level or another perched water level
  - If regional, the large hydraulic gradient may be "not-so-large"
  - If perched, what is the regional level?

Data from WT-24 and SD-6
(Continued)

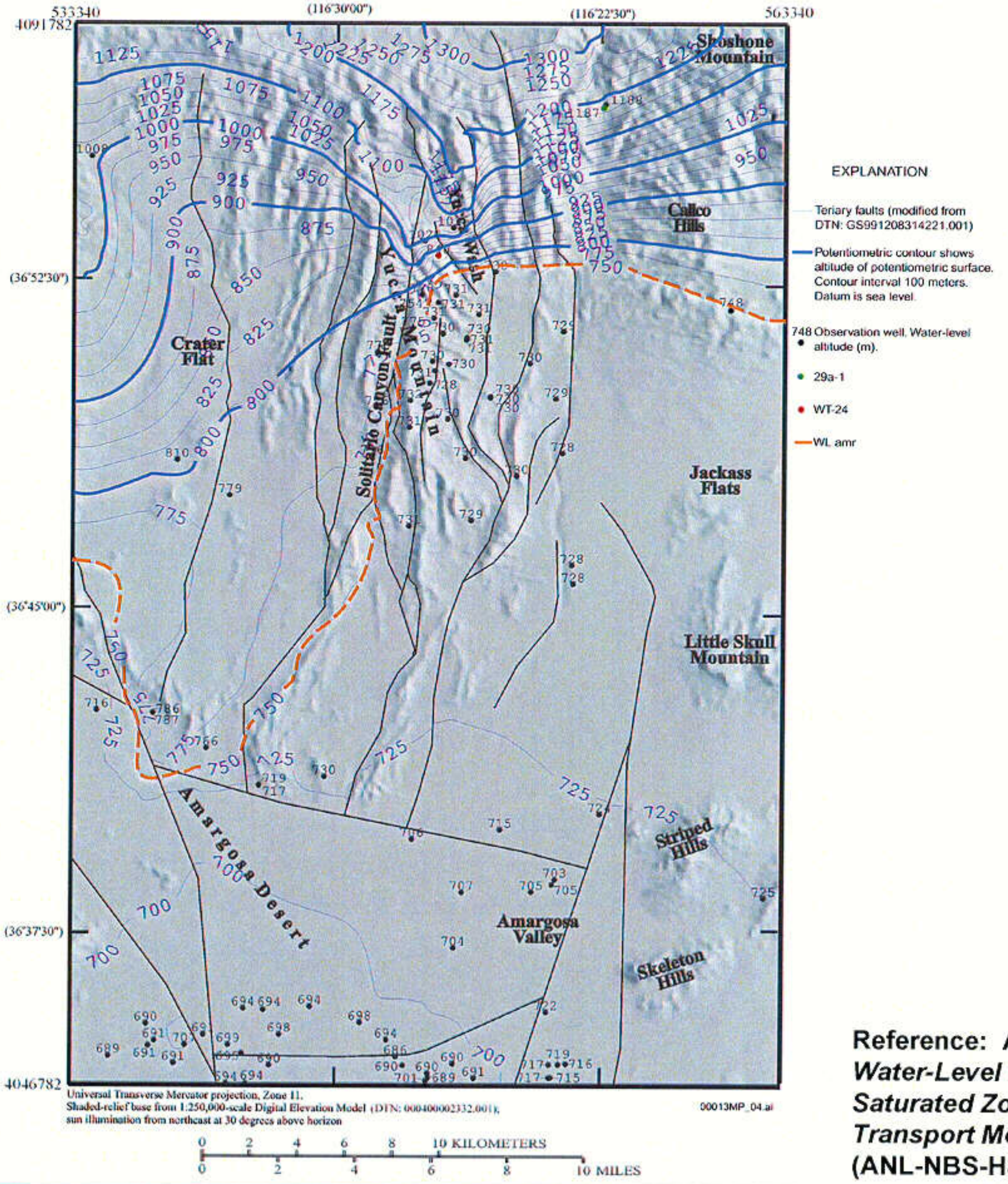
- **<u>Large Hydraulic Gradient: Alternate Conceptual Model</u>**

Assume:

- Water level at USW WT-24 (840 m) is saturated zone, and
- Water levels at USW G-2 (1020 m) and UE-25 WT#6 (1035 m) represent perched water, and
- Water level at UE-29 a#1 (1185 m) is saturated zone

LARGE HYDRAULIC GRADIENT DECREASES FROM 0.11 TO 0.06-0.07, *<u>BUT IT DOESN'T GO AWAY</u>*

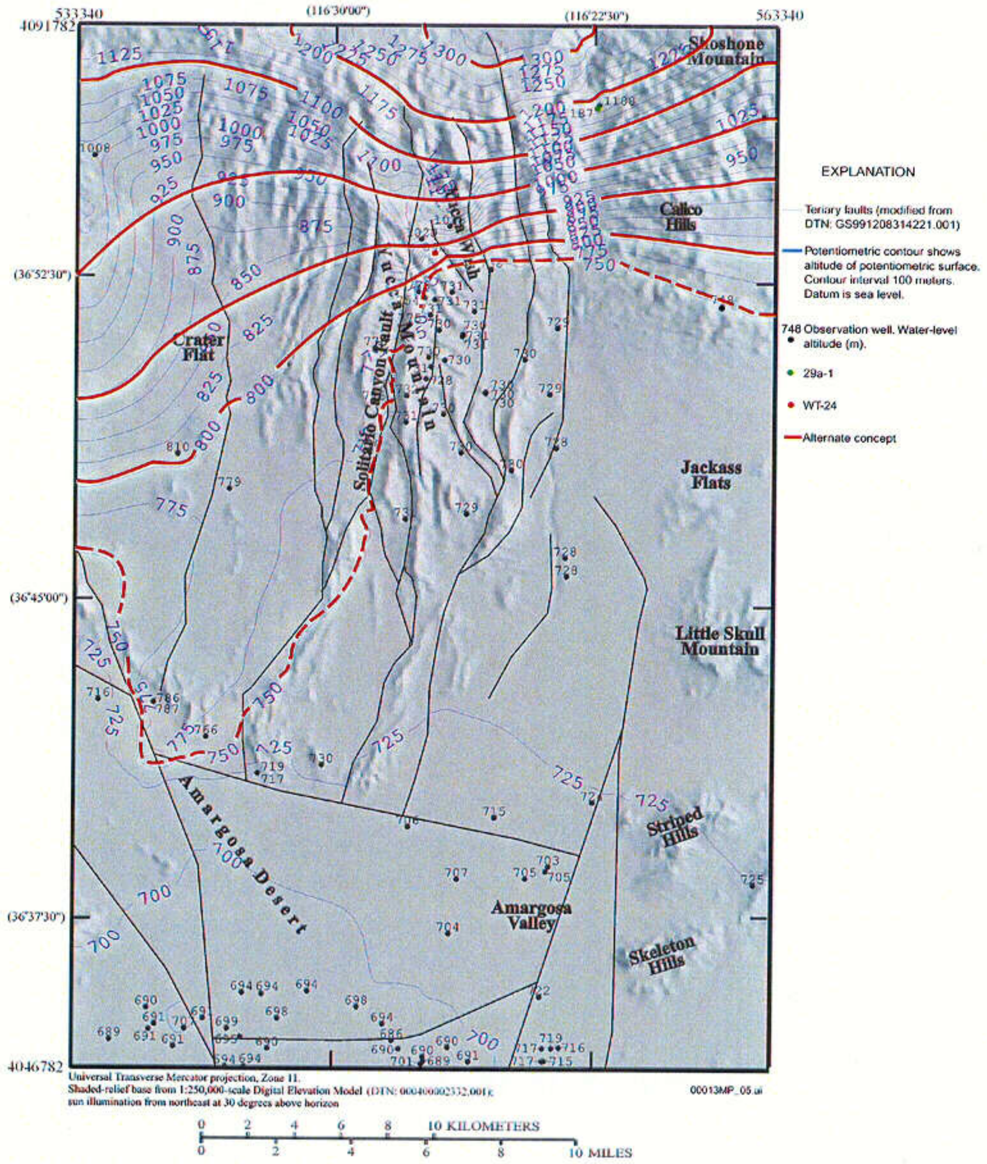
Potentiometric Surface Contour Map



Reference: Analysis and Model Report ***Water-Level Data Analysis for the Saturated Zone Site-Scale Flow and Transport Model*** **(ANL-NBS-HS-000034 REV 00)**

C30

Alternate Concept of Large Hydraulic Gradient



Reference: work in progress

C31

Data from WT-24 and SD-6
(Continued)

- **<u>USW SD-6 (also known as SD-6ST1)</u>**
  - Drilled to test Moderate Hydraulic Gradient (substitute for proposed borehole H-7)
  - Located on crest of Yucca Mountain, east of Solitario Canyon fault
  - Total depth = 856 m (2808 feet)
  - Open interval in Bullfrog? Tuff
  - Hydraulic testing May-June, 1999
  - Pump set 843-853 m.
  - Transducer set at 826 m.

Data from WT-24 and SD-6
(Continued)

- **<u>USW SD-6 (also known as SD-6ST1)</u>**
  - Static water level = 764 m below land surface (731m above sea level)
  - Water levels monitored in wells (WT-1, H-6 (upper), and H-4 (upper)
  - First series of short-term pump tests at 70-75 gallon per minute couldn't sustain pumping rate (too much drawdown)
  - Second series of short-term tests pumped at 17-27 gallon per minute
  - Final 14-day test pumped at about 16 gallon per minute

Data from WT-24 and SD-6
(Continued)

- **Test Results**
  - Water levels in SD-6 always recovered within about an hour.
  - No drawdown observed in other wells
  - Probably only testing secondary fractures, not main fracture system for saturated zone

Data from WT-24 and SD-6
(Continued)

- **References**
  - *Saturated Zone Flow and Transport Process Model Report* (TDR-NBS-HS-000001 REV 00 ICN 01)
  - *Integrated Site Model Process Model Report* (TDR-NBS-GS-000002 REV 00 ICN 01)
  - Analysis and Model Report *Mineralogical Model* (MDL-NBS-GS-000003 REV 00 ICN 01)
  - Analysis and Model Report *Geochemical and Isotopic constraints on Goundwater Flow Directions, Mixing, and Recharge at Yucca Mountain, Nevada* (ANL-NBS-HS-000021 REV 00)
  - Analysis and Model Report *Water-Level Data Analysis for the Saturated Zone Site-Scale Flow and Transport Model* (ANL-NBS-HS-000034 REV 00)
  - *Yucca Mountain Site Description* (TDR-CRW-GS-000001 REV 01)
- **This information need has been fully addressed by the additional information provided in the Process Model Reports and Analysis and Model Reports. No additional work is needed**

Conclusions

- **This criterion should be closed**
  - Large and moderate gradients are represented in the DOE Saturated Zone Flow and Transport Model
  - Through recent work, DOE has a good understanding of the causes of the gradients
  - Additional information on boreholes USW SD-6 and USW WT-24 is provided in the *Integrated Site Model Process Model Report* and its supporting documents, the *Yucca Mountain Site Description,* and the *Saturated Zone Flow and Transport Process Model Report*

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Subissue 5, Acceptance Criterion 4: Potentiometric Maps

Presented to:
DOE/NRC Technical Exchange on the Key Technical Issue Subissues related to Saturated Zone Flow

Presented by:
Al Aziz Eddebbarh
Civilian Radioactive Waste Management System Management and Operating Contractor
Pat Tucci
United States Geological Survey

October 31 - November 2, 2000
Albuquerque, NM

YUCCA MOUNTAIN PROJECT

Outline

- **Presentation Objectives**
- **Current Acceptance Criterion Status**
- **For Subissue 5, Acceptance Criterion 4, presentation will:**
  - Summarize technical basis for resolution of items
  - Identify basis documents
  - Summarize technical adequacy of basis
- **Conclusions**

Note: Additional summary information is provided in the delta analysis

Presentation Objectives

- **Provide the basis for resolving Acceptance Criterion 4 associated with potentiometric maps**
- **Subissue 5, Acceptance Criterion 4:**
  - The Department of Energy (DOE) has provided maps of approximate potentiometric contours of the regional uppermost aquifer for an area that, at a minimum, includes wells J-11 on the east, VH-1, VH-2, and the GEXA Well on the west, UE-29a#2 to the north, and domestic and irrigation wells south of Amargosa Valley (aka Lathrop Wells)
  - Maps of regional and site-scale recharge and discharge should be provided, along with site-scale hydrostratigraphic cross sections constructed along the paths to the accessible environment, and site-scale flow-net analysis of the Saturated Zone

Current Acceptance Criterion 4 Status

- **Unsaturated and Saturated Flow under Isothermal Conditions Issue Resolution Status Report, Rev. 02 indicates that status is open, pending review of relevant DOE milestone reports**
- **April 2000 Key Technical Issue Status Technical Exchange identified the Saturated Zone Flow and Dilution Subissue as open; did not specifically provide status of Acceptance Criterion 4**

Acceptance Criterion 4

- **Action or information needs identified**
  - At the April 2000 KTI Status Technical Exchange, the NRC indicated the need existed to develop revised potentiometric maps that include Nye County data; enough groundwater elevation data should be available to reasonably bound the direction of lateral flow from the Repository
  - In an agenda-setting telecon for this technical exchange, the NRC indicated the *Water-Level Data Analysis Analysis Model Report s*hould be updated and the potentiometric map revised to include data from SD-6 and WT-24 and the latest Nye County data

Acceptance Criterion 4

- **Basis for closure**
  - DOE has provided maps of approximate potentiometric contours of the regional uppermost aquifer for an area that includes wells J-11 on the east, VH-1, VH-2, and the GEXA Well on the west, UE-29a#2 to the north, and domestic and irrigation wells in the Amargosa Valley
  - Regional infiltration, evapotranspiration, spring discharges, and pumping estimates are included in the regional model and are being refined for the updated regional model. Flow net analyses were not performed. However, it is believed the three-dimensional modeling for the Site Scale Model obviates the need for flow net analyses as the three-dimensional modeling in the Analysis Model Report, *Calibration of the Site-Scale Saturated Zone Flow Model,* provides a more detailed analysis of flow than does a two-dimensional flow net
- **This acceptance criterion has been fully addressed**
  - DOE has appropriate site scale and regional maps and has incorporated all aspects called for in the acceptance criterion

Revised Potentiometric Maps

- **Basis for Resolution**
  - DOE has developed a new potentiometric map that includes Nye County and the Amargosa Valley
  - Lateral flow has been reasonably bounded

Potentiometric-Surface Maps Evolution

- Robison, J.H., 1984. *Ground-water Level Data and Preliminary Potentiometric-Surface Maps, Yucca Mountain and Vicinity, Nye County, Nevada.* Water-Resources Investigations Report 84-4197. Denver, Colorado: U.S. Geological Survey.

- Ervin, E.M.; Luckey, R.R.; and Burkhardt, D.J. 1994. *Revised Potentiometric-Surface Map, Yucca Mountain and Vicinty, Nevada.* Water-Resources Investigations Report 93-4000. Denver, Colorado: U.S. Geological Survey.

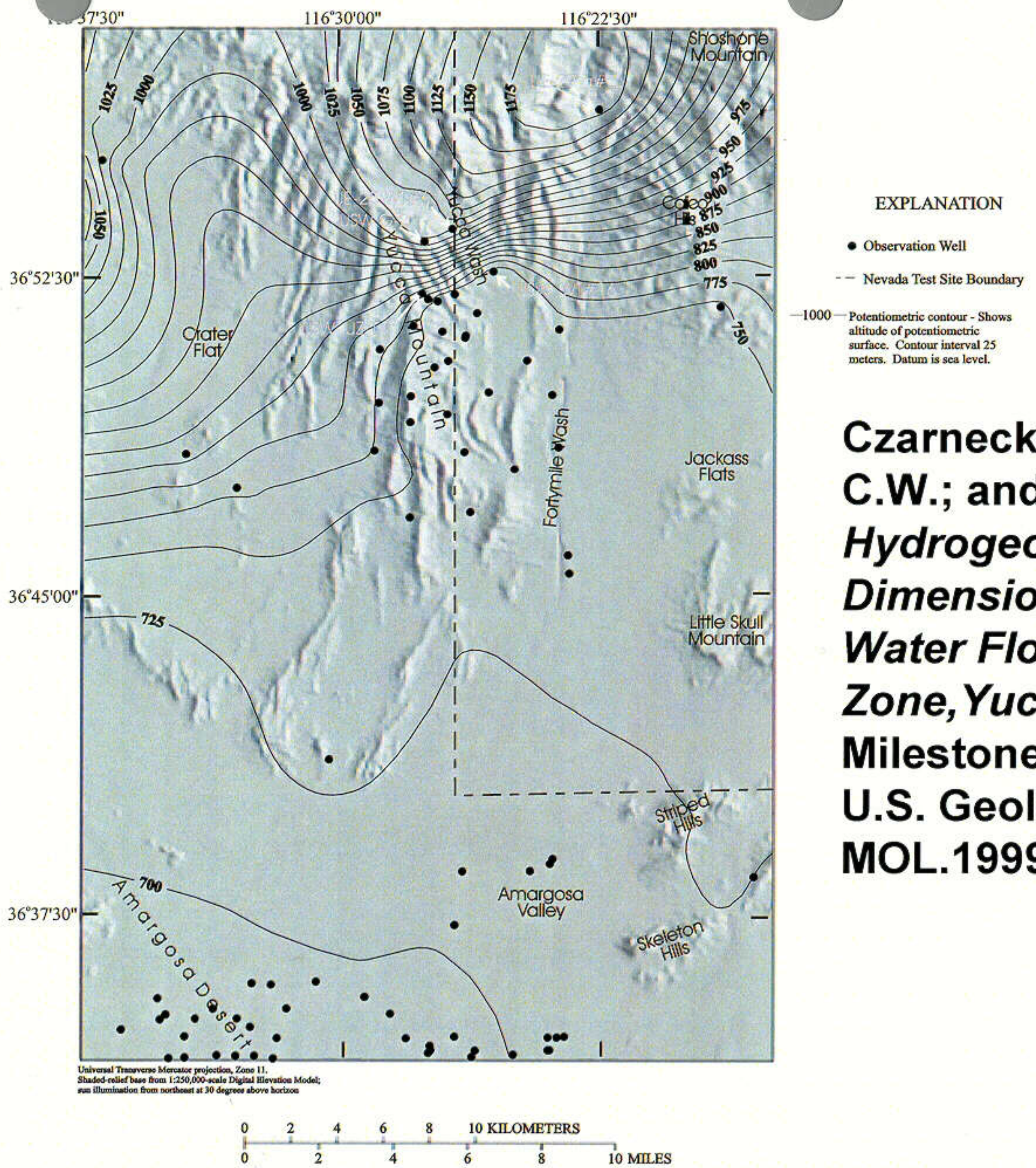
- Tucci, P. and Burkhardt, D.J. 1995. *Potentiometric-Surface Map, 1993, Yucca Mountain and Vicinity, Nevada. Water-Resources Investigations Report 95-4149.* Denver, colorado: U.S. Geological Survey.

- Lehman. L.L. and Brown, T.P. 1996. *Summary of State of Nevada - Funded Studies of the Saturated Zone at Yucca Mountain, Nevada, Performed by L. Lehman & Associates, Inc.* Burnsville, Minnesota: L. Lehman and Associates.

Potentiometric-Surface Maps Evolution

- Czarnecki, J.B.; Faunt, C.C.; Gable, C.W.; and Zyvoloski, G.A. 1997. *Hydrogeology and Preliminary Three-Dimensional Finite-Element Ground-Water Flow Model of the Site Saturated Zone, Yucca Mountain, Nevada.* Milestone SP23NM3. Denver, Colorado: U.S. Geological Survey. ACC: MOL.19990812.0180.

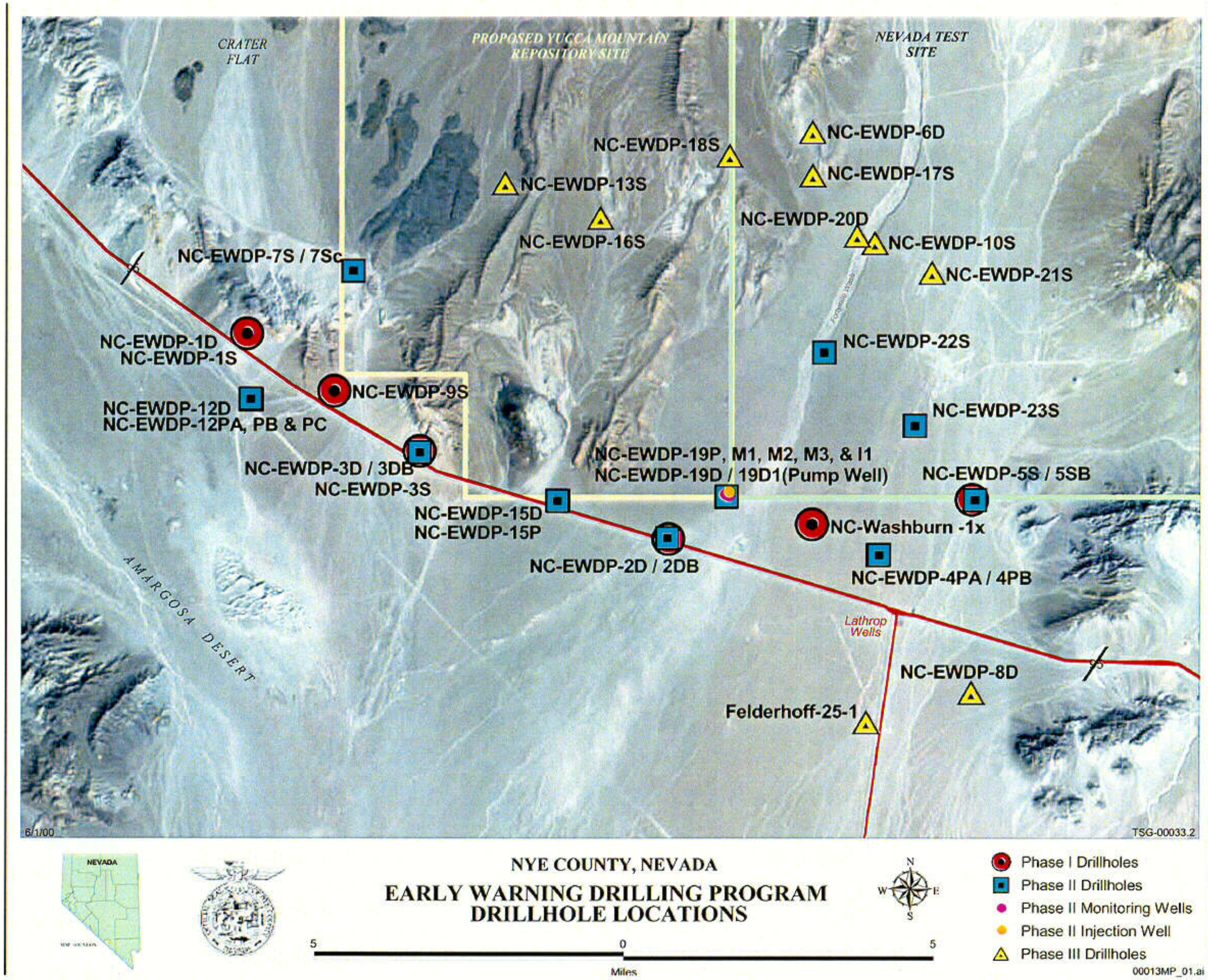
- USGS 2000. *Analysis and Model Report Water-Level Data Analysis for the Saturated Zone Site-Scale Flow and Transport Model.* ANL-NBS-HS-000034 REV 00. Denver, Colorado: U.S. Geological Survey.



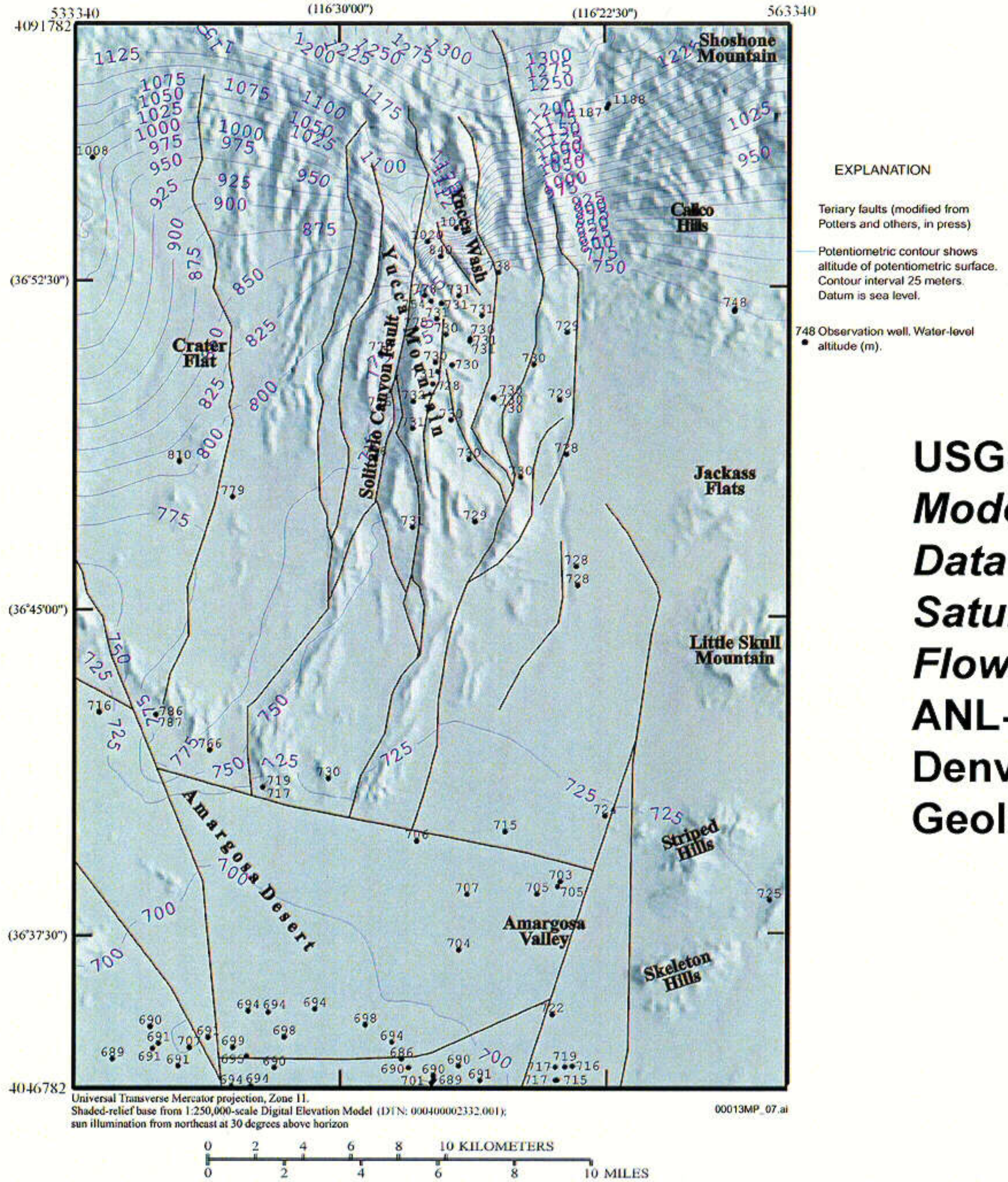
Czarnecki, J.B.; Faunt, C.C.; Gable, C.W.; and Zyvoloski, G.A. 1997. *Hydrogeology and Preliminary Three-Dimensional Finite-Element Ground-Water Flow Model of the Site Saturated Zone, Yucca Mountain, Nevada.* Milestone SP23NM3. Denver, Colorado: U.S. Geological Survey. ACC: MOL.19990812.0180.

Computer-Generated Potentiometric Surface for the Site Model Area

C32

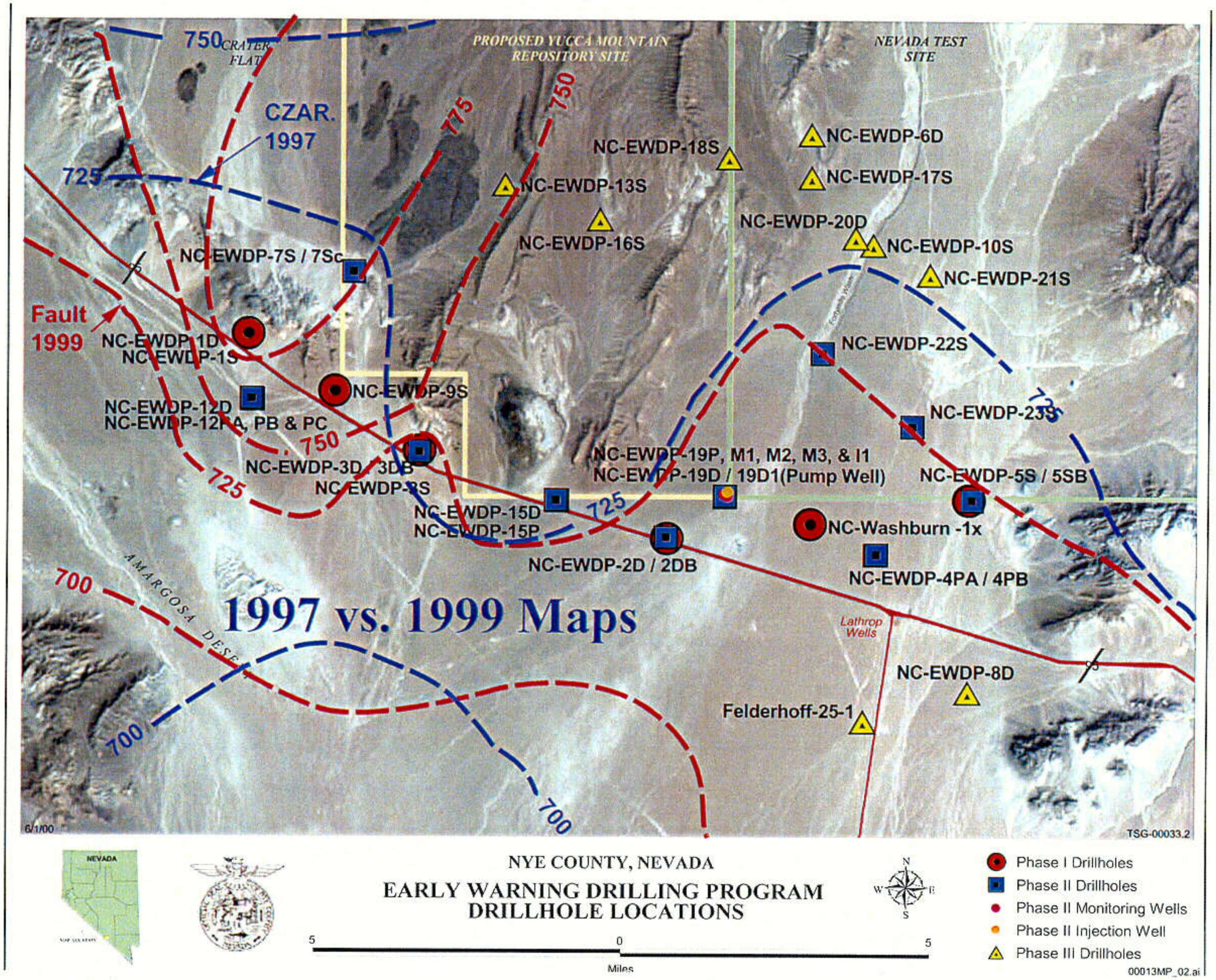

CRATER FLAT
PROPOSED YUCCA MOUNTAIN REPOSITORY SITE
NEVADA TEST SITE
NC-EWDP-18S
NC-EWDP-6D
NC-EWDP-17S
NC-EWDP-13S
NC-EWDP-16S
NC-EWDP-20D
NC-EWDP-10S
NC-EWDP-21S
NC-EWDP-7S / 7Sc
NC-EWDP-1D
NC-EWDP-1S
NC-EWDP-22S
NC-EWDP-9S
NC-EWDP-12D
NC-EWDP-12PA, PB & PC
NC-EWDP-23S
NC-EWDP-19P, M1, M2, M3, & I1
NC-EWDP-19D / 19D1(Pump Well)
NC-EWDP-5S / 5SB
NC-EWDP-3D / 3DB
NC-EWDP-3S
NC-EWDP-15D
NC-EWDP-15P
NC-Washburn -1x
NC-EWDP-2D / 2DB
NC-EWDP-4PA / 4PB
AMARGOSA DESERT
Lathrop Wells
NC-EWDP-8D
Felderhoff-25-1
6/1/00
TSG-00033.2
NEVADA
NYE COUNTY, NEVADA
EARLY WARNING DRILLING PROGRAM
DRILLHOLE LOCATIONS
N
W
E
S
5
0
5
Miles
Phase I Drillholes
Phase II Drillholes
Phase II Monitoring Wells
Phase II Injection Well
Phase III Drillholes
00013MP_01.ai

C33



USGS 2000. *Analysis and Model Report Water-Level Data Analysis for the Saturated Zone Site-Scale Flow and Transport Model.* ANL-NBS-HS-000034 REV 00. Denver, Colorado: U.S. Geological Survey.

C34


PROPOSED YUCCA MOUNTAIN REPOSITORY SITE
NEVADA TEST SITE
CRATER FLAT
CZAR. 1997
Fault 1999
750
775
725
700
AMARGOSA DESERT
Lathrop Wells
NC-EWDP-18S
NC-EWDP-6D
NC-EWDP-17S
NC-EWDP-13S
NC-EWDP-16S
NC-EWDP-20D
NC-EWDP-10S
NC-EWDP-21S
NC-EWDP-7S / 7Sc
NC-EWDP-1D
NC-EWDP-1S
NC-EWDP-9S
NC-EWDP-12D
NC-EWDP-12PA, PB & PC
NC-EWDP-22S
NC-EWDP-23S
NC-EWDP-3D / 3DB
NC-EWDP-3S
NC-EWDP-19P, M1, M2, M3, & I1
NC-EWDP-19D / 19D1(Pump Well)
NC-EWDP-5S / 5SB
NC-EWDP-15D
NC-EWDP-15P
NC-EWDP-2D / 2DB
NC-Washburn -1x
NC-EWDP-4PA / 4PB
NC-EWDP-8D
Felderhoff-25-1
1997 vs. 1999 Maps
6/1/00
TSG-00033.2
NEVADA
NYE COUNTY, NEVADA
EARLY WARNING DRILLING PROGRAM
DRILLHOLE LOCATIONS
N
S
E
W
5
0
5
Miles
Phase I Drillholes
Phase II Drillholes
Phase II Monitoring Wells
Phase II Injection Well
Phase III Drillholes
00013MP_02.ai

C35

Revised Potentiometric Maps
(Continued)

- **References**
  - D'Agnese, F.A.; Faunt, C.C.; Turner, A.K.: and Hill, M.C. 1997. *Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California.* Water-Resources Investigations Report 96-4300. Denver, Colorado: U.S. Geological Survey (ACC: MOL.19980306.253)
  - *Saturated Zone Flow and Transport Process Model Report* (TDR-NBS-HS-000001 REV 00 ICN 01)
  - *Analysis and Model Report Water-Level Data Analysis for the Saturated Zone Site-Scale Flow and Transport Model* (ANL-NBS-HS-000034 REV 00)
- **Nye County phase I data improved understanding of the hydrologic system south of Yucca Mountain**
- **The new potentiometric map addresses previous data needs. The map is sufficiently detailed to support performance assessment. No additional work is needed**

Update Water-level Analysis Model Report

- **Basis for Resolution**
  - DOE plans to update the Water Level Analysis Analysis Model Report to incorporate new Nye County data
- **Reference**
  - Update to Water Level Analysis Model Report is scheduled for completion for Site Recommendation and License Application
- **This information need is being fully addressed by revision of the Analysis and Model Report. No additional work is needed**

Conclusions

- **This criterion should be closed**
  - DOE has provided maps of approximate potentiometric contours of the regional uppermost aquifer for an area that includes wells J-11 on the east, VH-1, VH-2, and the GEXA Well on the west, UE-29a#2 to the north, and domestic and irrigation wells in the Amargosa Valley
  - Regional infiltration, evapotranspiration, spring discharges, and pumping estimates are included in the regional model and being refined for the updated regional model

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Subissue 5, Acceptance Criterion 6: Mathematical Groundwater Models

Presented to:
DOE/NRC Technical Exchange on the Key Technical Issue Subissues Related to Saturated Zone Flow

Presented by:
Al Aziz Eddebbarh, Ph.D
George Zyvoloski
Civilian Radioactive Waste Management System Management and Operating Contractor
Claudia C. Faunt
United States Geological Survey

October 31 - November 2, 2000
Albuquerque, NM

YUCCA MOUNTAIN PROJECT

Outline

- **Presentation Objectives**
- **Current Acceptance Criterion 6 Status**
- **For Acceptance Criterion 6, presentation will:**
  - Summarize technical basis for item resolution
  - Identify basis documents (References)
  - Summarize technical adequacy of basis
- **Conclusions**

Note: Additional summary information is provided in the delta analysis

Presentation Objectives

- Provide the basis for resolving Acceptance Criterion 6 associated with delineation of flow paths
- Subissue 5, Acceptance Criterion 6: Department of Energy (DOE) has used mathematical groundwater model(s) that incorporate site-specific climatic and subsurface information. "The models were reasonably calibrated and reasonably represent the physical system. Fitted aquifer parameters compare reasonably well with observed site data. Implicitly- or explicitly-simulated fracturing and faulting are consistent with the data in the 3-D geologic model. Abstractions are based on initial and boundary conditions consistent with site-scale modeling and the regional models of the Death Valley groundwater flow system. Abstractions of the groundwater models for use in PA simulations should use appropriate spatial- and temporal-averaging techniques."

Current Acceptance Criterion 6 Status

- Unsaturated and Saturated Flow under Isothermal Conditions Issue Resolution Status Report, Rev. 02 indicates that status is open pending review of future DOE performance assessments
- April 2000 Key Technical Issue Status Technical Exchange identified the Saturated Zone Flow and Dilution Subissue as open; did not specifically provide status of Acceptance Criterion 6

Acceptance Criterion 6

- **Action or Information Needs**
  - Discussion of hydrogeolgoic framework cross sections
  - Discussion of numerical flow model
- **Basis for closure**
  - DOE has used mathematical groundwater model(s)
    - That incorporate site-specific climatic and subsurface information
    - That are reasonably calibrated and reasonably represent the physical system
    - Whose fitted aquifer parameters compare reasonably well with observed site data
    - Whose implicitly or explicitly simulated fracturing and faulting are consistent with the data in the 3D geologic model
    - Whose abstractions are based on initial and boundary conditions consistent with site-scale modeling and the regional model of the Death Valley groundwater flow system

Acceptance Criterion 6
(Continued)

- **Basis for closure** **(Continued)**
  - DOE has used mathematical groundwater model(s) whose abstractions of the groundwater models for use in Performance Assessment simulations use appropriate spatial- and temporal-averaging techniques
- **This acceptance criterion has been fully addressed**
  - DOE has used mathematical groundwater models that incorporate all aspects of the acceptance criterion and are appropriate for the representation of the Yucca Mountain groundwater system

Discussion of Hydrogeologic Framework Model

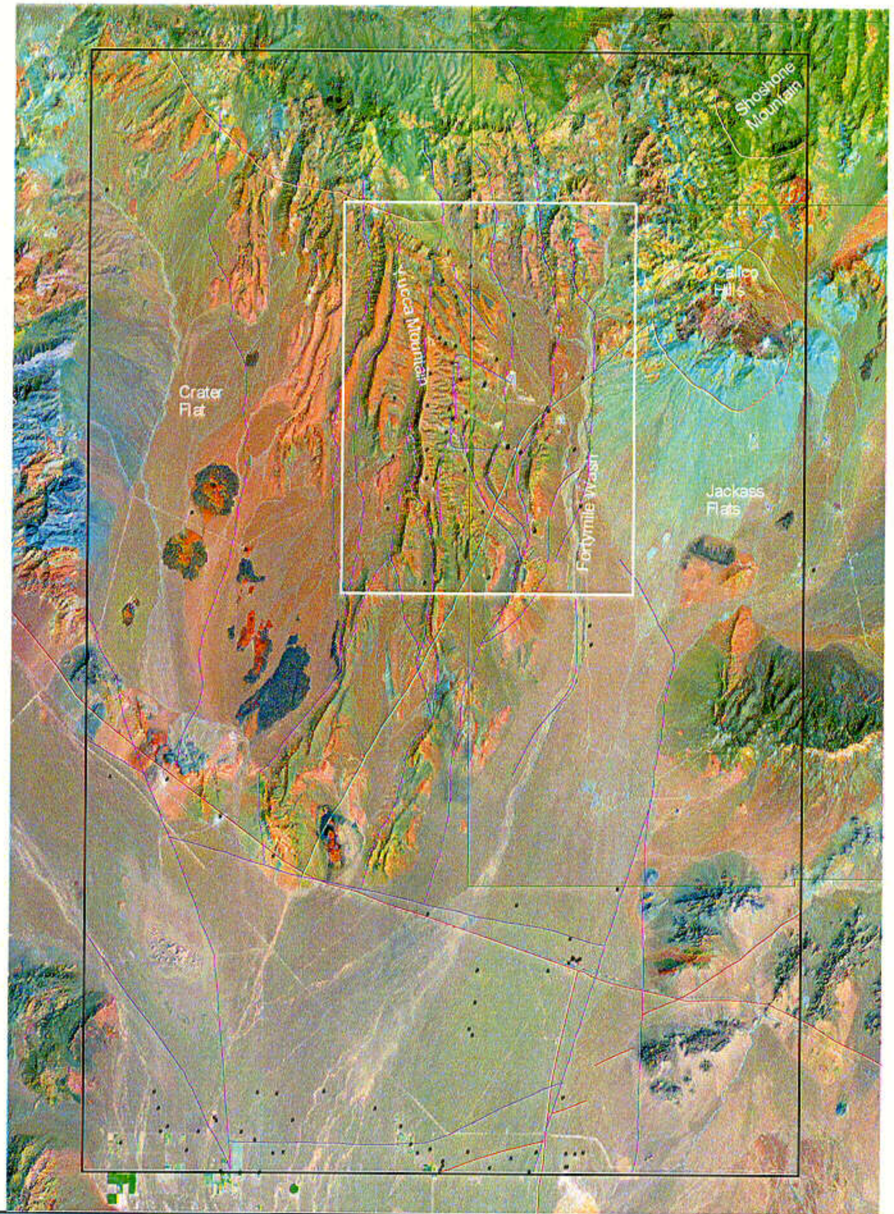
- **Basis for Resolution**
  - DOE has developed a comprehensive hydrogeologic framework model that fully addresses the acceptance criterion

Purpose of the Hydrogeologic Framework Model

- **Provides the fundamental geometric framework for development of a site-scale three-dimensional groundwater flow and transport model DOE plans to use to evaluate potential radionuclide transport through the Saturated Zone from beneath the potential repository to down-gradient compliance points**

Overview of Hydrogeologic Framework Model

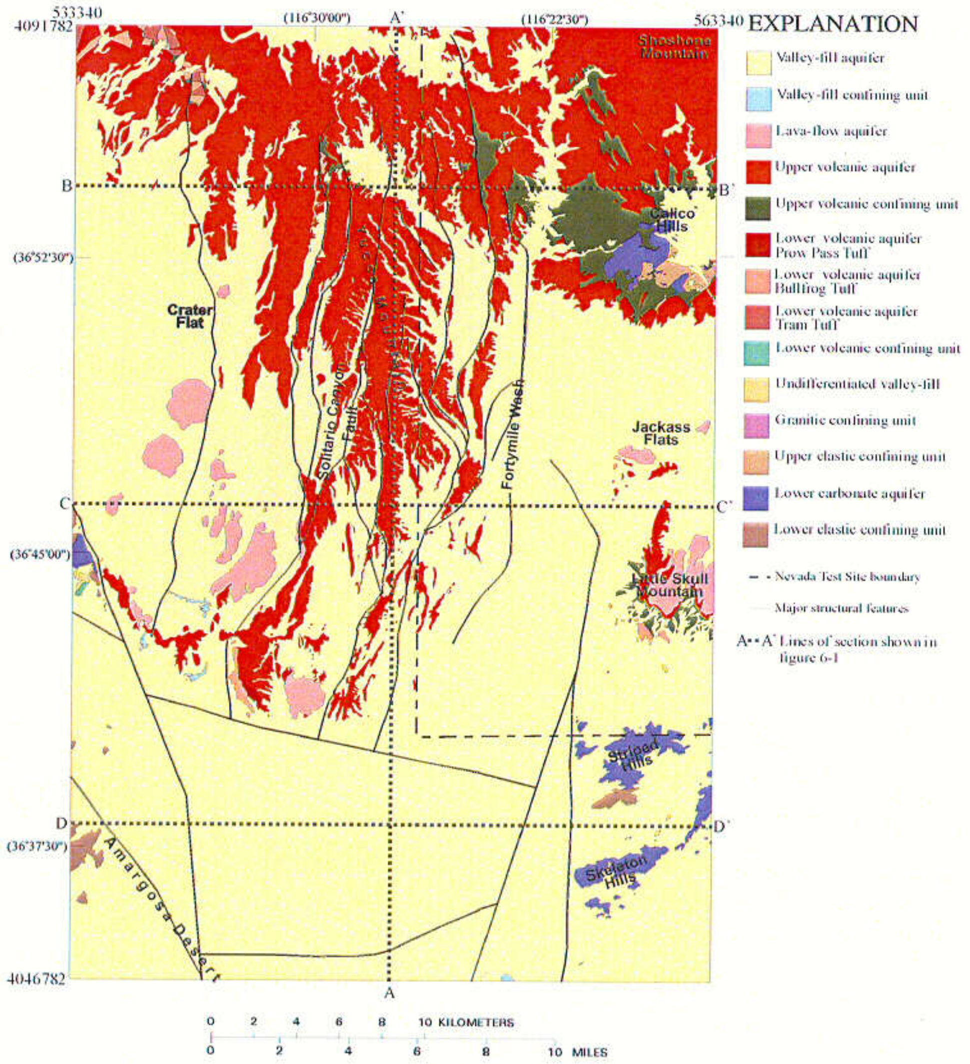
- **Hydrogeologic Units**
- **Data Sources and Feeds**
- **Hydrologic features**
  - **Faults**
  - **Heterogeneity**



Reference: ANL-NBS-HS-000033

Overview of Hydrogeologic Framework Model

- **Domain:**
  - Coincident with regional model
  - 125 m spacing (for transport)
  - 360 rows by 240 columns
- **Area of 1350 sq. km.**
- **Areal extent (UTM m):**
  - 533340-563340 (west to east)
  - 4046782-4091782 (south to north)
- **Vertical extent (m):**
  - Top: Land surface
  - Base: 2750 m below smoothed water table



Reference: ANL-NBS-HS-000033

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Hydrogeologic Units

Hydrogeologic Unit	Major Unit - General Description	Comments
valley-fill aquifer (alluvium)	Alluvial fan, fluvial, fanglomerate, lakebed, eolian and mudflow deposits	uncertain location of contact with volcanic units
valley-fill confining unit (playas)	Playa deposits and fine-grained alluvium	
limestone aquifer (amarls)	Lacustrine limestones, calcareous spring deposits	
lava-flow aquifer (basalts)	Basalt flows, dikes and cinder cones, and latite dikes	
upper volcanic aquifer (uva)	Paintbrush Tuff - Variably welded ash-flow tuffs and rhyolite lavas (non-welded tuffs)	
upper volcanic confining unit (uvcu)	Tuffaceous Beds of Calico Hills - Rhyolite lavas, volcanic breccias, non-welded to welded tuffs, commonly argillaceous or zeolitic	
lower volcanic aquifer – prow pass (tcp)	Crater Flat Tuff (Prow Pass) - Variably welded ash-flow tuffs and rhyolite lavas	
lower volcanic aquifer – bullfrog (tcb)	Crater Flat Tuff (Bullfrog) - Variably welded ash-flow tuffs and rhyolite lavas	
lower volcanic aquifer – tram (tct)	Crater Flat Tuff (Tram) - Variably welded ash-flow tuffs and rhyolite lavas	
lower volcanic confining unit (mvcu)	Lithic Ridge Tuff - Non-welded tuff, commonly zeolitized	
older volcanic aquifer (lva)	Tub Spring Tuff - Variably welded ash-flow tuffs, rhyolite lavas	
older volcanic confining unit (lvcu)	Older Tuffs - Non-welded tuff, commonly zeolitized	
undifferentiated valley fill (leaky)	Tuffaceous sandstone, tuff breccia, siltstone, claystone, conglomerate, lacustrine limestone, commonly argillaceous or calcareous. Sedimentary breccia.	lumped unit
upper clastic confining unit – thrust (uccu,uccut2)	Eleana Formation - Siliceous siltstone, sandstone, quartzite, conglomerate, limestone	
lower carbonate aquifer (lca, lcat1, lcat2)	Dolomite and limestone, locally cherty and silty	
lower clastic confining unit (lccu, lccut1)	Quartzite, siltstone, shale, dolomite	
granitic confining unit (granites)	Granodiorite and quartz monzonite in stocks, dikes and sills	
base	n/a	bottom of regional model

Hydrogeologic Unit Hierarchy

- **Valley-Fill**
  - Aquifer
    - Valley-fill aquifer
    - Limestone aquifer
  - Confining units
    - Valley-fill confining unit
  - Variable
    - Undifferentiated valley-fill

Hydrogeologic Unit Hierarchy
(Continued)

- **Volcanics**
  - Aquifer
    - Upper Volcanic Aquifer
    - Lower Volcanic Aquifer
      - » Prow Pass
      - » Bullfrog
      - » Tram
    - Older Volcanic Aquifer
    - Lava-flow Aquifer
  - Confining Units
    - Upper volcanic confining unit
    - Lower volcanic confining unit
    - Older volcanic confining unit

Hydrogeologic Unit Hierarchy
(Continued)

- **Paleozoics**
  - Aquifer
    - Lower Carbonate Aquifer
    - Lower Carbonate Aquifer – thrusts
  - Confining Units
    - Clastic Confining Unit
      - » Upper clastic confining unit
      - » Upper clastic confining unit – thrusts
      - » Lower clastic confining unit
      - » Lower clastic confining unit – thrusts
    - Crystalline confining unit
      - » Granitic confining unit (granites)

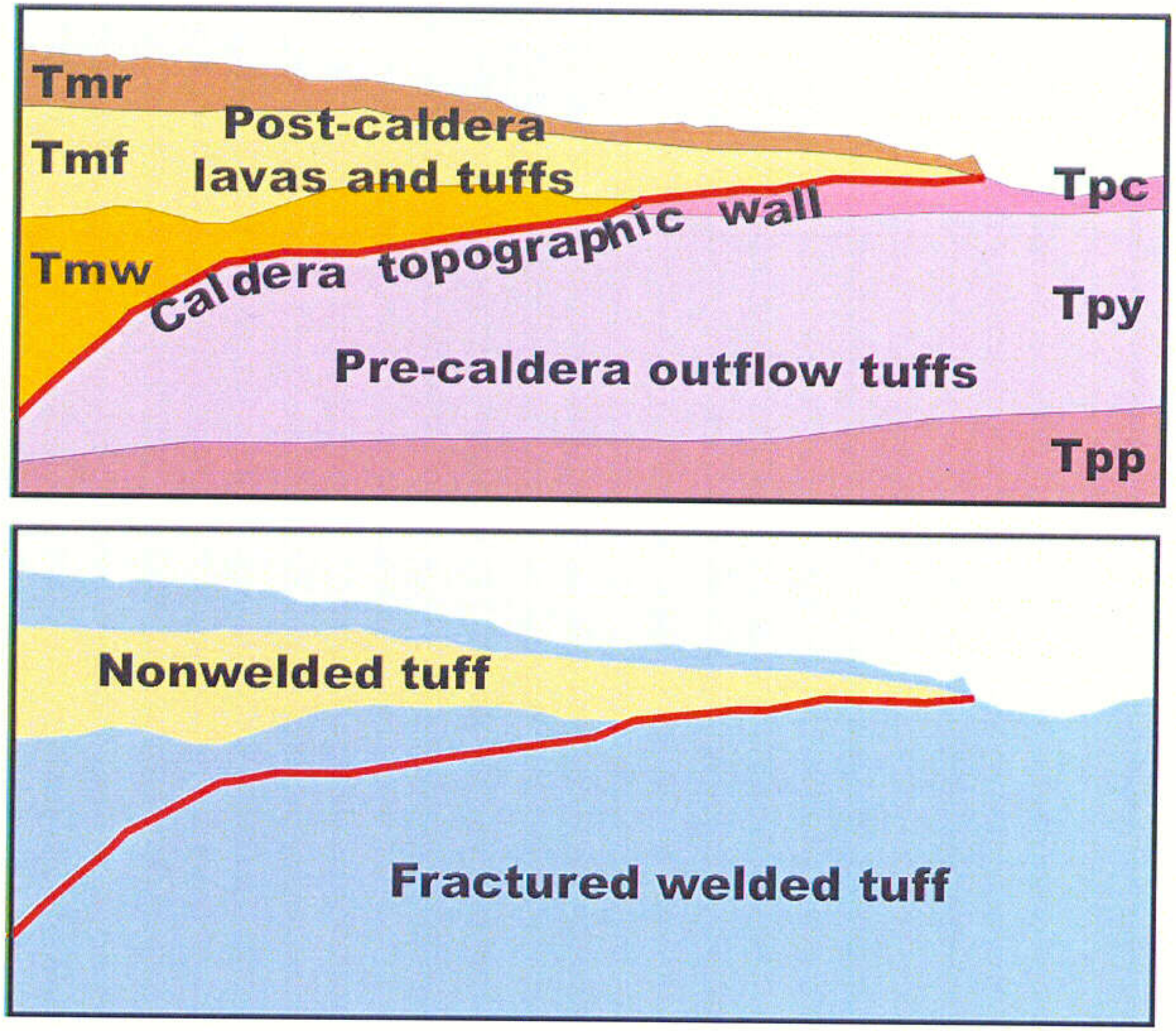
Geologic vs. hydrogeologic significance

Topographic margin, Claim Canyon caldera

Geologic vs. hydrogeologic significance

Geologic section

Hydrogeologic section



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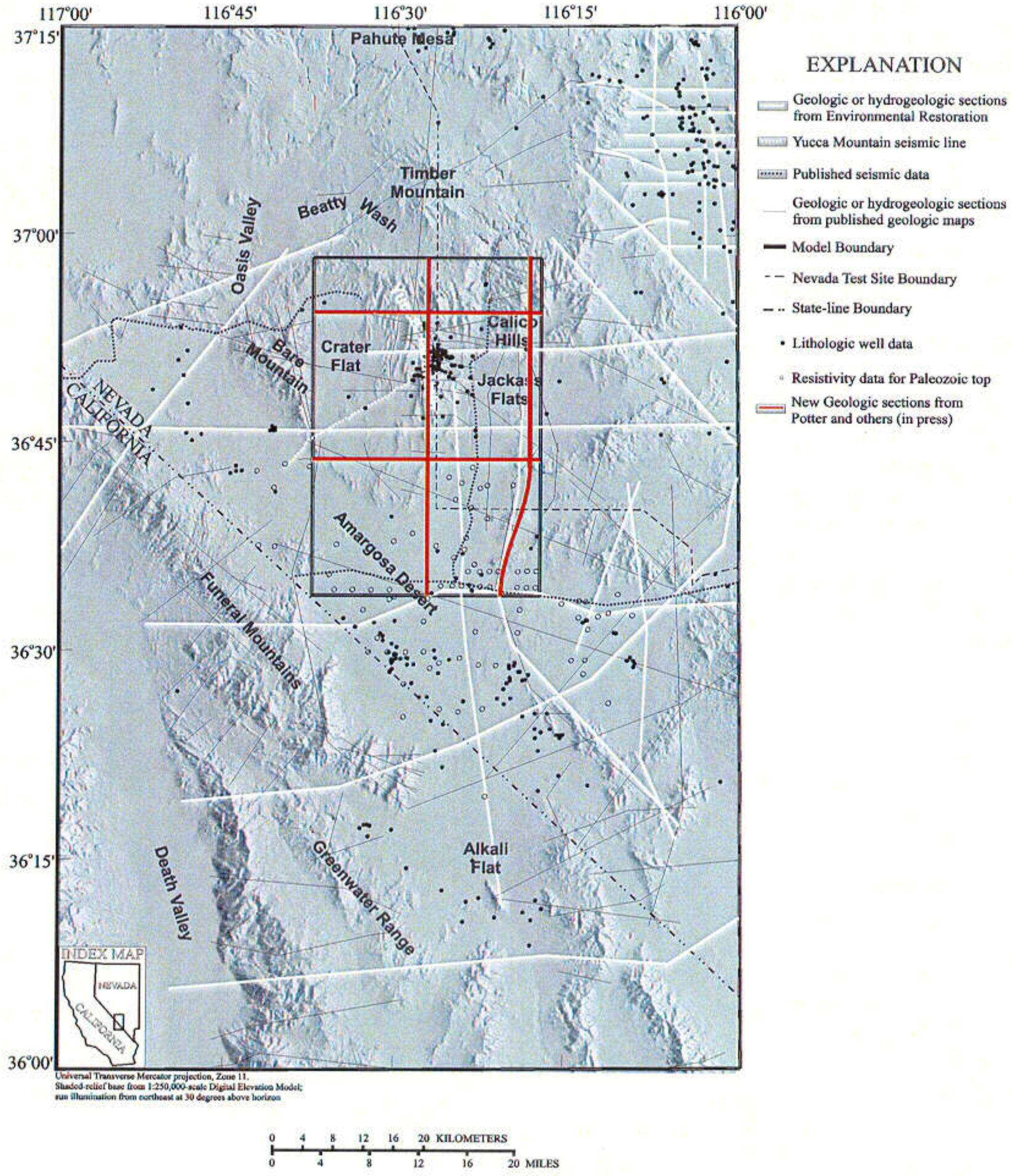
Data Sources

- Geologic Framework Model
- Geologic Map
- Geologic Cross Sections
- Stratigraphic logs
- Geophysical data
- Environmental Restoration Program Hydrogeologic Framework Model



Geologic, geophysical, and well-data locations used in the construction of the hydrogeologic framework model .

Ref: MDL-NBS-HS-000011

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Data Sources

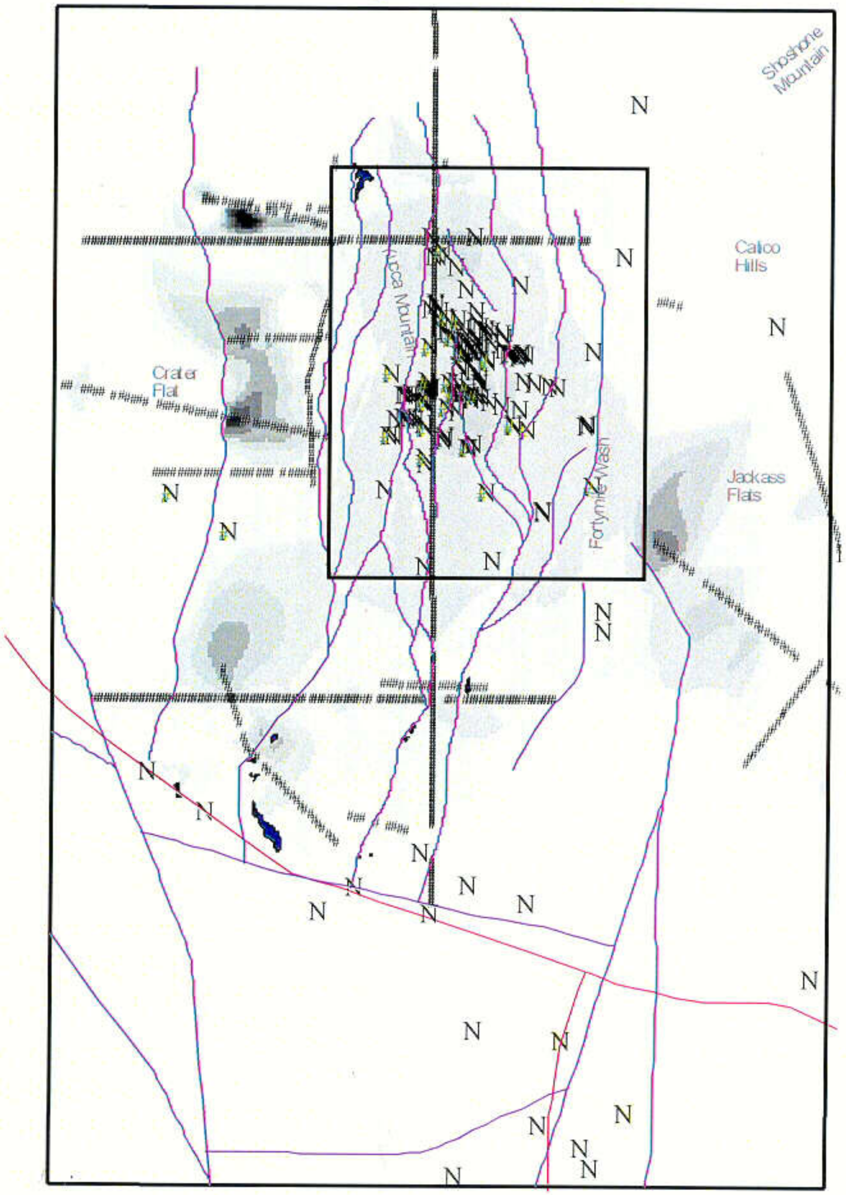
Hydrogeologic Unit	Data Sources						
	Geologic Section[1]	Lithologic Log[2]	Geologic Map[3]	GFM 3.1[4]	ERP Model Geologic Section[5]	ERP Model Grid and Geophysical Data[6]	Interpreted subcrop based on top of basement[6]
Valley-fill Aquifer			X				
Valley-fill Confining Unit		X	X				
Limestone Aquifer		X					
Lava-flow Aquifer	X	X	X				
Upper Volcanic Aquifer	X	X	X				
Upper Volcanic Confining Unit	X	X	X	X			
Lower Volcanic Aquifer –Prow Pass Tuff	X	X	X	X			
Lower Volcanic Aquifer – Bullfrog Tuff	X	X	X	X			
Lower Volcanic Aquifer – Tram Tuff	X	X	X	X			
Lower Volcanic Confining Unit	X	X	X				
Older Volcanic Aquifer	X	X					
Older Volcanic Confining Unit	X	X					
Undifferentiated Valley-Fill	X	X	X				
Upper Clastic Confining Unit (thrust)	X	X	X		X		X
Lower Carbonate Aquifer (thrust)	X		X		X	X	X
Upper Clastic Confining Unit	X	X	X		X		X
Lower Carbonate Aquifer (thrust)	X		X		X	X	X
Lower Clastic Confining Unit (thrust)	X		X		X		X
Lower Carbonate Aquifer	X	X	X		X	X	X
Lower Clastic Confining Unit	X	X	X		X		X
Granitic Confining Unit	X	X	X				

Ref: MDL-NBS-HS-000011

Data Feeds Since Analysis Model Report

- **Nye County phase I wells**
  - NC-EWDP-01Dx
  - NC-EWDP-02D
  - NC-EWDP-03Dx
  - NC-EWDP-09Sx
- **SD-6 and WT-24**
- **No longer cut off by potentiometric surface**
- **If adequate funds are available:**
  - Nye County Phase II wells
  - Updates to any boreholes
  - New cross sections
  - New aeromagnetic information
  - Regional model consistency

Example: Lower Volcanic Aquifer–Prow Pass



Roads
Text Geographic Names
GFM 3.1 outline
Fault subset
Model Boundary
Well data
N Well locations
Cross Section data

Hydrogeologic Map Data

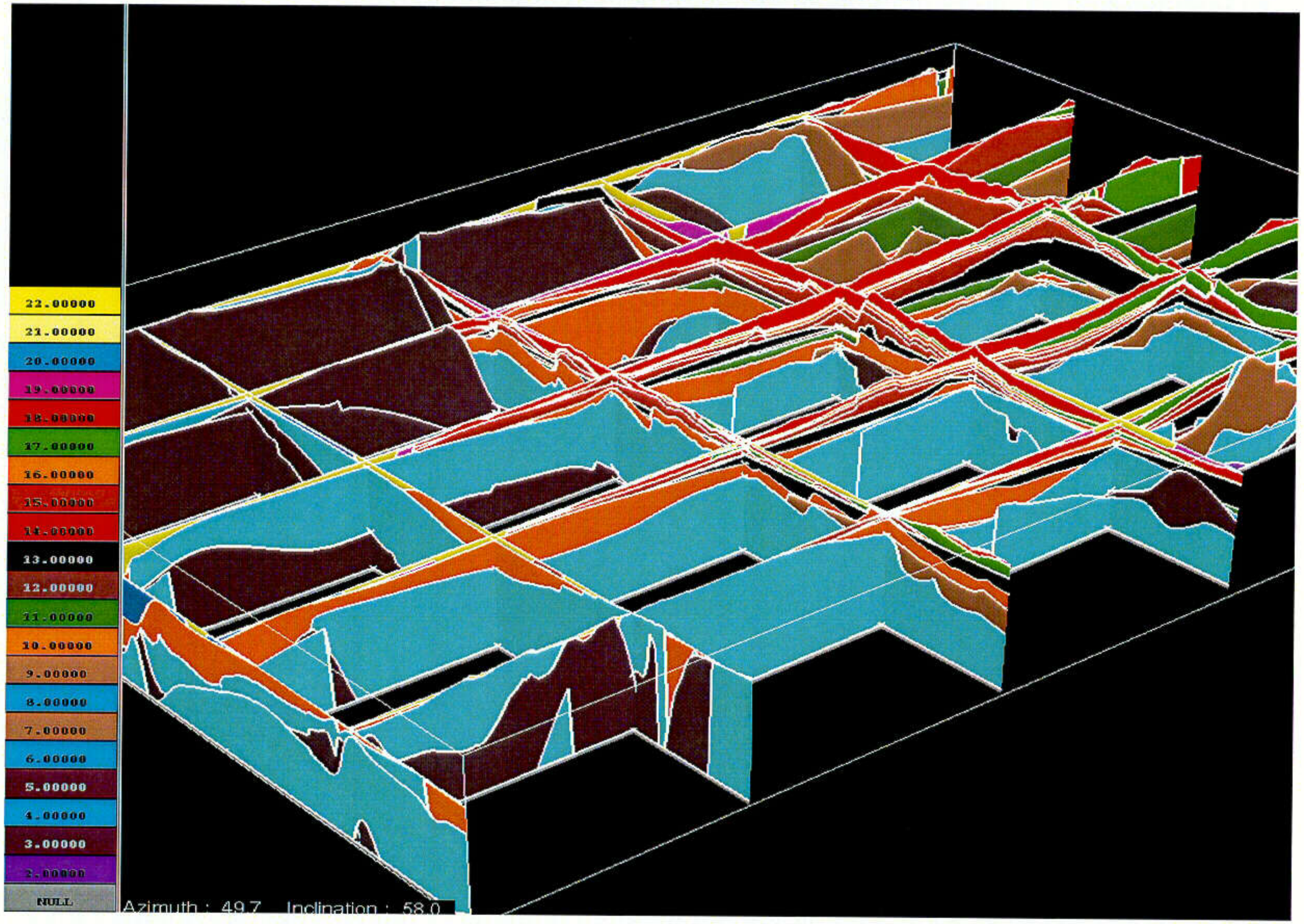
Lower volcanic aquifer - Prow Pass

Thickness (LVA - Prow)

- 0.1 - 74.667
- 74.667 - 149.333
- 149.333 - 224
- 224 - 298.667
- 298.667 - 373.333
- 373.333 - 448
- 448 - 522.667
- 522.667 - 597.333
- 597.333 - 672
- No Data

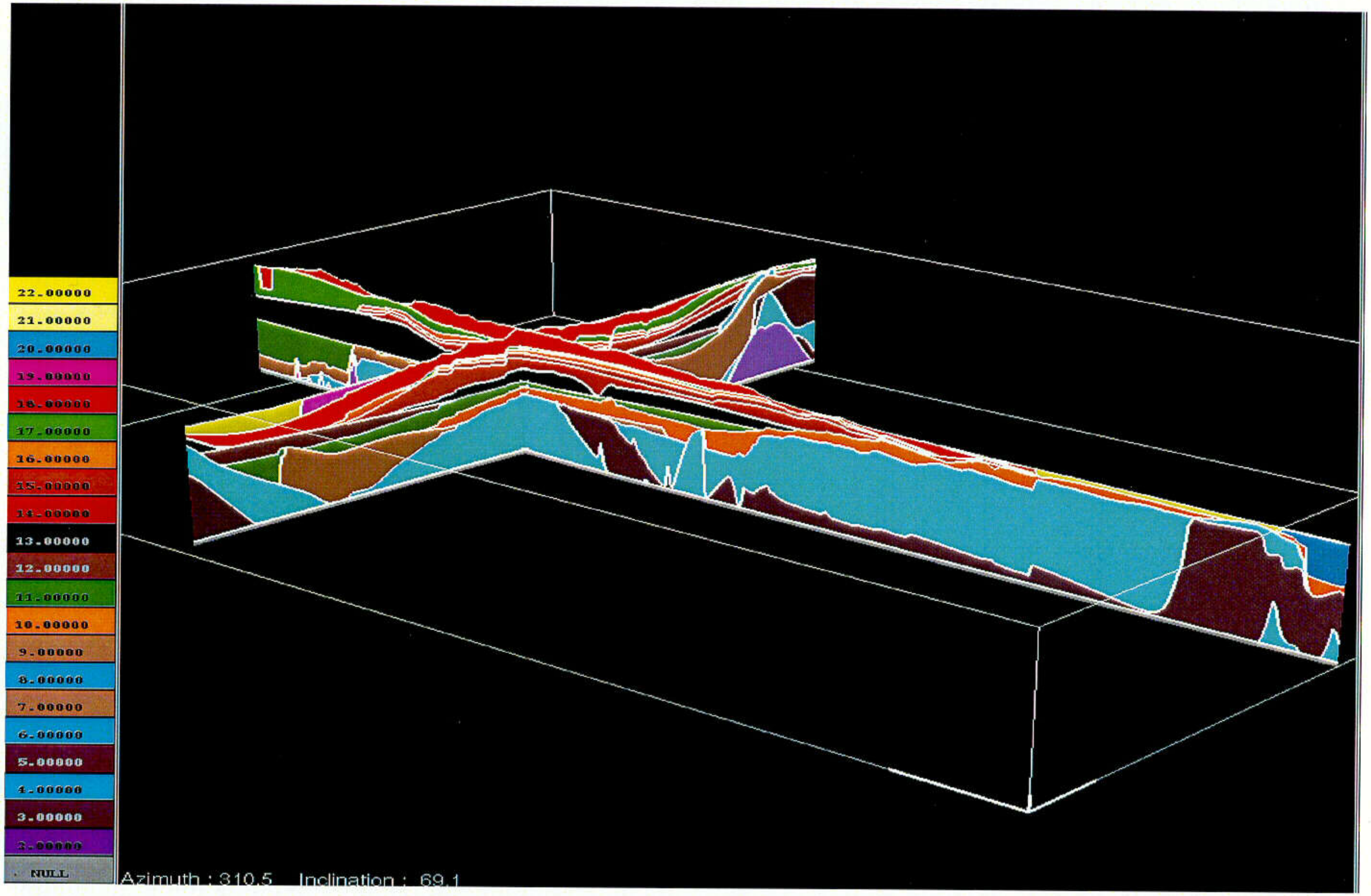
Ref: MDL-NBS-HS-000011

View Toward the Northwest of Hydrogeologic Framework Model



Ref: MDL-NBS-HS-000011

Cross Sections through Potential Repository



Ref: MDL-NBS-HS-000011

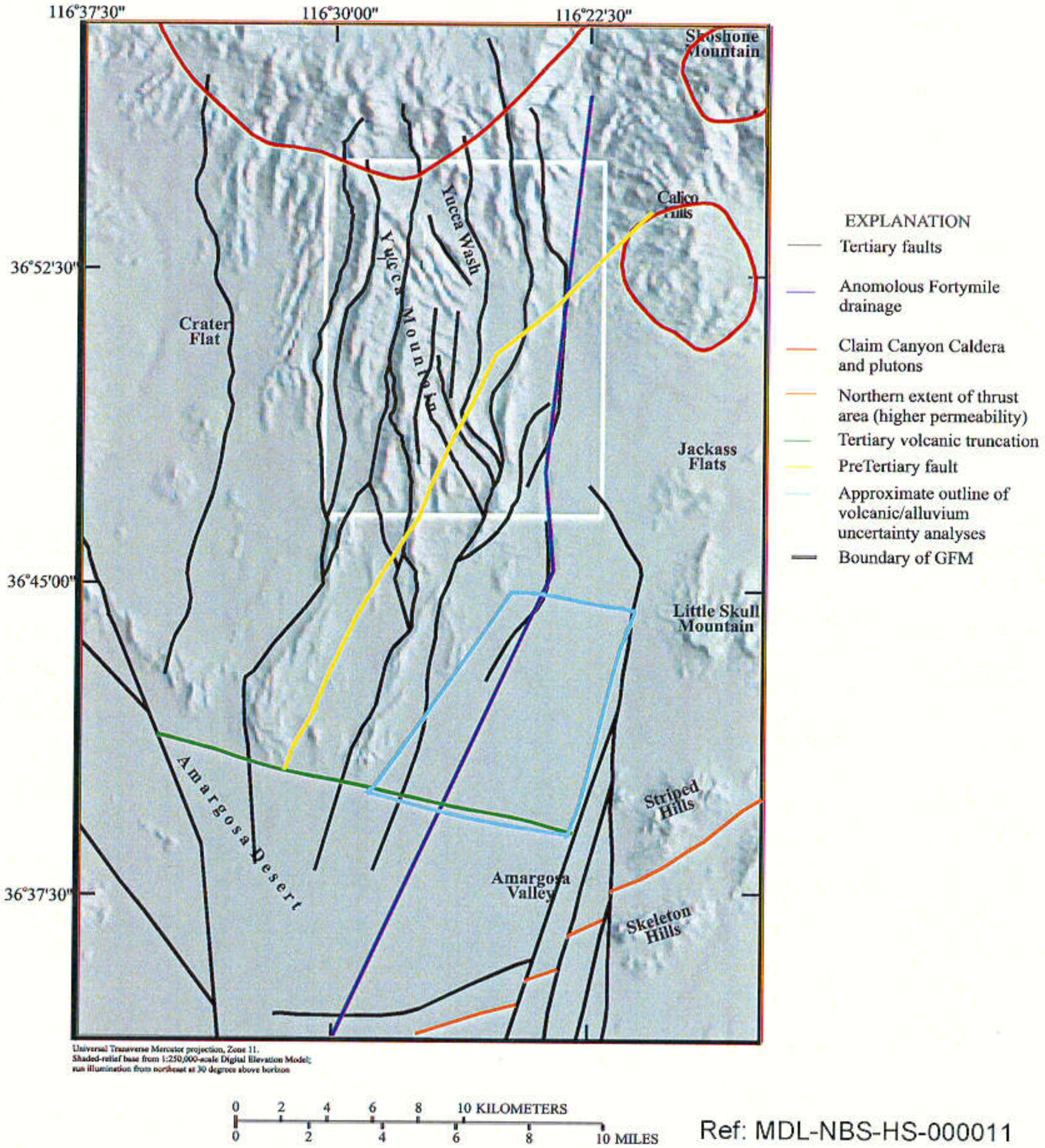
Hydrologic Features:

Faults

- conduits vs. barriers
- locations

Heterogeneity

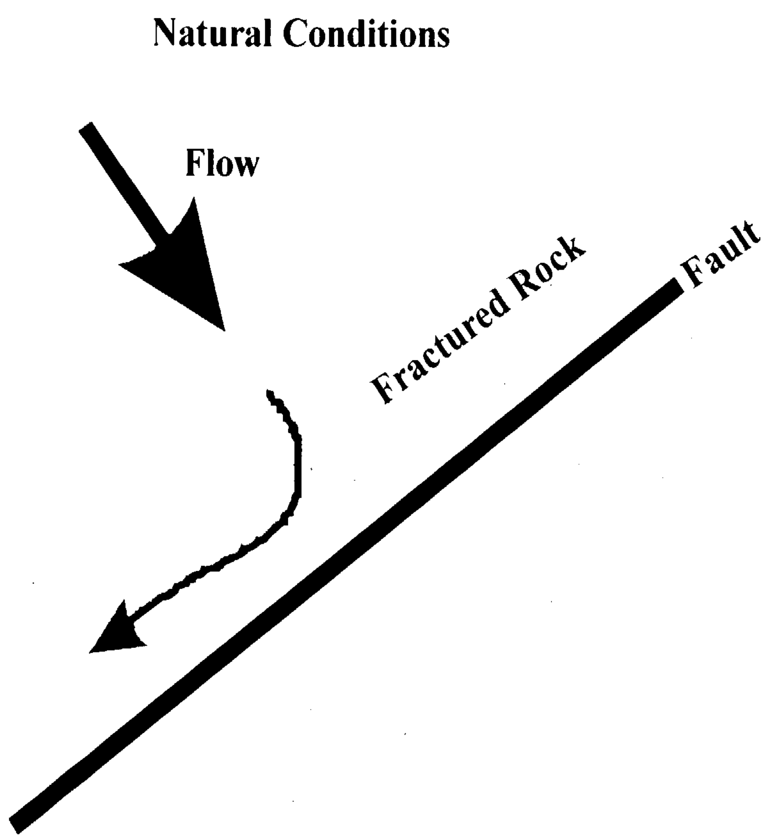
Preliminary map of major structures affecting groundwater flow

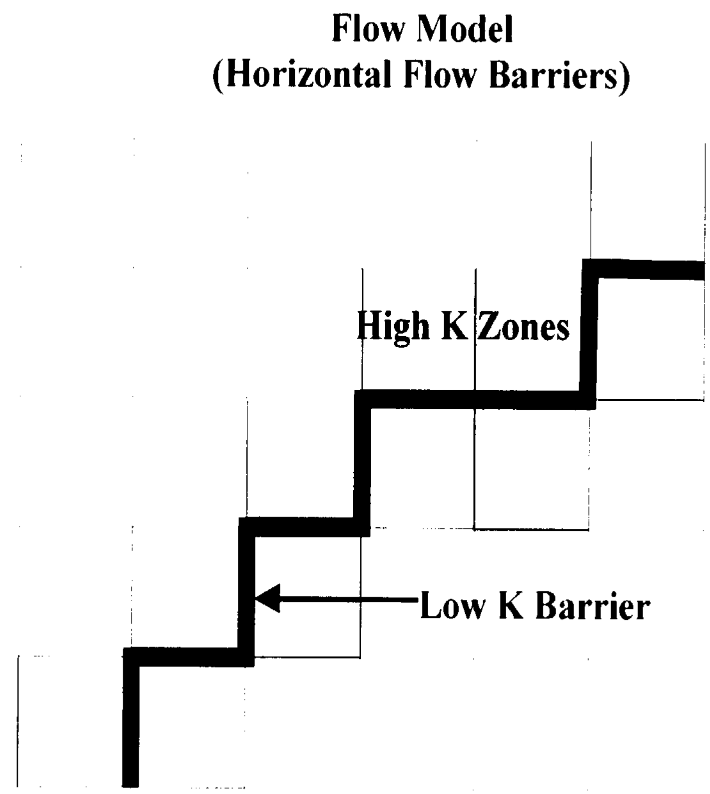


Ref: MDL-NBS-HS-000011

Hydrologic Feature Example

- Gouge could be barrier across zone
- Fracture zone could be conduit along zone



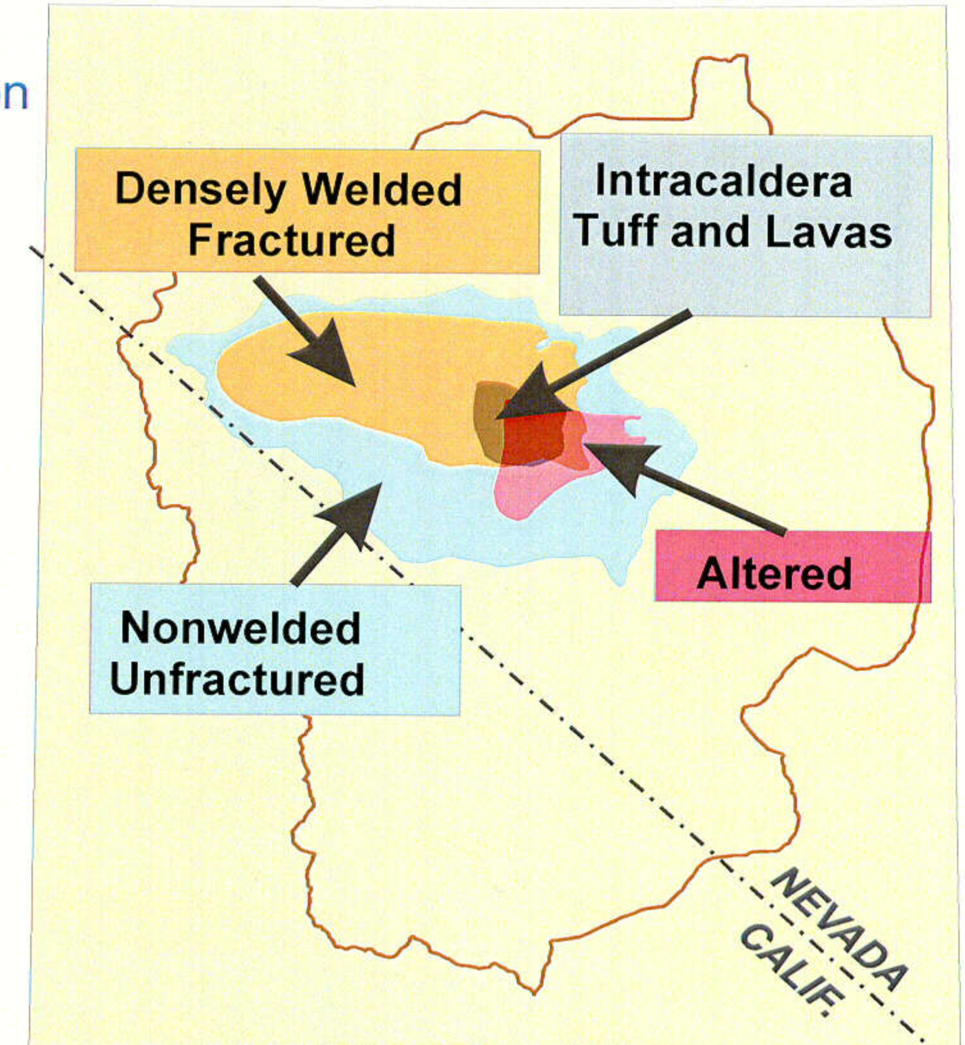


Ref: MDL-NBS-HS-000011

Heterogeneity

Feeds hydrogeologic parameterization in flow model

- Facies
- Alteration
- Structures
  - Fault characteristics
  - Fracture zones
  - Fault topology



FACIES MAP, TIMBER MOUNTAIN GROUP

Ref: MDL-NBS-HS-000011

Hydrogeologic Framework Model
(Continued)

- **Reference**
  - Analysis and Model Report *Hydrogeologic Framework Model for the Saturated-zone Site-scale Flow and Transport* (ANL-NBS-HS-000033)
- **DOE's Hydrogeologic Framework Model provides a basis for the mathematical model to incorporate site-specific subsurface information**
- **The model has been, and continues to be, updated to incorporate Nye County and new data, new geologic cross sections, and aeromagnetic data**
- **The regional-scale Saturated Zone flow model is being revised to incorporate a hydrogeologic framework model that includes a significantly higher-resolution stratigraphy and to reflect new data**

Discussion on Numerical Flow Model

- **Basis for Resolution**
  - DOE has developed a numerical flow model that adequately incorporates site data, is reasonably calibrated, and reasonably represents the physical system

Saturated Zone Site-Scale Flow and Transport Model

- **3-D model implemented with Finite Element Heat and Mass software code has domain 30 km x 45 km x 2750 m below water table**
- **Hydrogeologic framework model contains 19 units**
- **Orthogonal grid with 500 m horizontal spacing and variable resolution in the vertical direction**
- **Flow model calibration used automated inversion**
- **Model calibration and validation use data including:**
  - Water level measurements in wells
  - Simulated groundwater fluxes at lateral boundaries
  - Inferred flow paths from hydrochemical data
  - Upward hydraulic gradient from carbonate aquifer
  - Ranges of measured permeability
  - Average specific discharge in volcanic aquifer

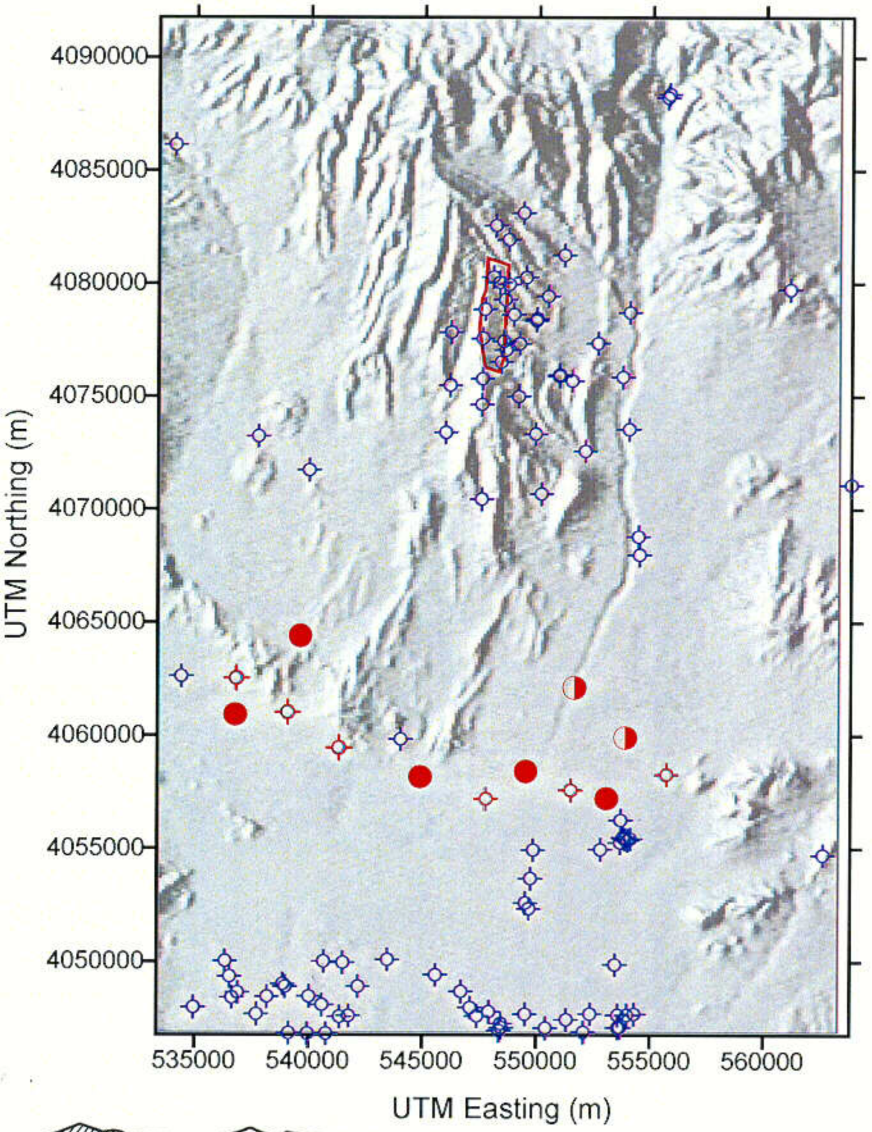
Numerical Model

- **Appropriate Conservation Laws**
  - Darcy law for momentum
  - Conservation of water mass
- **Optimal Grid**
  - Accurate representation of hydrogeology
  - Small numerical error
- **Verified**

Numerical Model (continued)

- **Boundary Conditions**
  - Specified Head (sides : regional potentiometric surface)
  - Specified Flux (top : recharge map)
- **Water budget**
  - Regional fluxes are calibration targets
  - Steady state model, no water storage
  - Numerical mass balance error is negligible (0.00002)

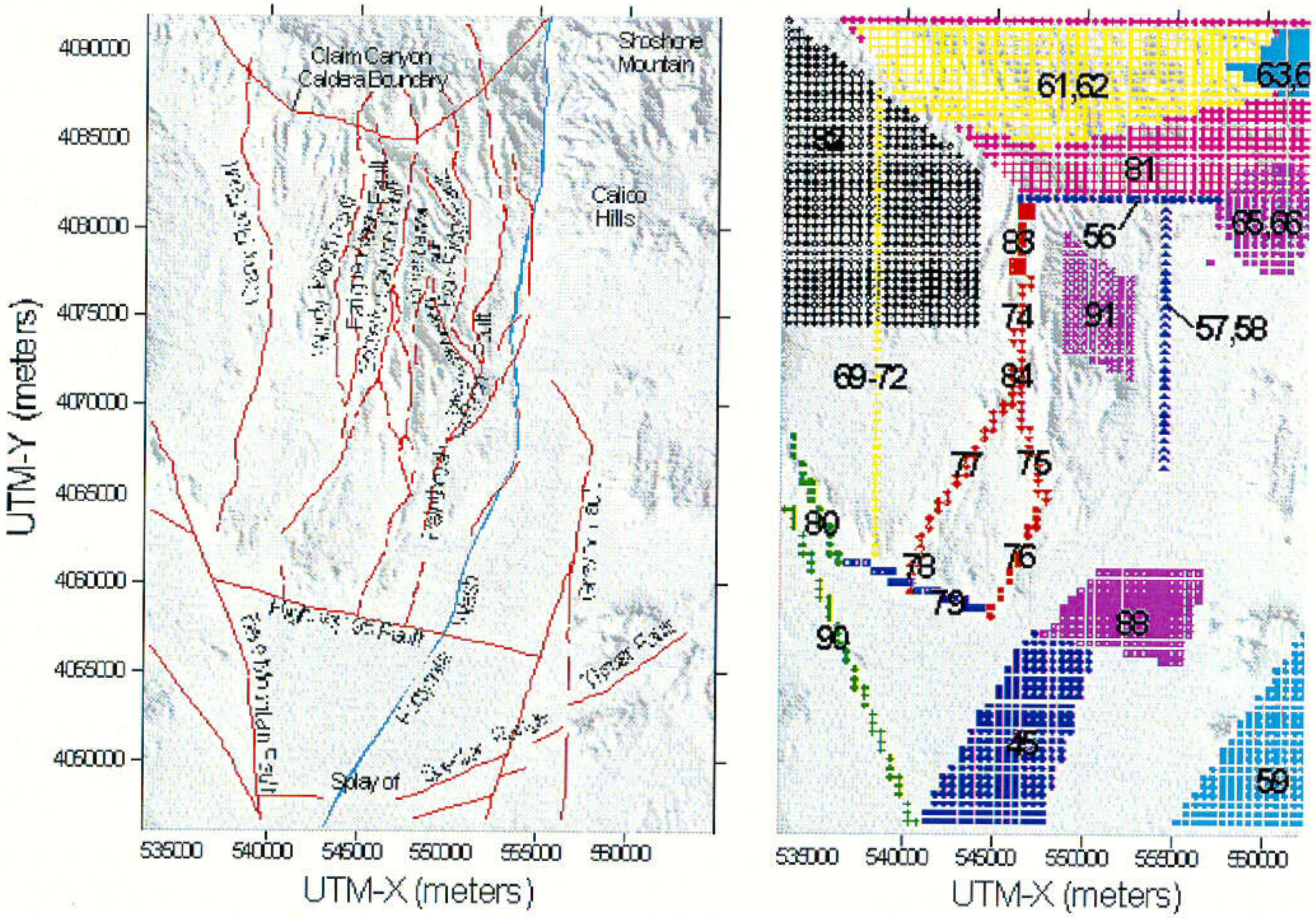
Saturated Zone Well Data Used in the Saturated Zone Site-Scale Flow and Transport Model



- **115 water-level measurements used in calibration of the Saturated Zone site-scale model for Total System Performance Assessment - Site Recommendation**
- **Water-level measurements at six locations from the Nye County drilling program were used**
- **Batch sorption tests of alluvium samples from three Nye County wells were performed for sorption of Np, Tc, and I**
- **Ongoing work of the Nye County drilling program includes wells at seven locations for FY00, including alluvial tracer complex**

Ref: MDL-NBS-HS-000011

Faults and Features

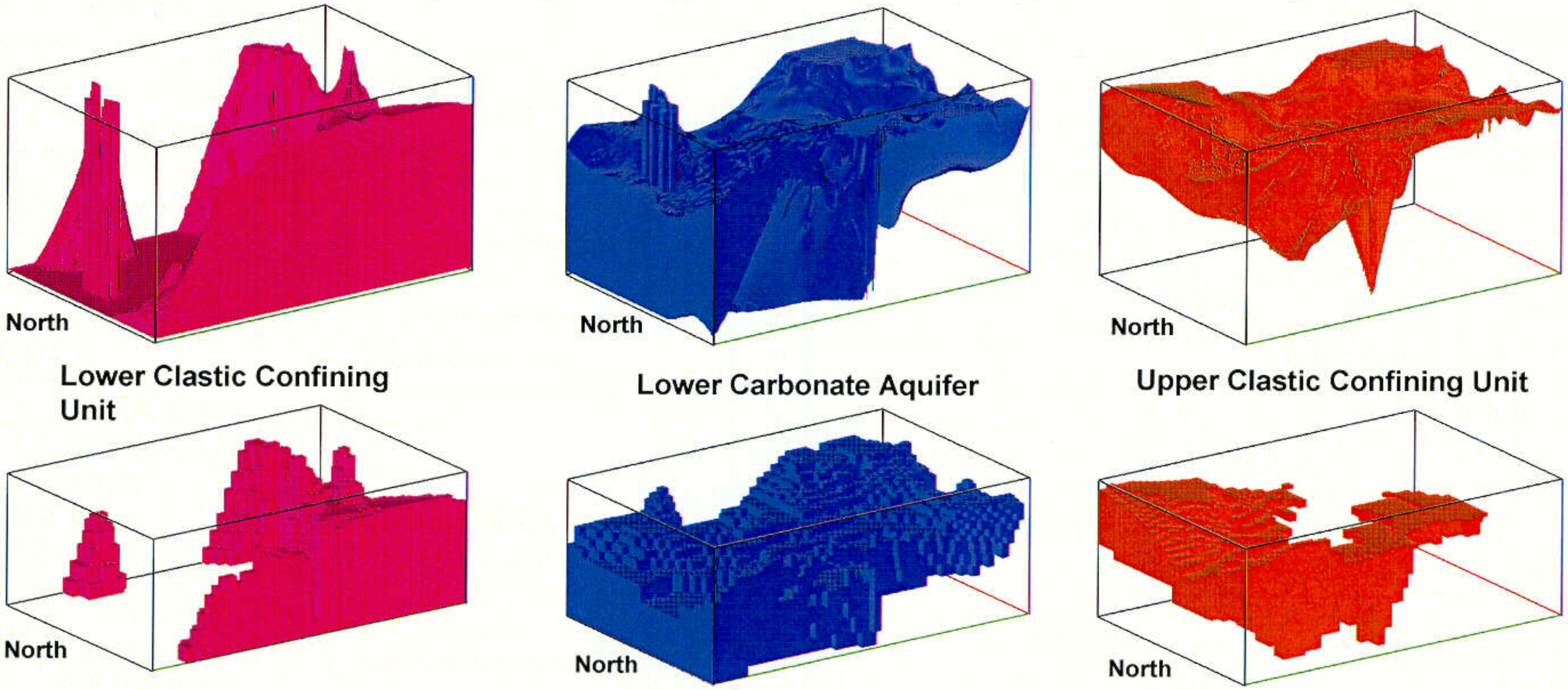


Ref: MDL-NBS-HS-000011

C47

Comparison of Hydrogeologic Framework to Computational Grid

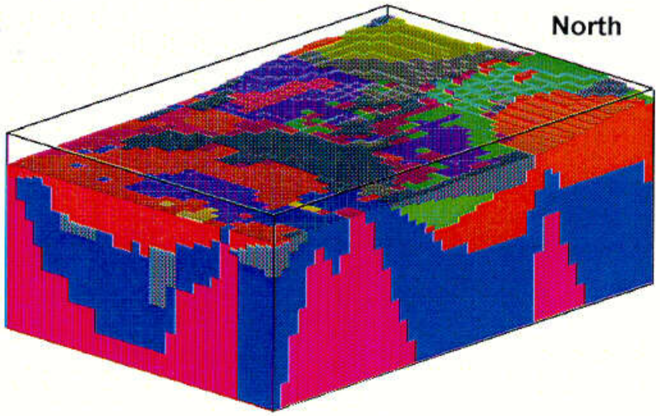
Hydrogeologic Framework (5 x vertical)



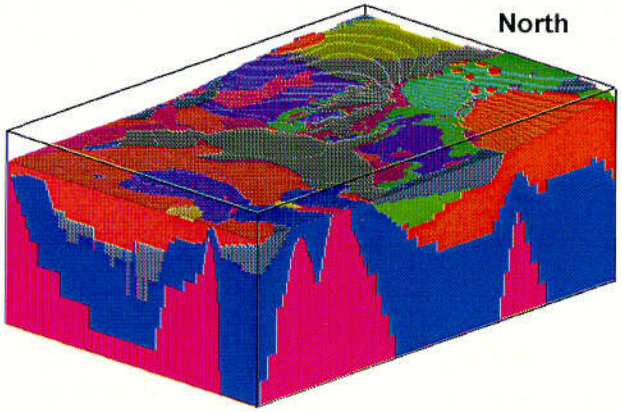
Computational Grid - 1000m (5 x vertical)

Reference: MDL-NBS-HS-000011

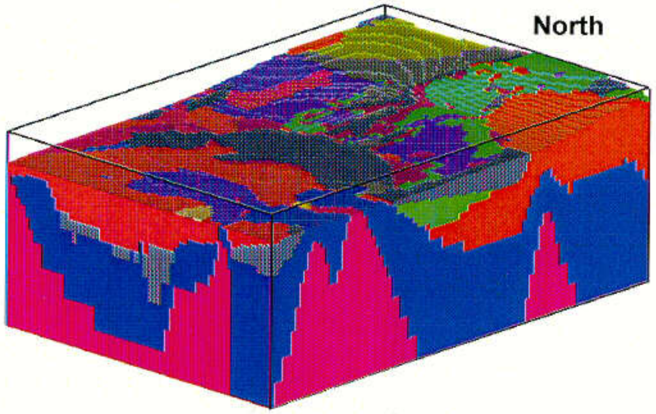
Horizontal and Vertical Discretization of Flow and Transport Grids



1000m xy
variable 400-10m z
37,548 nodes



250m xy
variable 400-10m z
575,724 nodes



500m xy
variable 400-10m z
146,016 nodes

Reference: MDL-NBS-HS-000011

Model Calibration (Parameter Estimation)

- **Finite Element Heat and Mass - Parameter Estimation used to minimize difference between observed and simulated data**
  - Quantitative measures of parameter uncertainty
  - Identify most sensitive parameters and observations
- **Manual adjustments also used**

Calibration Targets

- **Water levels and heads (115); special consideration given:**
  - Low gradient area (flow path region)
  - High head area
  - Well P-1
- **Fluxes from regional model (10)**

Calibration Parameters

- Permeabilities of hydrogeologic units
- Permeabilities of features
- Permeability multipliers of features

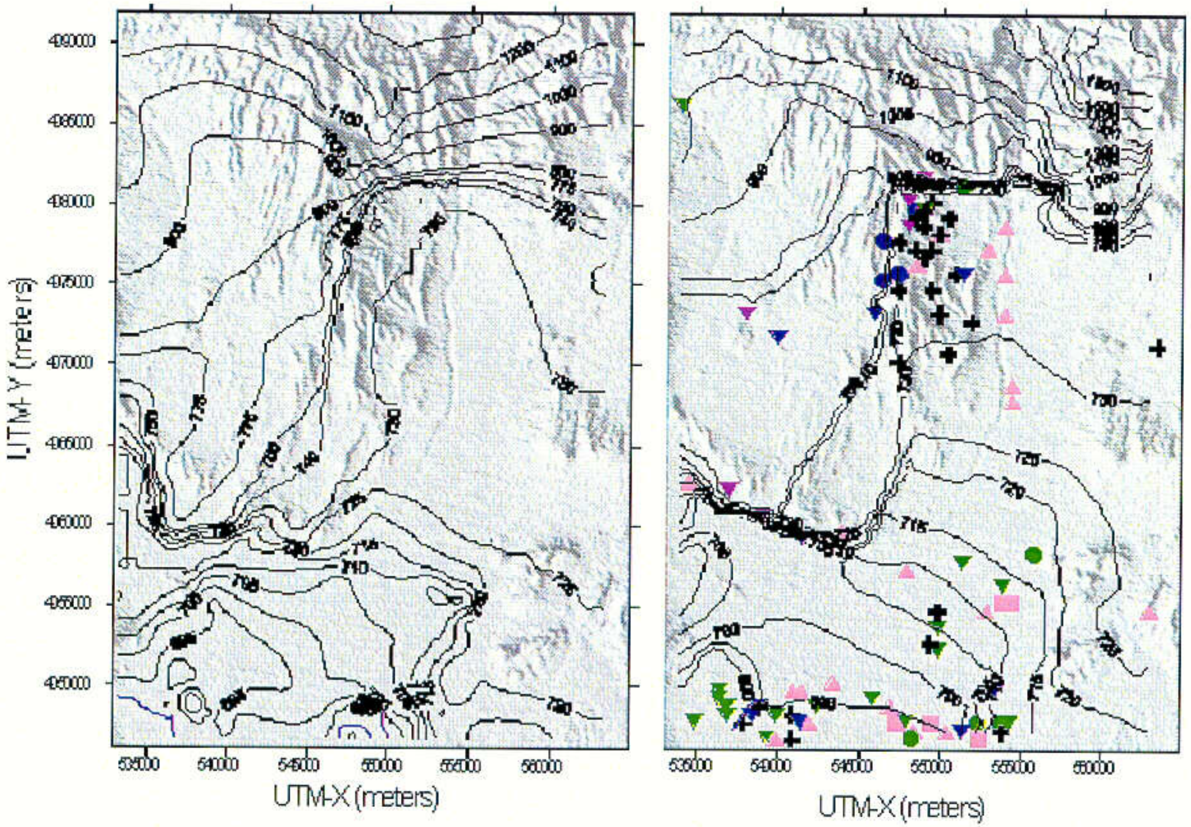
Calibration Strategy : Focus on Pathways

- Weight low gradient area
- Check specific discharge values
- Check fluid pathlines

Calibration Results

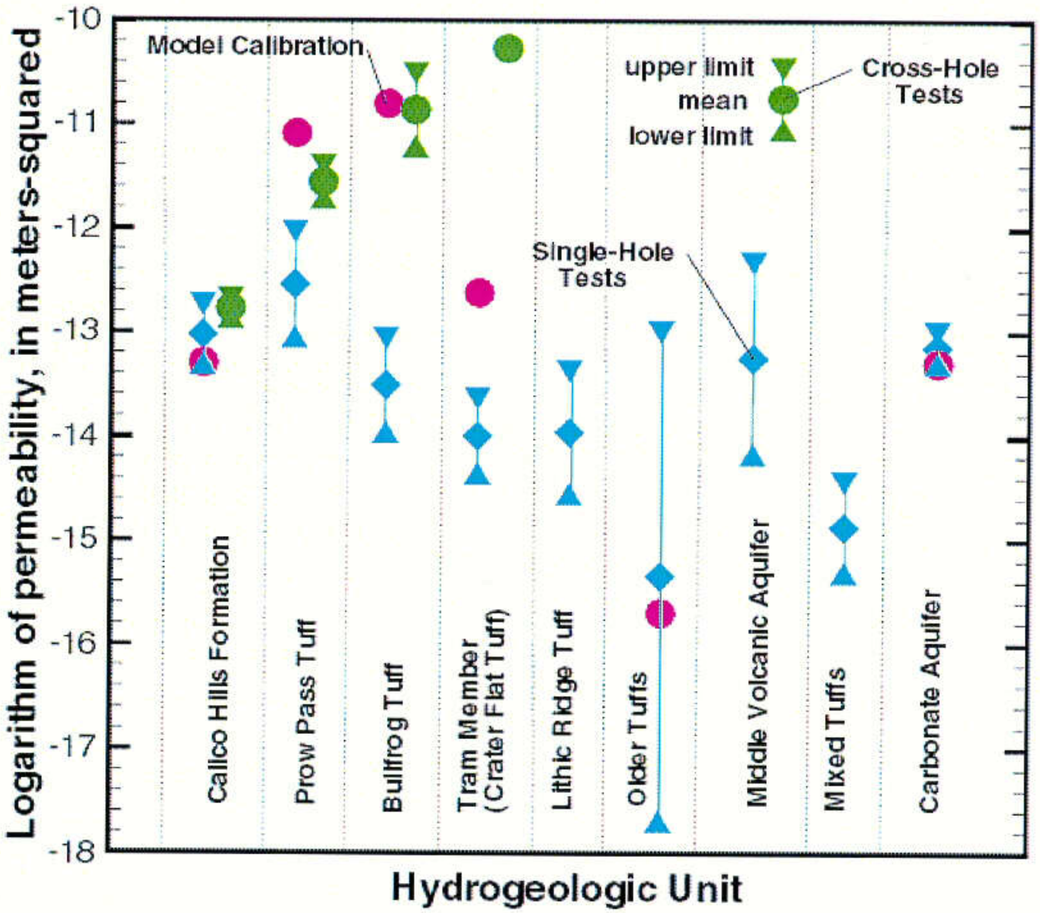
- Simulated vs. observed water levels
- Calibrated permeabilities vs. field data
- Simulated fluid pathlines vs. pathlines inferred from geochemistry
- Simulated fluxes vs. regional fluxes
- Simulated upward gradient vs. observed upward gradient

Water Levels : Data and Simulations



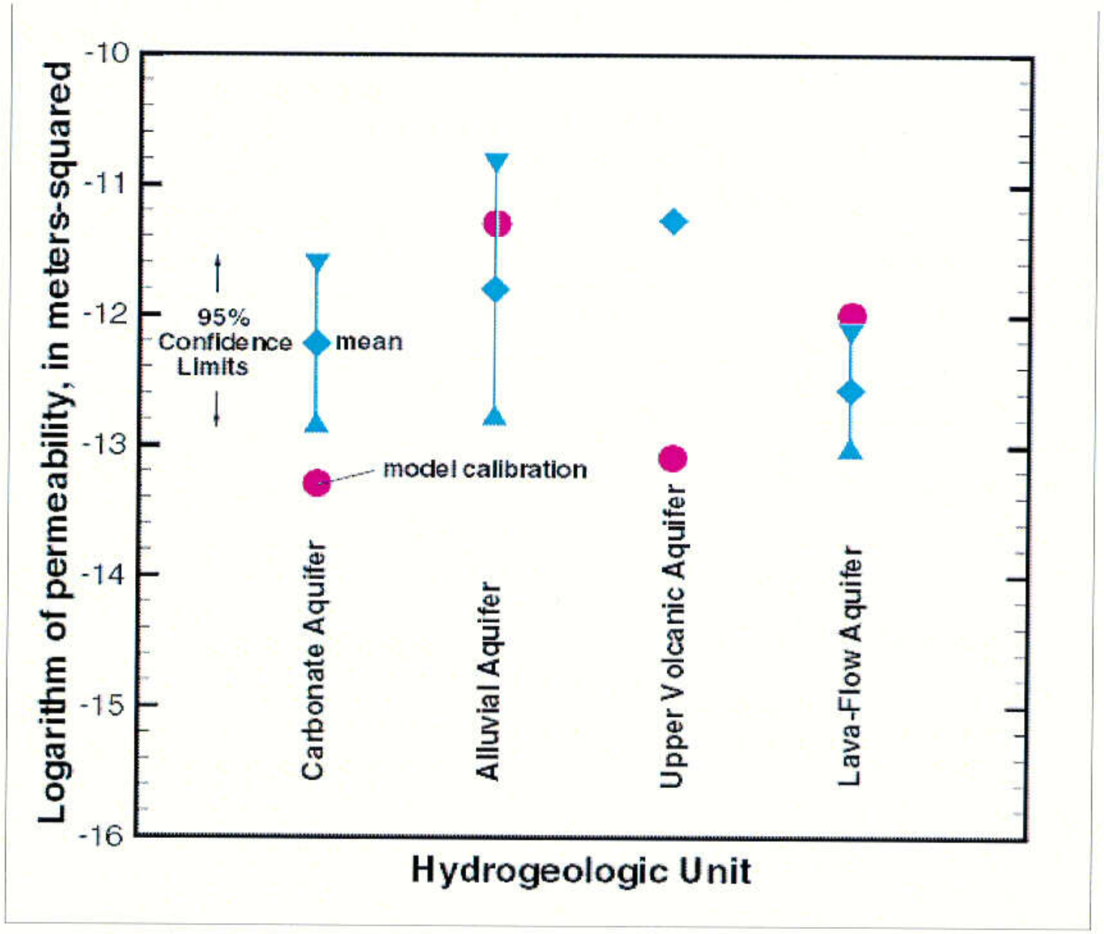
Ref: MDL-NBS-HS-000011

Comparison of Model Permeability with Field Data (Yucca Mountain)



Ref: MDL-NBS-HS-000011

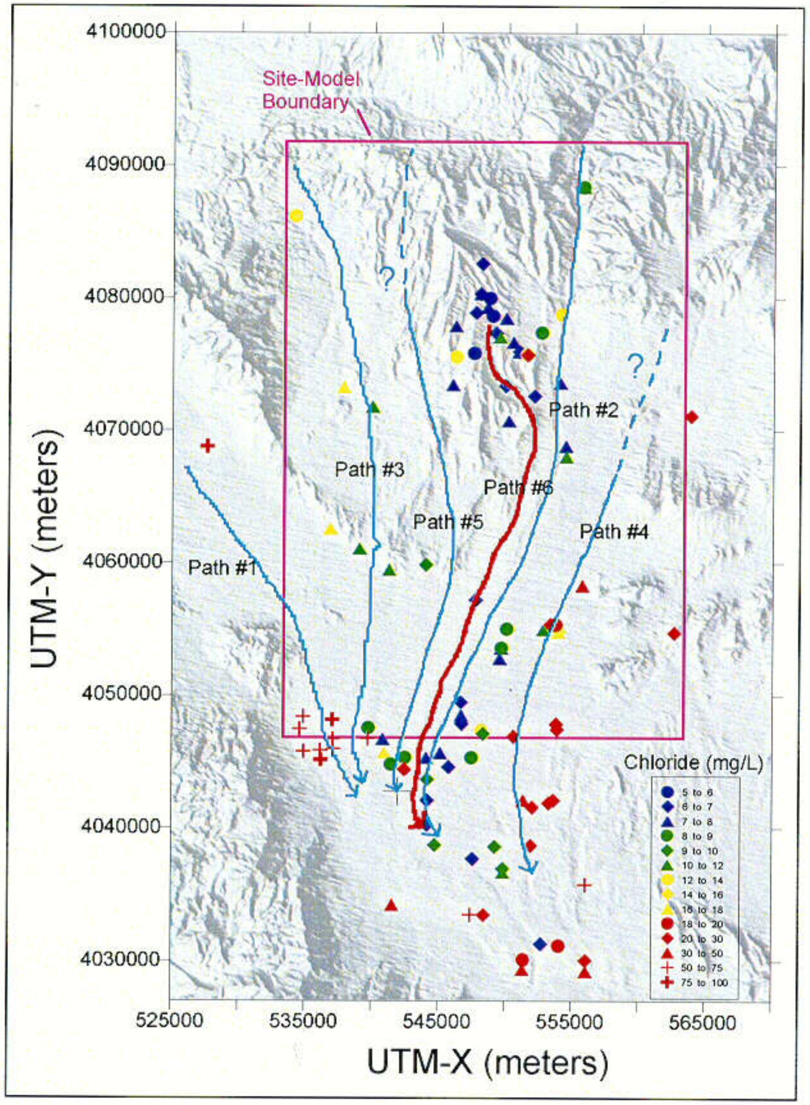
Comparison Of Model Permeability with Field Data (NTS)



Ref: MDL-NBS-HS-000011

C52

Use of Hydrochemistry to Constrain Flow Model

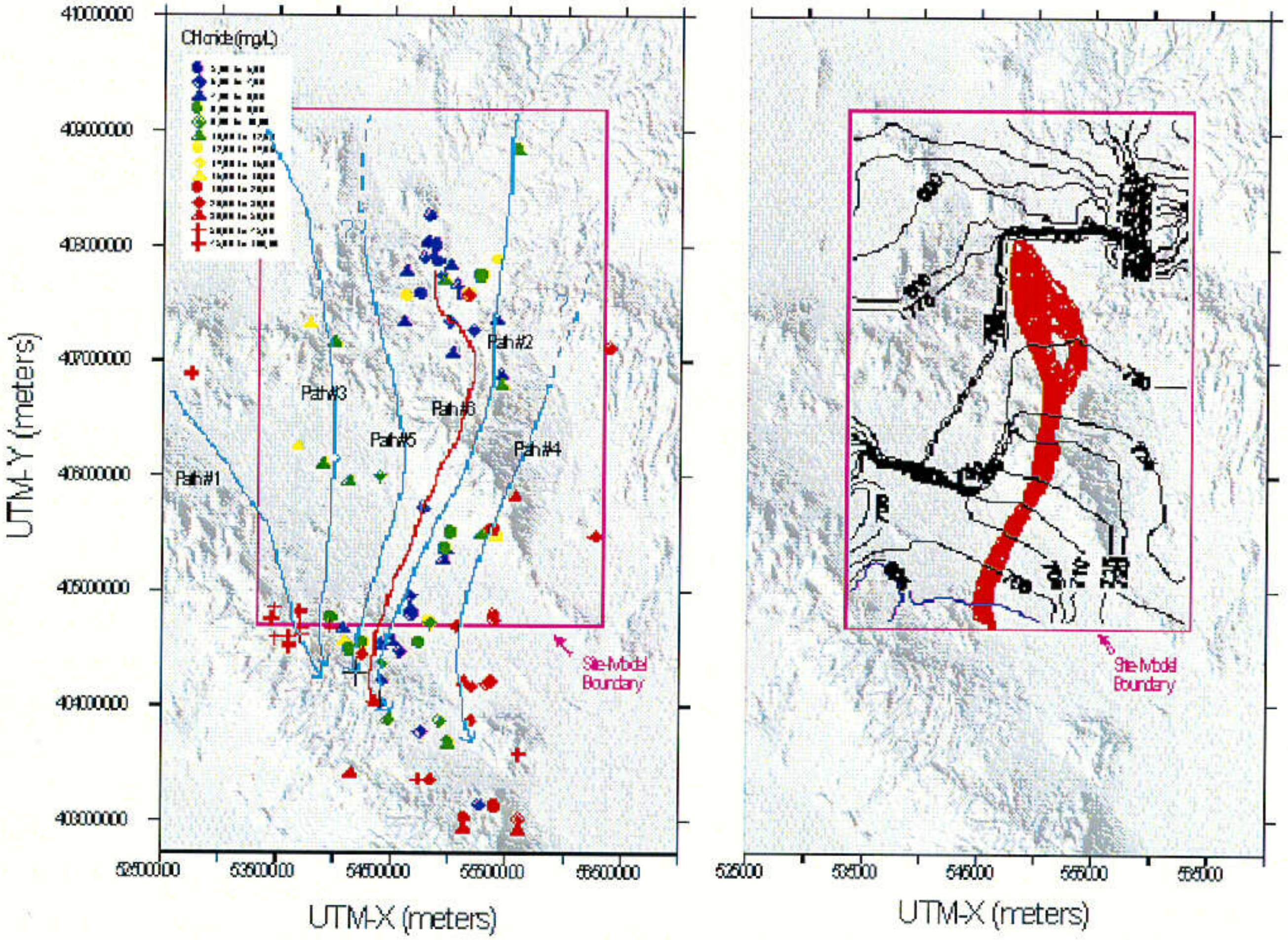


- **Assumption - trends in the chemical data can be used to delineate large-scale features of the groundwater flow patterns**
- **Multiple chemical and isotopic species were used to constrain the flow model (d^2H, $d^{18}O$, Cl^-, SO_4^{2-}, Na^+, Ca^+)**
- **Flow model results using particle tracking are consistent with the flow patterns deduced from the hydrochemical data**

Ref: MDL-NBS-HS-000011

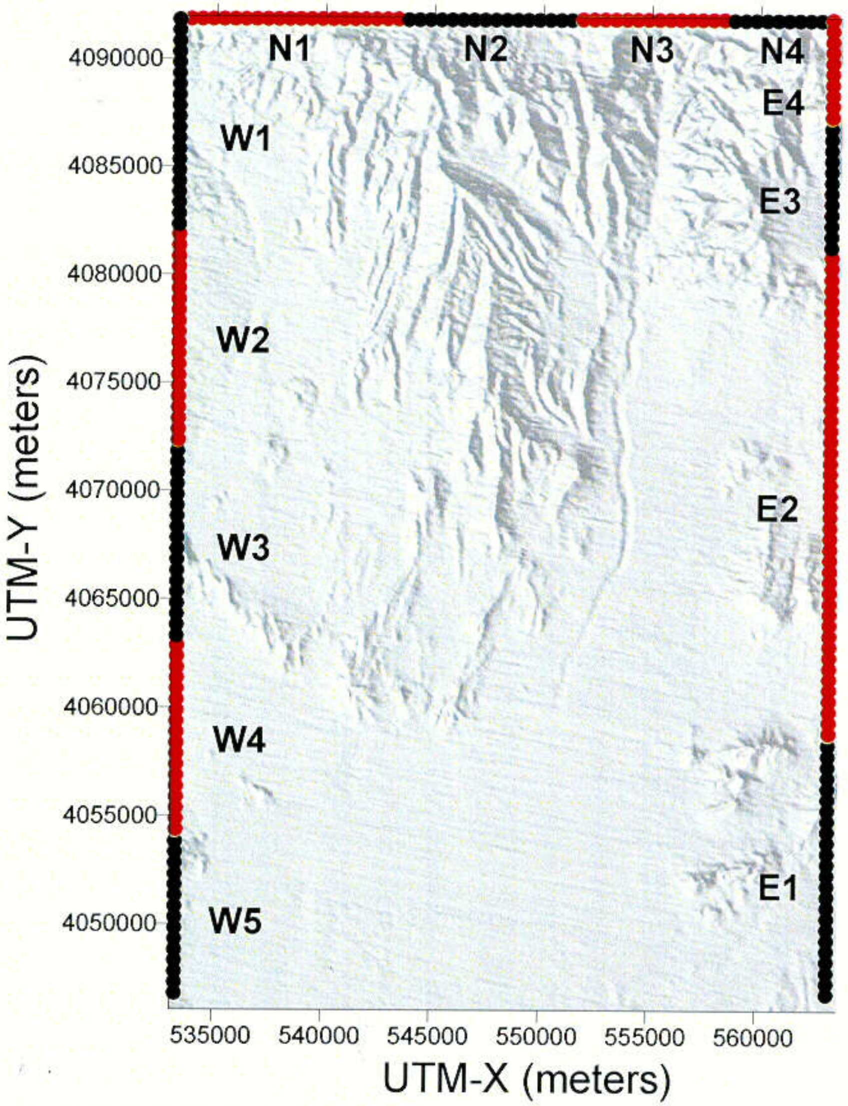
C53

Fluid Pathlines



Ref: MDL-NBS-HS-000011

Groundwater Fluxes at the Model Boundaries



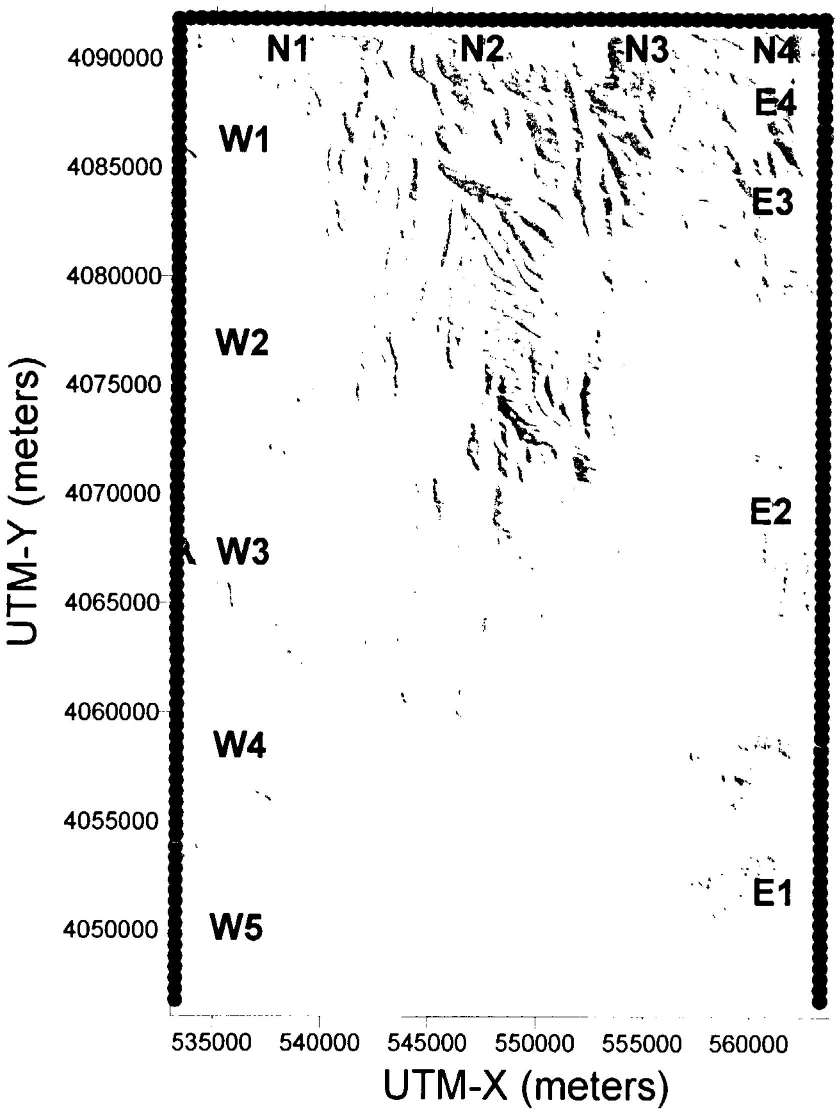
Boundary Zone	Regional Flux (kg/s)	Site-Scale Flux (kg/s)
N1	–101.24	–60.0
N2	–16.48	–33.4
N3	–53.05282	–30.6
N4	–18.41	–44.8
W1	3.45	4.17
W2	–71	–0.00719
W3	–6.9	–0.0000078
W4	2.73	–0.0000223
W5	–46.99	–6.85
E1	–555.45	–553.9
E2	–5.46	3.53
E3	2.65	16.50
E4	–3.07	16.8
S	918	724

Source: D'Agnese et al. (1997); DTN: LA9911GZ12213S.001.

Fluxes computed from the site scale model boundaries agree with the regional model results to within the accuracy warranted by such a comparison

Ref: MDL-NBS-HS-000011

Groundwater Fluxes at the Model Boundaries



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Fluxes computed from the site scale model boundaries agree with the regional model results to within the accuracy warranted by such a comparison

Ref: MDL-NBS-HS-000011

Model Sensitivities

- Determine which parameters affect transport pathways
- Investigate grid size calibration issues
- Determine permeabilities most important for flow calibration
- Understand effect of data not used

Sensitivity of Objective Function to Parameters

- No East-West barrier
- Alluvial uncertainty zone fixed at 1.6×10^{-12}
- 5:1 North-South to East-West anisotropy

Model Limitations

- Conservative vs. reasonable
- Difficult to evaluate uncertainty in data
- Evaluate data not used
- Understand grid resolution in high gradient areas

Field Data Currently Being Incorporated in Fiscal Year 00 Models

- Transient C-Wells tests (though the derived permeabilities were used)
- Temperature distribution (viscosity dependence was incorporated)
- Pre-development water levels
- Geology from recent Nye County wells

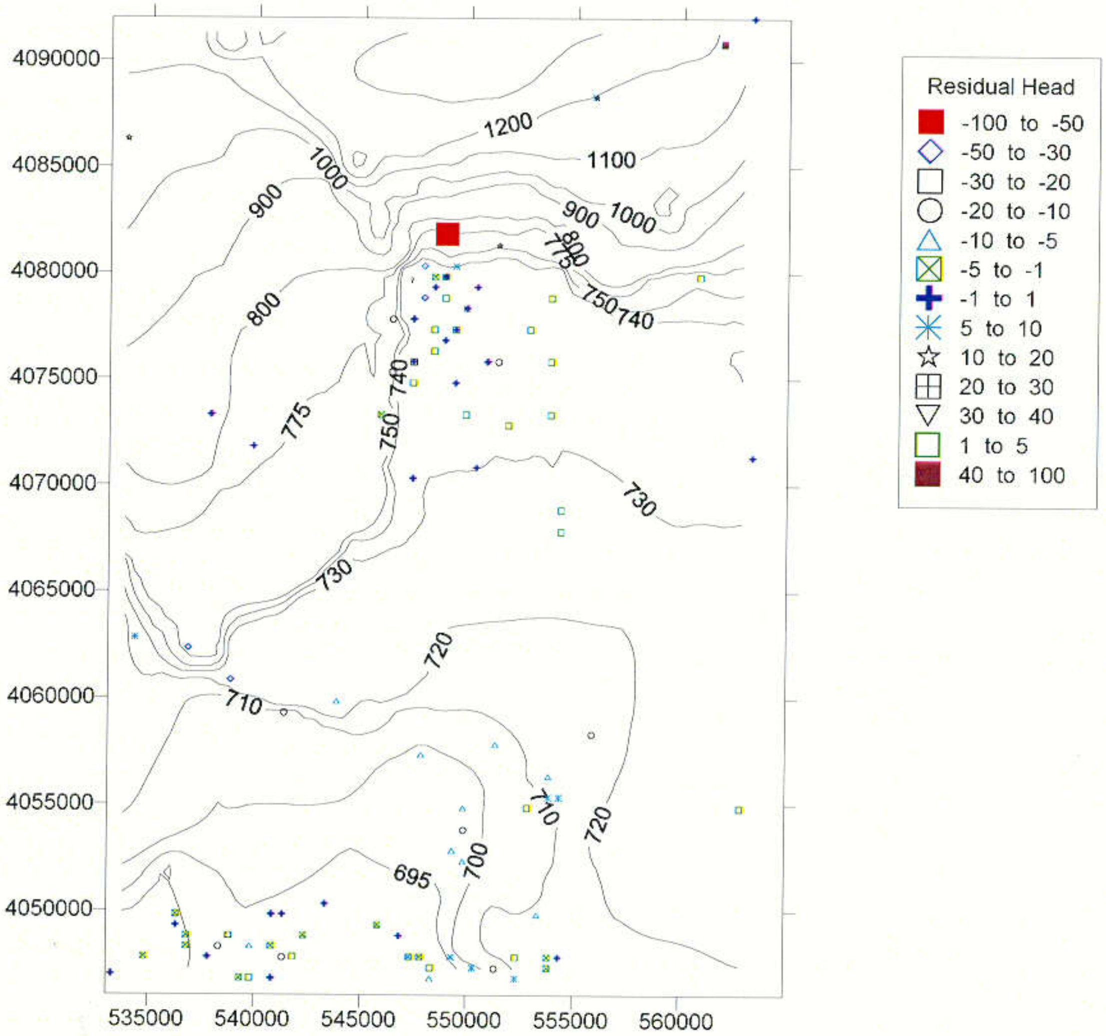
Alternate Conceptual Models
Large Hydraulic Gradient

- East-West Barrier (Saturated Zone Analysis Model Report)
- No East-West Barrier (Hydro-Thermal Alteration)
- Northwest-Southeast Trending Faults (washes) North of Yucca Mountain
- Perched Water

No East-West Barrier

- Caldera complex faulting and hydrothermal alteration causes differences in permeability in northern and southern portions of hydrogeologic units
- Calibrate to additional parameters to represent northern permeabilities
- Simplify feature parameter set

No East-West Barrier
(Continued)



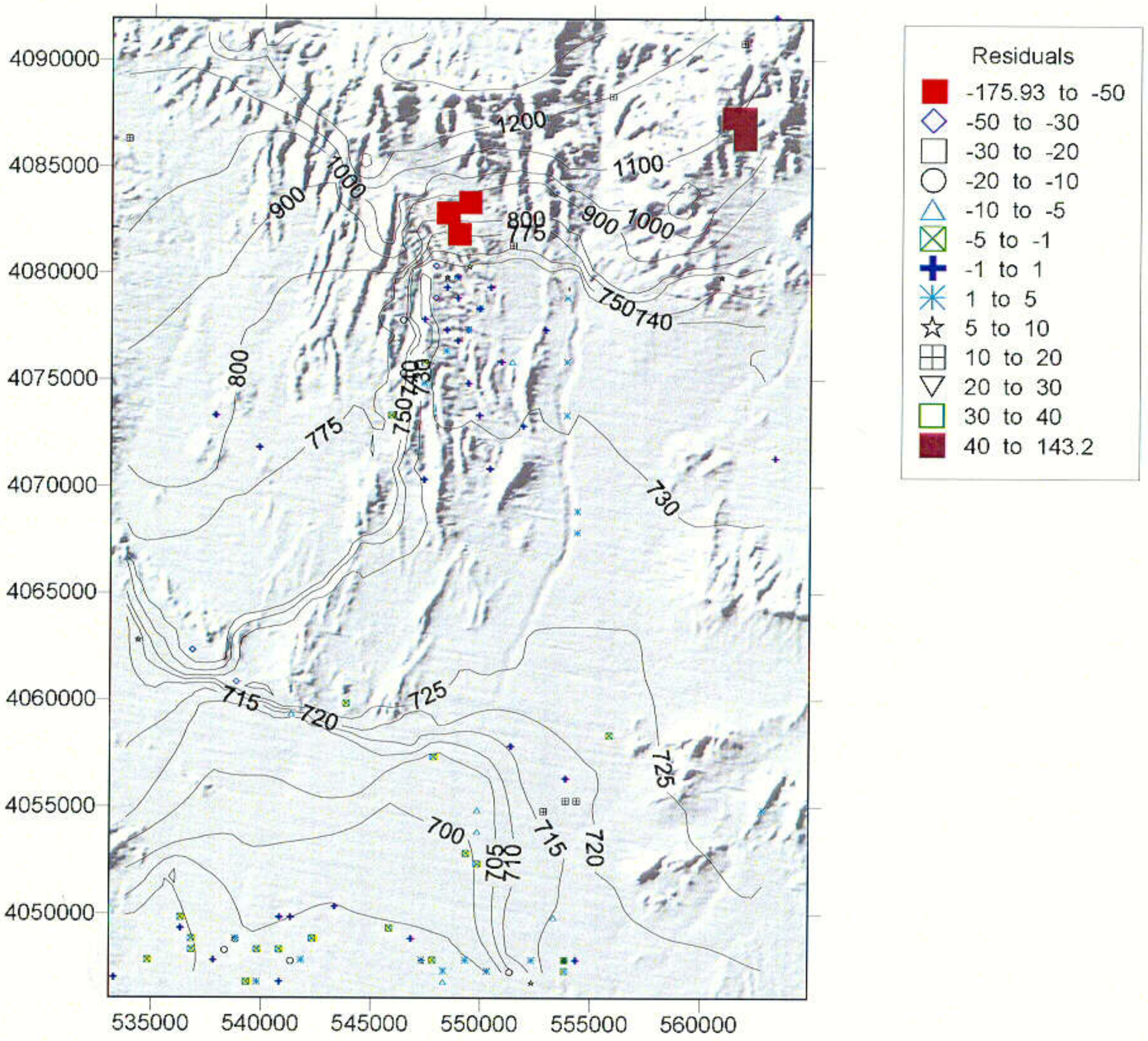
Ref: MDL-NBS-HS-000011

C56

Anisotropy

- **Vertical to Horizontal (1:10)**
  - Carbonates, Undifferentiated, Some Volcanics, Alluvium
  - Faults (Solitario, Fortymile, Crater Flat, etc.) Have Higher Vertical Conductivity
- **Horizontal North-South to East-West (5:1)**
  - Yucca Crest to Fortymile Wash, Length of Yucca Mountain
  - Top to 200m Depth

No Barrier with Anisotropy



Reference: work in progress

C 57

Perched Water

- Large residuals just north of Yucca Mountain are low in all conceptual models of the Large Hydraulic Gradient
- Correspond to wells suspected to be perched
- Need to investigate grid effect in region

Numerical Model

- **References**
  - *Saturated Zone Flow and Transport Process Model Report* (TDR-NBS-HS-000001 REV 00 ICN 01)
  - *Calibration of the Site-Scale Saturated Zone Flow Model* (MDL-NBS-HS-000011 REV 00)
- **DOE's numerical Saturated Zone model satisfies many data constraints and includes realistic fluid pathlines. No additional work needed**

Conclusions

- **This criterion should be closed**
  - DOE's models incorporate site-specific climatic and subsurface information
  - The models was reasonably calibrated and reasonably represent the physical system
  - Fitted aquifer parameters compare reasonably well with observed site data
  - Implicitly- or explicitly-simulated fracturing and faulting are consistent with the data in the three-dimensional hydrogeologic model
  - Abstractions are based on initial and boundary conditions consistent with site-scale modeling and the regional model of the Death Valley groundwater flow system
  - Abstractions of the groundwater model for use in Performance Assessment simulations use appropriate spatial- and temporal-averaging techniques
- **The models will be updated with new information to further reduce uncertainty**

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Subissue 5, Acceptance Criterion 8: Dilution

Presented to:
DOE/NRC Technical Exchange on the Key Technical Issue Subissues Related to Saturated Zone Flow

Presented by:
Al Aziz Eddebbarh, Ph.D
Bruce A. Robinson, Ph.D
Civilian Radioactive Waste Management System Management and Operating Contractor

October 31 - November 2, 2000
Albuquerque, NM

YUCCA MOUNTAIN PROJECT

Outline

- **Presentation Objectives**
- **Current Acceptance Criterion Status**
- **For Subissue 5, Acceptance Criterion 8, presentation will**
  - Summarize technical basis for resolution of items
  - Identify basis documents
  - Summarize technical adequacy of basis
- **Conclusions**

Note: Additional summary information is provided in the delta analysis

Presentation Objectives

- Provide the basis for resolving Acceptance Criterion 8 associated with delineation of flow paths
- Subissue 5, Acceptance Criterion 8: If credit is taken for dilution due to either dispersion, groundwater mixing below the repository footprint, or mixing of the Yucca Mountain water with water from the north in Fortymile Wash, reasonable assumptions have been made about spatial and temporal variations of aquifer properties and groundwater volumetric fluxes

Current Acceptance Criterion 8 Status

- Unsaturated and Saturated Flow under Isothermal Conditions Issue Resolution Status Report, Rev. 02 indicates that status is open, pending review of future DOE performance assessments. At that time the use of random walk particle tracking in the overall Total System Performance Assessment will be evaluated
- April 2000 Key Technical Issue Status Technical Exchange identified the Saturated Zone Flow and Dilution Subissue as open; did not specifically provide status of Acceptance Criterion 8

Acceptance Criterion 8

- **Actions or Information Needs**
  - Discussion on the particle tracking based transport methodology
- **Basis for Closure**
  - Longitudinal and transverse dispersions are explicitly simulated as a random-walk process in the site-scale Saturated Zone Flow and Transport Model
  - As discussed in the Saturated Zone Analysis Model Report: *Saturated Zone Transport Methodology and Transport Component Integration,* the particle-tracking algorithm used is suitable for performing saturated-zone flow and transport simulations for the Total System Performance Assessment analyses
- **This acceptance criterion has been fully addressed. In assessing dilution due to dispersion or mixing, DOE has made reasonable assumptions about spatial and temporal variations of aquifer properties and groundwater volumetric fluxes**

Particle Tracking Based Transport Methodology

- **Basis for Resolution**
  - DOE has implemented a particle tracking-based transport methodology to simulate radionuclide transport in the saturated zone.

Particle Tracking Based Transport Methodology (Continued)

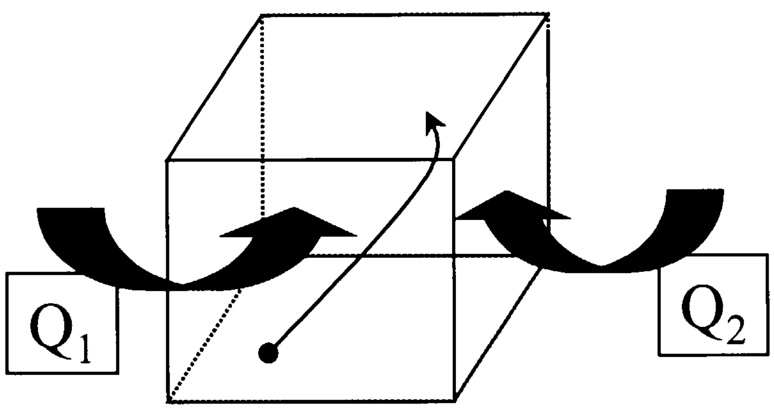
- Motivation for model development
- Key features of the particle tracking model
- Code verification simulations
- Sensitivity studies
- Treatment of dilution
- Ongoing model development

Requirements of the Transport Model

- Transport model calculations must be based on the three-dimensional process-level flow model
- Must handle a wide range of dispersivity values, including very low values
- Source term at the water table may be large or small in extent
- Plume size may have smaller dimensions than the grid spacing
- Must simulate matrix diffusion and sorption transport processes
- Results have to be abstracted for use in Total System Performance Assessment analyses

Streamline Particle Tracking

Computational Cell and Particle Pathway



- Trajectory and travel times of particles are computed within a cell by velocity interpolation (Pollack, 1988)
- Dispersion is modeled with a random-walk algorithm (Tompson and Gelhar, 1993)
- Matrix diffusion and sorption are modeled using a transfer function approach

Random Walk Dispersion

- **Particles move randomly off streamlines subject to an assumed dispersion coefficient tensor**
- **Anisotropic dispersion tensor of Burnett and Frind (1987) is assumed:**
  - Longitudinal dispersivity (100 m*)
  - Transverse horizontal dispersivity (2 m*)
  - Transverse vertical dispersivity (5×10^{-3} m*)

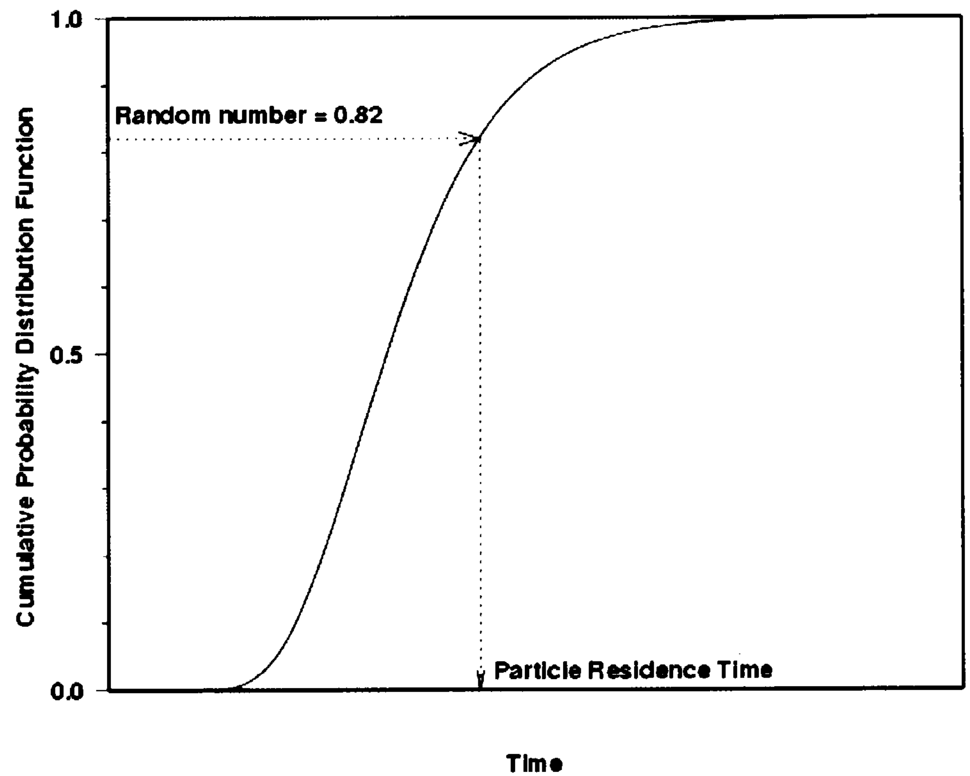
* Mean value of distribution used in Total System Performance Assessment calculations

Sorption and Matrix Diffusion

Transfer Function Approach

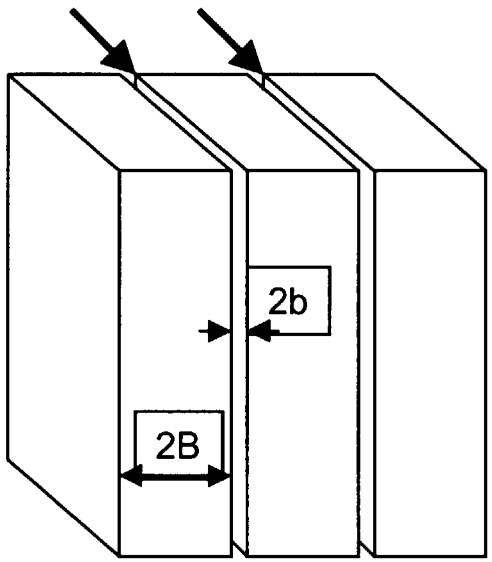
- Transfer function corresponds to a distribution of residence times that reproduces an analytical solution
- Travel time through each cell is computed based on the transport properties in that cell
- Similar approach is used in the unsaturated zone

Determination of Particle Travel Time



Matrix Diffusion Model

Parallel Fracture Model



Parameters:
- q (specific discharge)
- ϕ_m (matrix porosity)
- ϕ_f (fracture porosity)
- B (fracture spacing)
- D (diffusion coefficient)
- R_f (retardation factor)

Dimensionless Groups

$$\boxed{T_1^0 = \frac{t}{\tau_0} - R}$$

$$\boxed{\tau_0 = \frac{z}{v}}$$

$$\boxed{\omega_1 = \frac{\theta(R'D'\tau_0)^{1/2}}{b}}$$

$$\boxed{\sigma_1 = \left(\frac{R'}{D'\tau_0}\right)^{1/2}(B-b)}$$

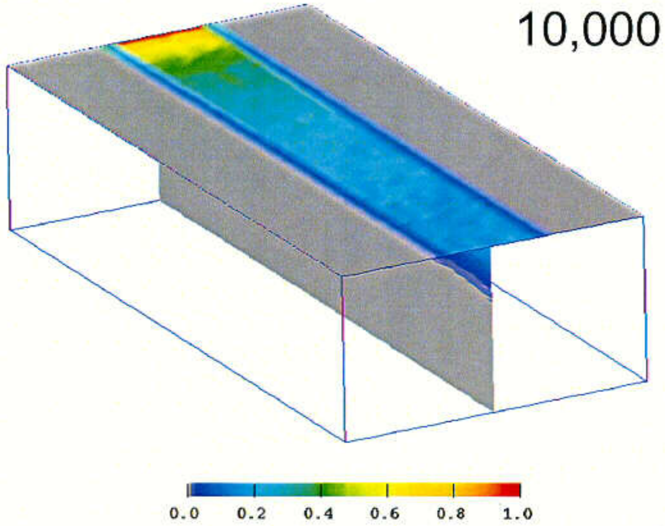
Solution: Sudicky and Frind (1982) Contaminant Transport in Fractured Porous Media: Analytical Solutions for a System of Parallel Fractures: Water Resources Research 18, 16), 1634-1642. American Geophysical Union

Transport Model Test System

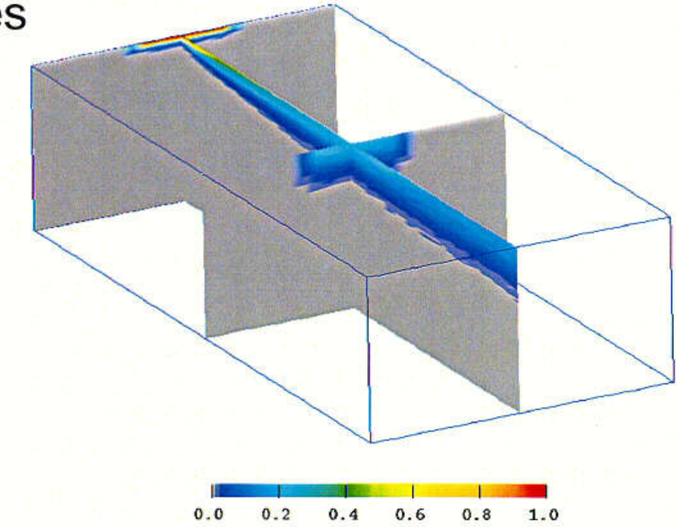
- Three-dimensional model with similar numbers of nodes and node spacings as the site-scale model
- One-dimensional flow, uniform properties
- Particles inserted at the inlet at a point or a smeared plane
- Breakthrough curves and concentrations monitored at various distances up to 20 km

Concentration Distribution: Dispersion Test Case

10X Vertical Exaggeration
10,000 particles



Concentration



Concentration

3D Grid, 128,775 nodes, 20 km travel distance

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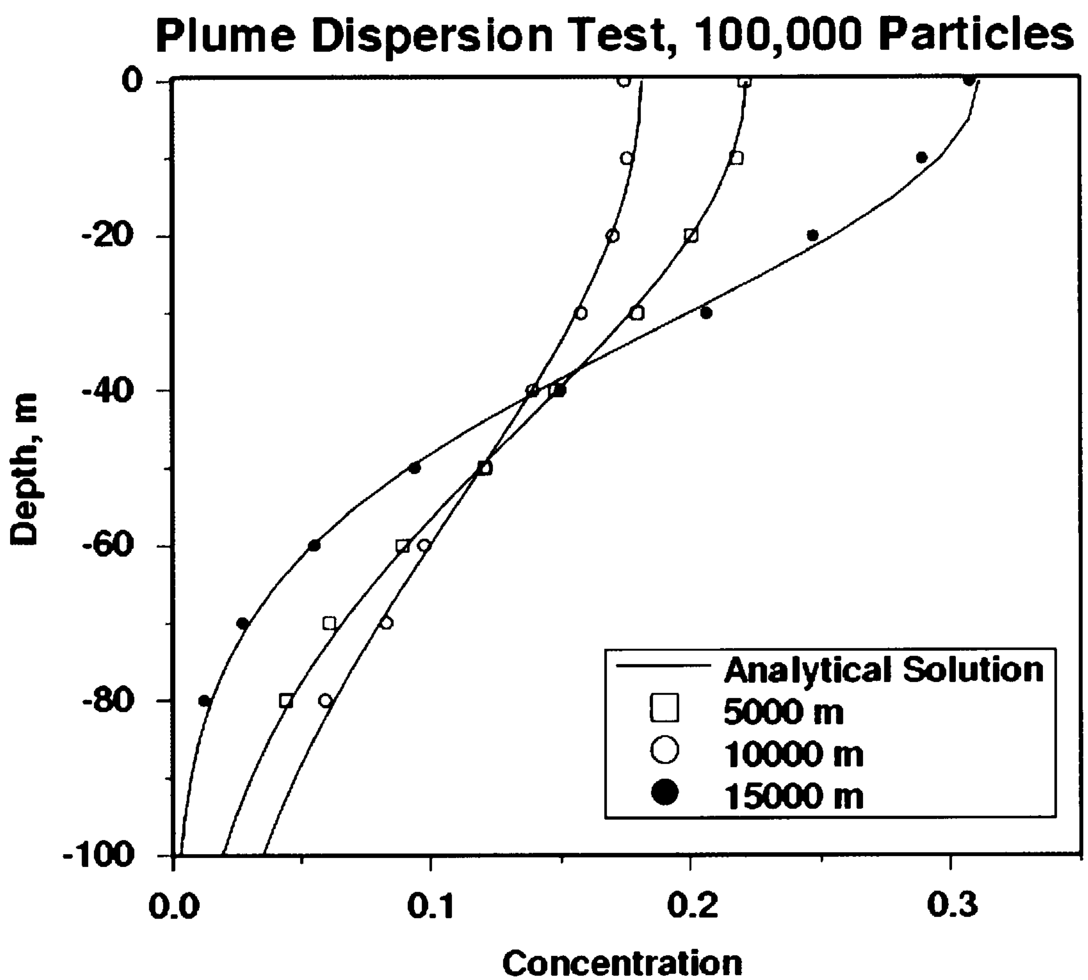
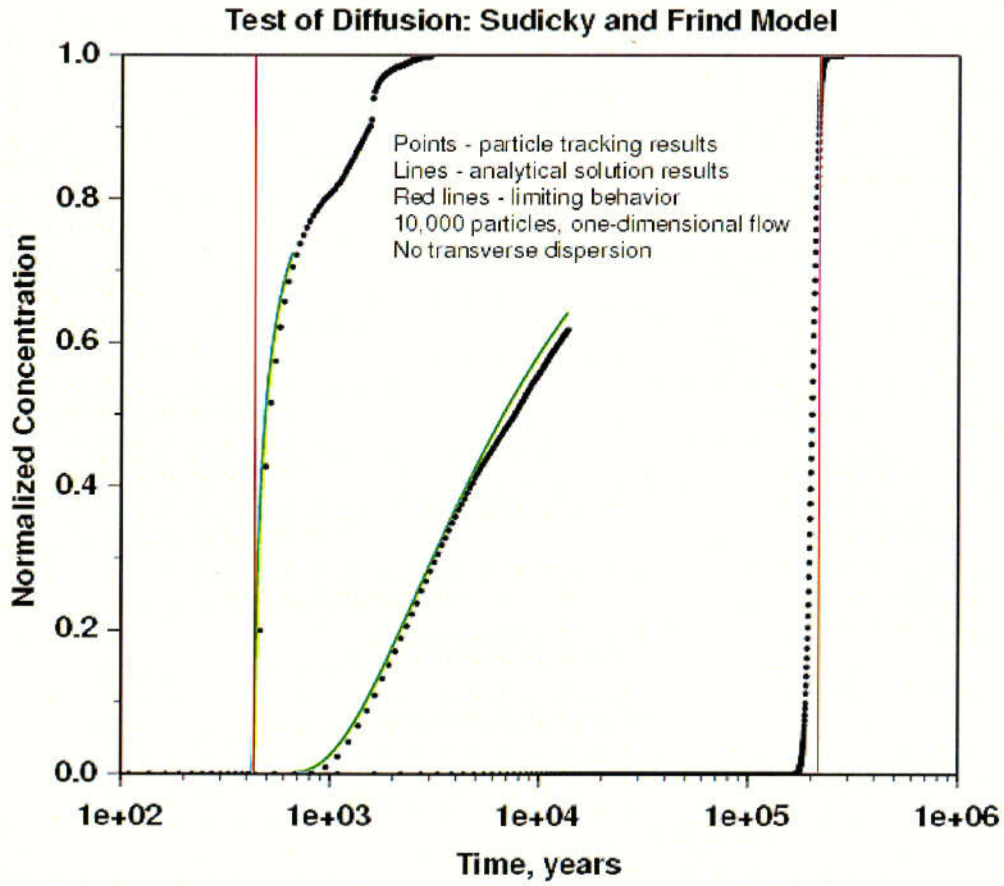
Validation of Random Walk Dispersion Model



Reference: Analysis and Model Report Saturated Zone Transport Methodology and Transport Component Integration (MDL-NBS-HS-000010 REV 00)

Validation of Diffusion Model

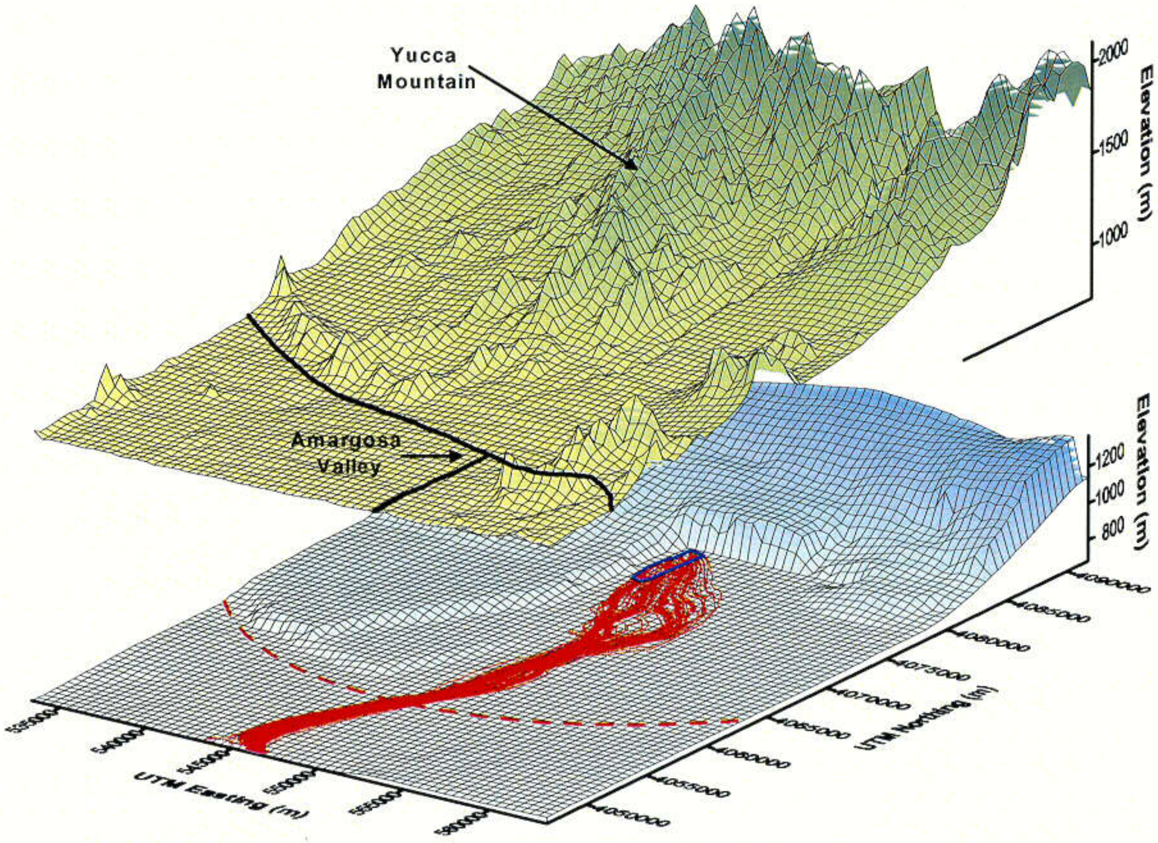


Reference: Analysis and Model Report Saturated Zone Transport Methodology and Transport Component Integration (MDL-NBS-HS-000010 REV 00)

C59

Saturated Zone Site-Scale Flow and Transport Model

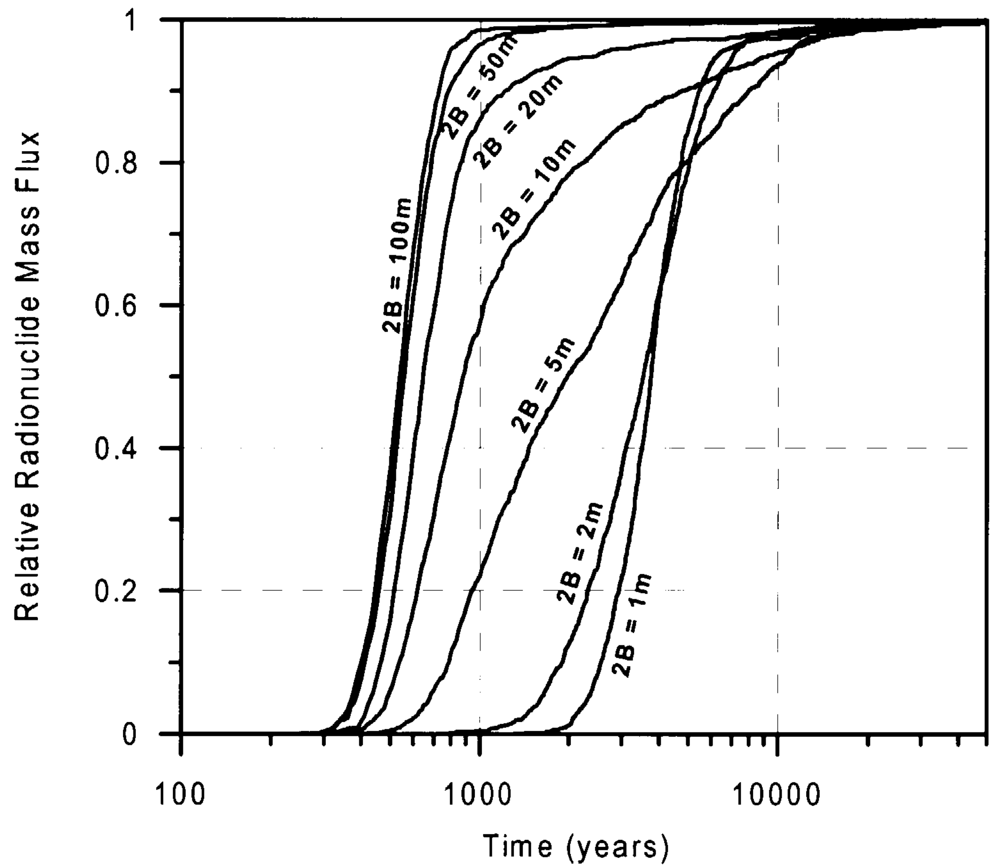
Radionuclide Pathways in the Site-Scale Saturated Zone Flow and Transport Model Area



- **Particle tracking method includes radionuclide transport processes of advection, dispersion, matrix diffusion in fractured volcanic units, and sorption**
- **Simulated flow paths from the repository occur in the upper few hundred meters of the Saturated Zone**
- **Simulated flow paths cross the 20 km "fence" approximately 5 km west of the town of Amargosa Valley**

Reference: Input and Results Analysis Model Report (ANL-NBS-HS-00030)

Influence of Fracture Spacing



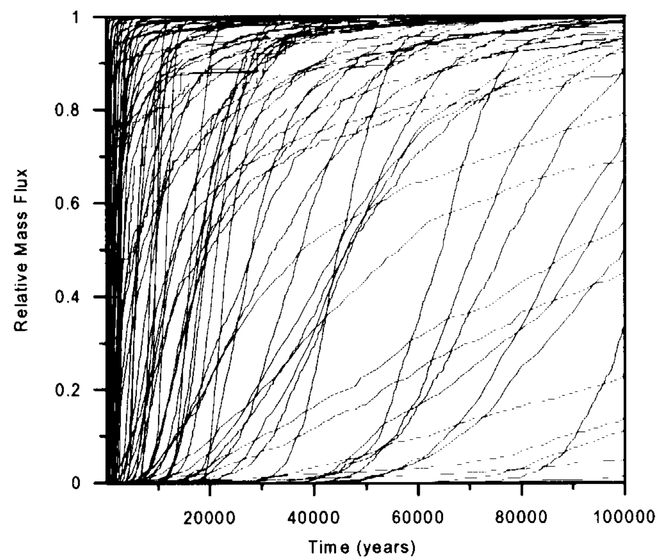
Breakthrough at 20 km, no sorption, expected value for all other parameters

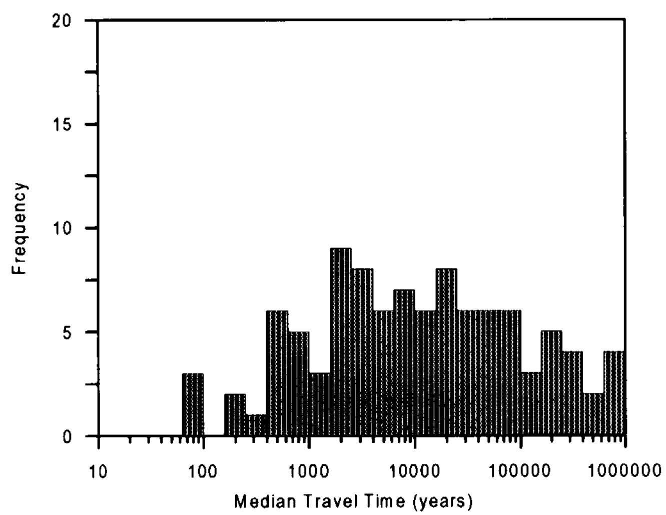
Fracture spacing expected value 2B = 21 m

Reference: work in progress

Saturated Zone Site-Scale Transport Results - ^{237}Np

Simulated Unit Breakthrough Curves and Histogram of Median Travel Times of Mass Flux for Neptunium, Present Climate





- Variability in travel times among realizations for transport of ^{237}Np extends from less than 1000 years to 1,000,000 years
- Sorption and retardation for ^{237}Np is generally moderate in alluvium and minor in the matrix of fractured volcanic units
- Approximately half the realizations exhibit median travel times of greater than 10,000 years in the SZ*

Note: Breakthrough curves do not include decay and represent transport only in the Saturated Zone

Reference: Saturated Zone Flow and Transport Process Model Report

Comparison of Total System Performance Assessment-Viability Assessment and Current Model

TSPA-Viability Assessment	Current Model
• Matrix diffusion: "effective porosity"	• Matrix diffusion: semi-analytical solution
• Dispersion: dilution factor	• Dispersion: full tensor
• Flow paths: 1D "streamtubes"	• Flow paths: from 3D process model
• Source regions: smeared	• Source regions: any size, including point source
• Concentrations: convolution	• Concentrations: convolution

Outstanding Technical Issues

- Method for applying random-walk dispersion in regions for contrasting flow velocity results in particles occasionally getting hung up in the system
- Dispersion coefficient tensor can be made more general
- Particle tracking on unstructured grids is under development
- Particle capture at pumping wells will be incorporated

Particle Tracking Model

- **References**
  - *Saturated Zone Process Model Report* (TDR-NBS-HS-000001 REV 00 ICN 01)
  - Analysis and Model Report, *Saturated Zone Transport Methodology and Transport Component Integration* (MDL-NBS-HS-000010 REV 00)
- **DOE's particle tracking model simulates advection, matrix diffusion, dispersion, and sorption. It fully supports closure of the acceptance criterion**

Wellbore Dilution

- Acceptance Criterion 7: If credit for wellbore dilution is taken, a demonstration has been provided that reasonable assumptions have been made about well design, aquifer characteristics, plume geometry, withdrawal rates, and capture zone analysis for the receptor location
- Issue Resolution Status Report, Rev.0 2 indicates status is resolved
- April 2000 Key Technical Issue Status Technical Exchange identified this subissue as open, but did not specifically address Acceptance Criterion 7
- This criterion has been fully addressed and should be closed. No additional credit for any wellbore dilution specifically due to well pumping is taken in Total System Performance Assessment

Conclusions

- Subissue 5, Acceptance Criterion 8 should be closed
- As discussed in the Saturated Zone Analysis Report: *Saturated Zone Transport Methodology and Transport Component Integration,* the particle-tracking algorithm incorporated in the Saturated Zone Site-scale Flow and Transport Model is suitable for performing saturated-zone flow and transport simulations for the Total System Performance Assessment analyses

Subissue 5, Acceptance Criterion 9: Potential Effects on the Saturated Zone Flow System

Presented to:
DOE/NRC Technical Exchange on the Key Technical Issue Subissues Related to Saturated Zone Flow

Presented by:
Drew Coleman
United States Department of Energy
Dr. Zell E. Peterman
U.S. Geological Survey

October 31 - November 2, 2000
Albuquerque, NM

Outline

- **Presentation Objectives**
- **Current Acceptance Criterion Status**
- **For Subissue 5, Acceptance Criterion 9, presentation will:**
  - Summarize technical basis for item resolution
  - Identify basis documents (References)
  - Summarize technical adequacy of basis
- **Conclusions**

Note: Additional summary information is provided in the delta analysis

Presentation Objectives

- Provide the basis for resolving Acceptance Criterion 9 associated with potential geothermal and seismic effects on the ambient Saturated Zone flow system
- Subissue 5, Acceptance Criterion 9: Department of Energy (DOE) has incorporated key conclusions regarding potential geothermal and seismic effects on the ambient Saturated Zone flow system (e.g., National Research Council 1992; Nuclear Waste Technical Review Board 1998d; Craig 1997)

Current Acceptance Criterion 9 Status

- **Unsaturated and Saturated Flow under Isothermal Conditions Issue Resolution Status Report, Rev. 02 indicates that status is open, pending review of data on fluid inclusions and review of future DOE performance assessments**
- **April 2000 Key Technical Issue Status Technical Exchange identified the Saturated Zone Flow and Dilution Subissue as open; did not specifically provide status of Acceptance Criterion 9**

Acceptance Criterion 9

- **Action or information needs identified**
  - A discussion of the potential geothermal or seismic effects on the water table and an update on the fluid inclusion study are needed

Acceptance Criterion 9
(Continued)

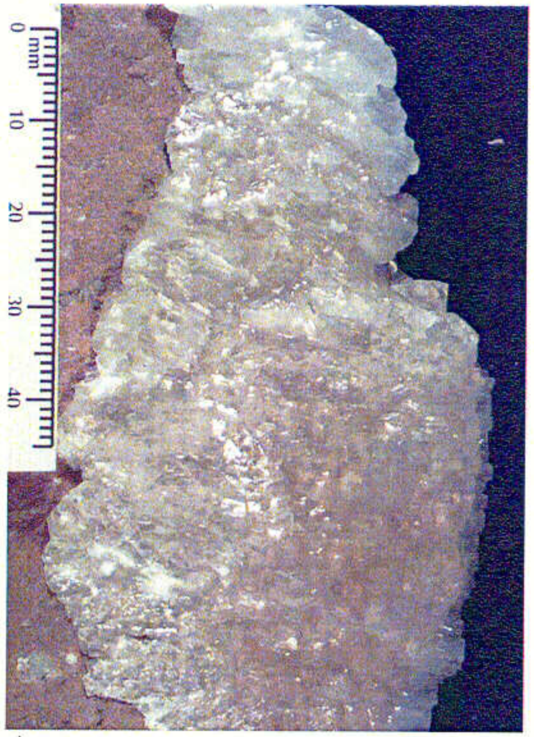
- **Basis for closure**
  - The DOE has extensively investigated deposits that have been interpreted as providing evidence of potential geothermal and seismic effects on the ambient Saturated Zone flow system and the alternative models resulting from this interpretation. A detailed discussion of these investigations, interpretations, published reports, and reviews is provided in Section 4.4.5 of Rev. 01 of the *Yucca Mountain Site Description* and Section 3.8 of the *Saturated Zone Flow and Transport Process Model Report*
  - The results of the fluid inclusion study are expected to confirm validity of conclusions regarding upwelling flow
- **This acceptance criterion has been fully addressed. DOE has appropriately assessed and incorporated key conclusions regarding potential geothermal and seismic effects on the ambient Saturated Zone flow system**

Potential Geothermal and Seismic Effects on Water Table and Update on Fluid Inclusion Study

- **Basis for Resolution**
  - DOE will evaluate results of the fluid inclusion study when they are available
  - DOE does not expect these results to change conclusions previously drawn regarding geothermal and seismic effects on the water table

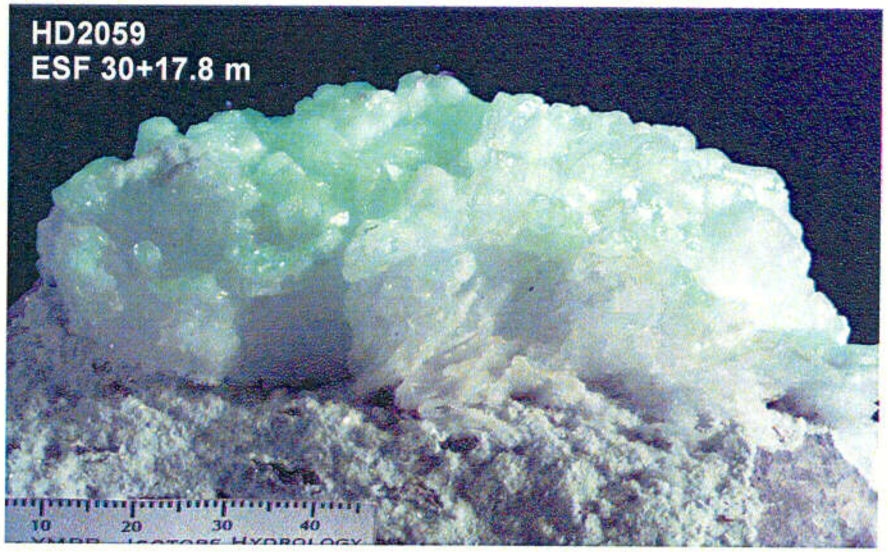
Fracture Minerals in the Unsaturated Zone

- Fracture and lithophysal cavities contain coatings of calcite and opal deposited from water flowing through the Unsaturated Zone after ash-flow tuffs cooled below 100°C
- Coatings are dominantly calcite + silica (chalcedony, quartz, and opal)
- Minor fluorite, clay minerals, zeolites & manganese oxides are present most commonly in older parts of deposits
- Coatings range in thickness from several millimeters to several centimeters



Fracture surface

- Calcite ($CaCO_3$): grey to white, blocky prisms to elongated blades
- Opal ($SiO_2 \bullet H_2O$): green fluorescing (ultraviolet illumination), water-clear sheets and hemispheres



Lithophysal cavity floor

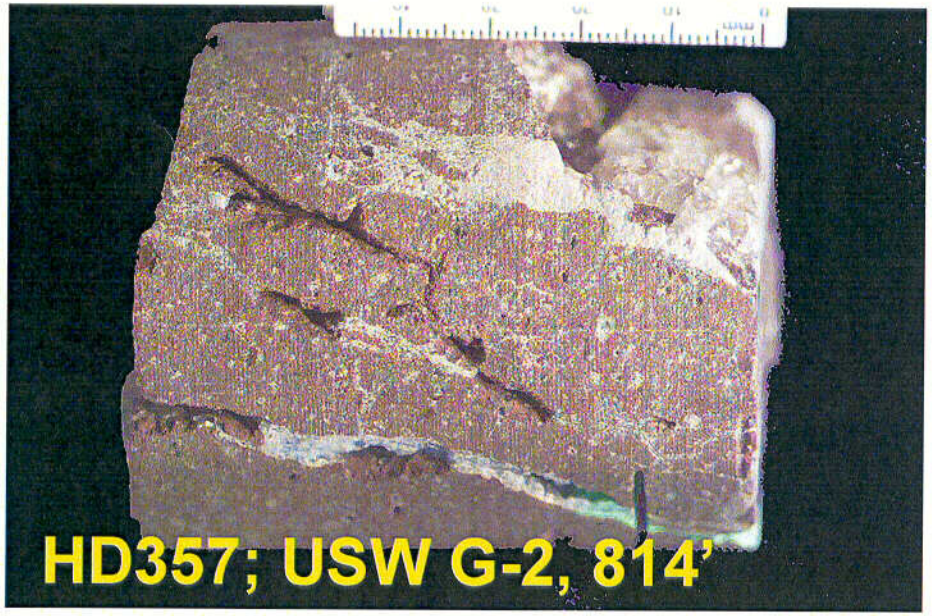
C61

Why Study Fracture Minerals?

- They are the only physical records of long-term infiltration through the Unsaturated Zone
- Can be isotopically dated to establish the history of deposition and infiltration (U-series, U-Pb, C-14)
- Contain isotopes related to water source, conditions of deposition, and influence of water-rock interaction ($\delta^{18}O$, $\delta^{13}C$, $\delta^{87}Sr$, $^{234}U/^{238}U$)
- Contain fluid inclusions that may yield information on thermal history of rock mass

History of U.S. Geological Survey Research

- Pre-1990 to 1995: Only available samples were from drill core. Data include mineralogy/petrology, stable isotopes, strontium isotopes, initial attempts at geochronology



Drill Core

C62

History of U.S. Geological Survey Research
(Continued)

- **1995 to present**
  - Exploratory Studies Facility and Cross Drift exposures yield higher-quality samples in a geologic context

Exploratory Studies Facility Specimen

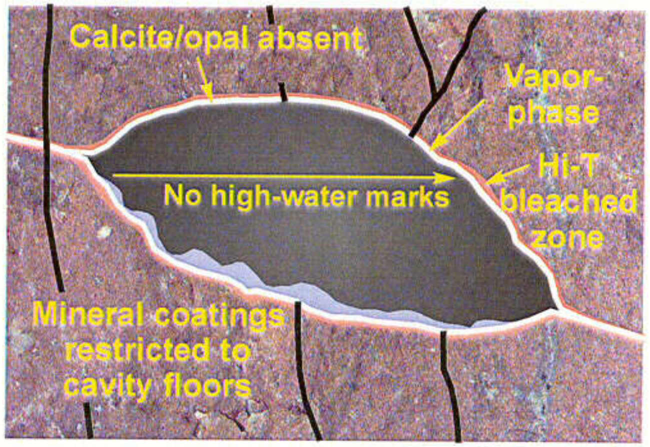
C63

History of U.S. Geological Survey Research
(Continued)

- **1995 to present (Continued)**
  - Ramped-up research efforts
  - Data include detailed mineralogy/petrology, isotopes, geochronology, fluid inclusion, and some geochemistry
  - Early focus:
    - History of the outer mineral surfaces
    - Translation of mineral data into Unsaturated Zone flux estimates
    - Constraints on water source and response of Unsaturated Zone to climate shifts
  - Recent focus:
    - Long-term depositional and thermal history of the Unsaturated Zone
    - Compositional evolution of fracture water
    - Estimates of seepage flux
    - Geochemical and age data at finer spatial resolutions
- **April 1999: Started parallel study of fluid inclusions**

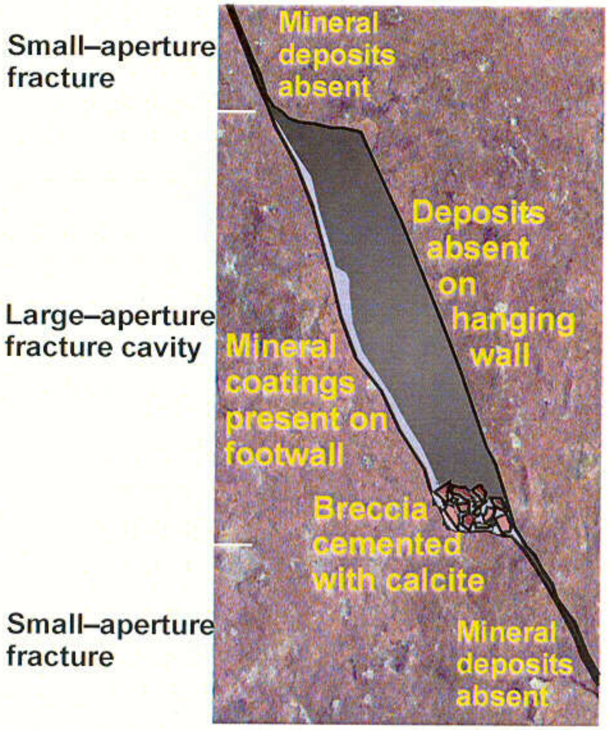
Location of Calcite — Opal Coatings within Rock Cavities

- **Most deposits are present in ROCK VOIDS:**
  - Fracture footwall surfaces
  - Surfaces of breccia clasts
  - Floors of lithophysal cavities



Lithophysal Cavities

Calcite and opal coatings
Host tuff
Void space



Fracture Cavities

Filled veins are present, but they are:
- **Usually less than several mm thick**
- **Volumetrically minor**

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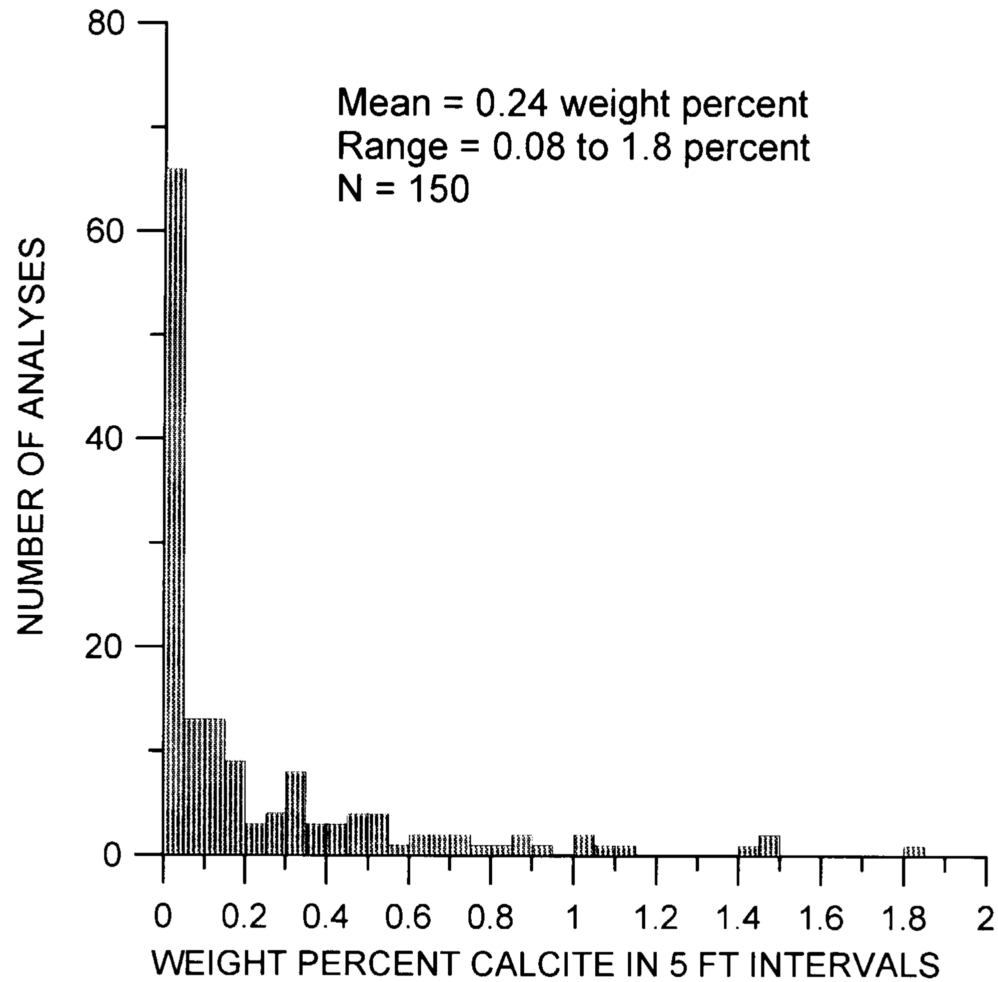
Location of Calcite — Opal Coatings within Rock Cavities (Continued)

- **Calcite below the water table coats all surfaces of cavities**
- **In contrast, Unsaturated Zone coatings exhibit evidence of gravitational influence**
  - Fracture water flowed downward along fracture footwalls and cavity floors
  - Strong evidence that cavities have always remained hydrologically unsaturated

Observational Information

- Calcite and opal intimately associated in microstratigraphic relationships
- Calcite averages 0.24 weight percent of rock mass in the crystal-poor Topopah Spring Tuff (WT-24 data)
- Calcite dominates—typically 90 percent or more calcite and 10 percent or less opal and other minerals
- Deposits not homogeneously distributed in the Exploratory Studies Facility
- Greatest abundance beneath Drill Hole Wash

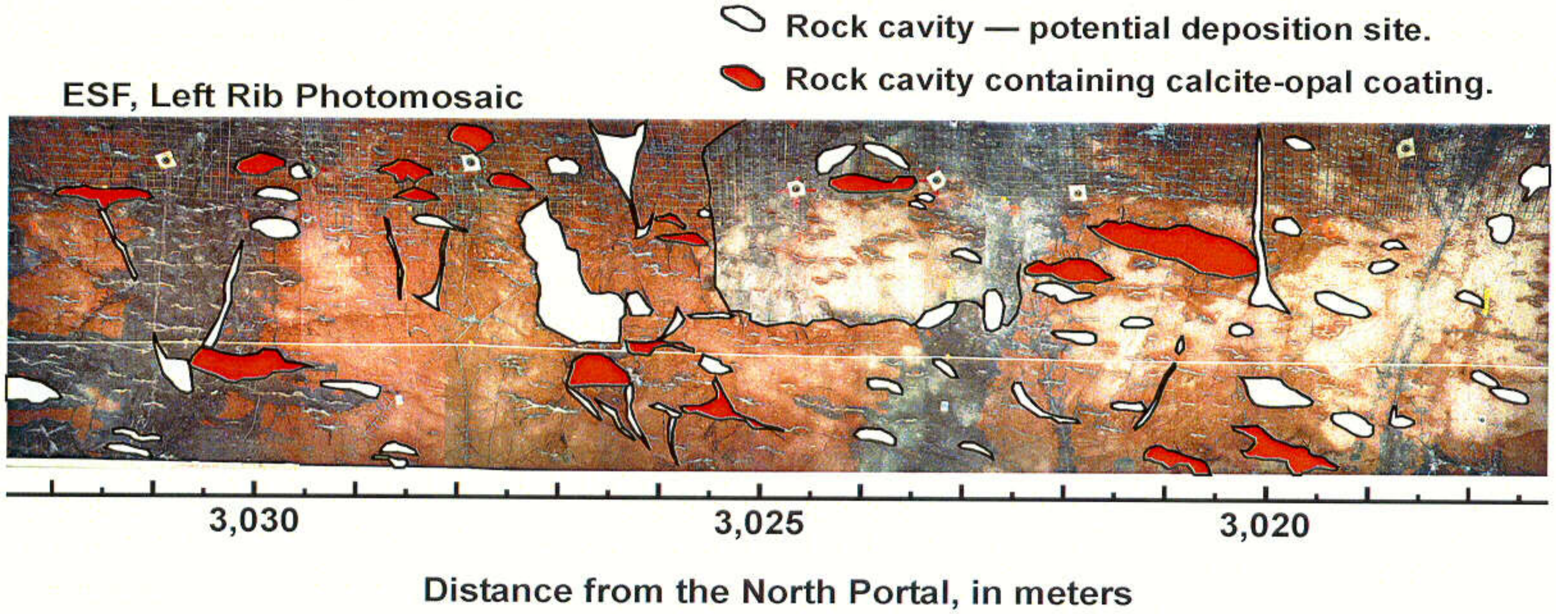
Abundance of Calcite in Tptp WT-24 Cuttings



Reference: Work in progress

Distribution of Fracture Minerals in the Unsaturated Zone

- **Only a small proportion of all fractures and rock voids contain calcite and opal**
- **In 30-m long surveys of the Exploratory Studies Facility tunnel walls, only a small percentage (0 to 40%, but typically less than 10%) of all lithophysal cavities contain mineral coatings**



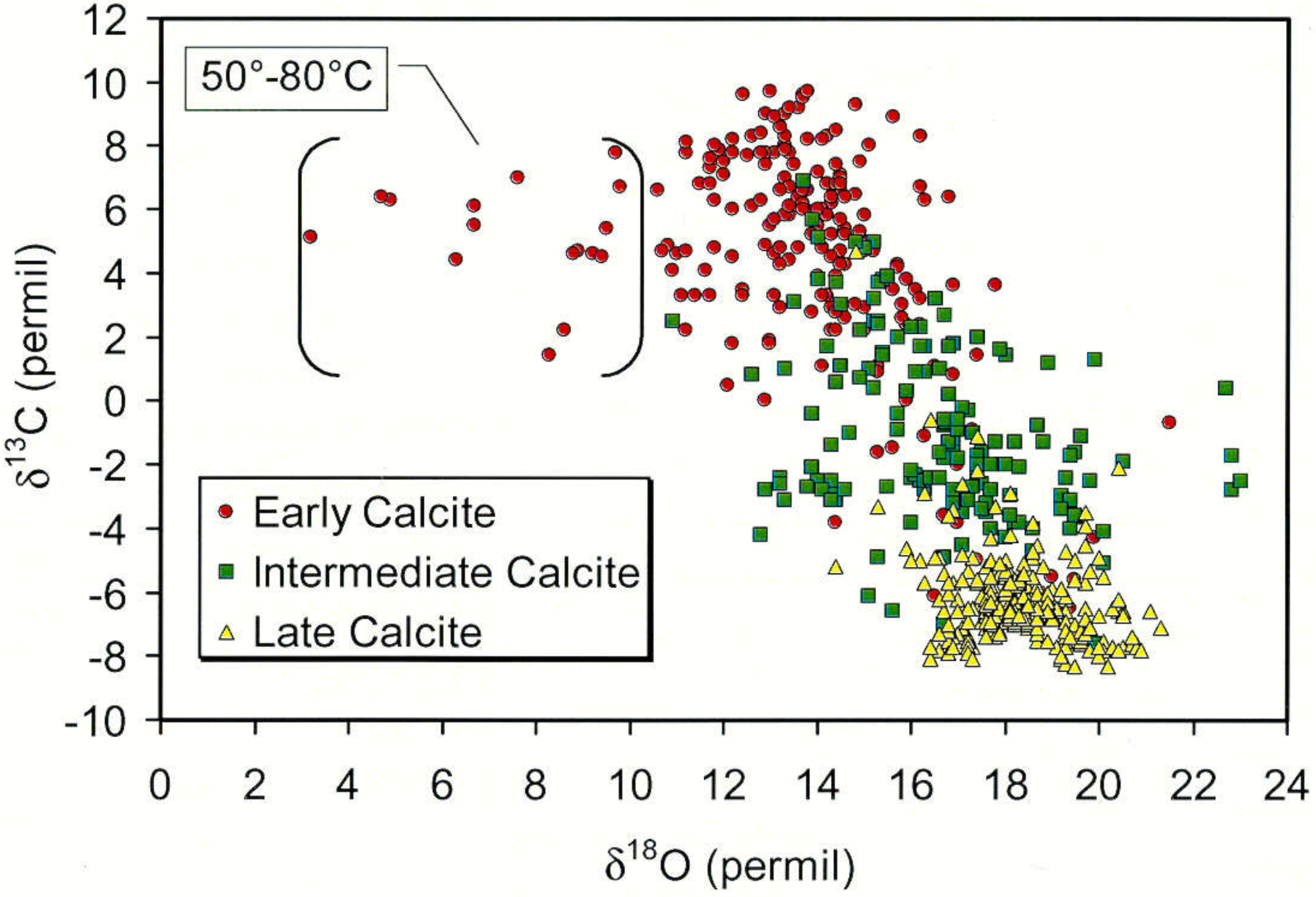
- **Provides strong evidence that the Unsaturated Zone was never inundated with water, otherwise all rock voids would contain calcite and opal**

Chemical and Isotopic Evidence for Descending Fracture Water

- $\delta^{13}C$ - **Youngest Unsaturated Zone calcite values overlap those in calcrete**
- $\delta^{18}O$ - **Youngest Unsaturated Zone calcite values are consistent with a meteoric water source heated during downward percolation**
- $\delta^{87}Sr$ - **Youngest Unsaturated Zone calcite values overlap those in calcrete**
- **REE - Unsaturated Zone calcite has pronounced negative Ce anomalies**
  - Not observed in Saturated Zone calcite (Vaniman & Chipera, 1996)
  - Small or nonexistent in ground water (Johannesson et al., 1997)
- $^{234}U/^{238}U$ - **Shallow Unsaturated Zone calcite $^{234}U/^{238}U$ identical to calcrete and runoff**
  - Much smaller than values observed in Tertiary volcanic (Tv) or Paleozoic (Pz) ground water

Conclusion: Chemical and isotopic arguments preclude an upwelling ground-water source for Unsaturated Zone calcite/silica

Oxygen and Carbon Isotopes in Calcite



Reference: Work in progress

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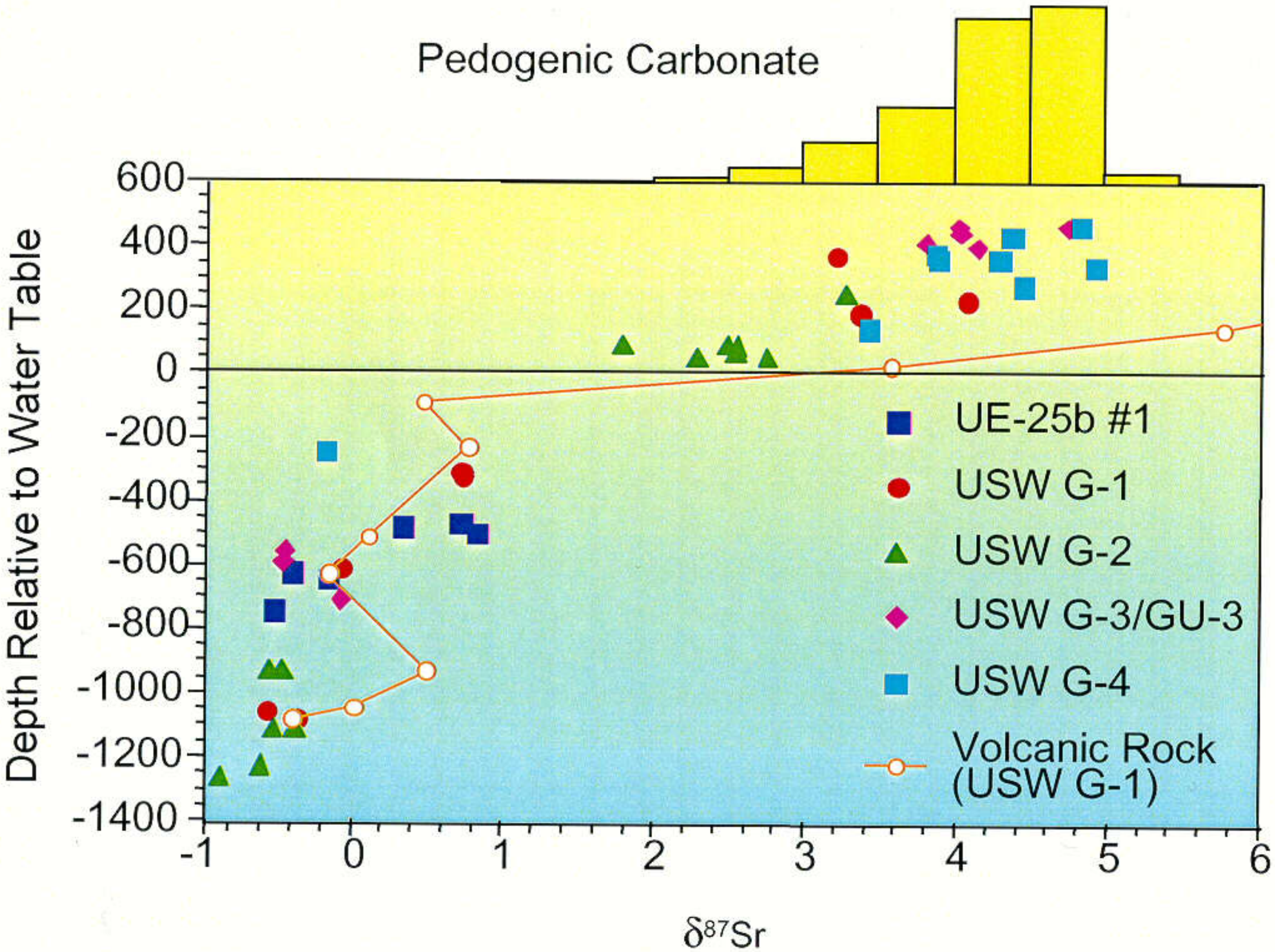
Vertical Variability of Strontium Isotopes in Calcite Fracture Fillings

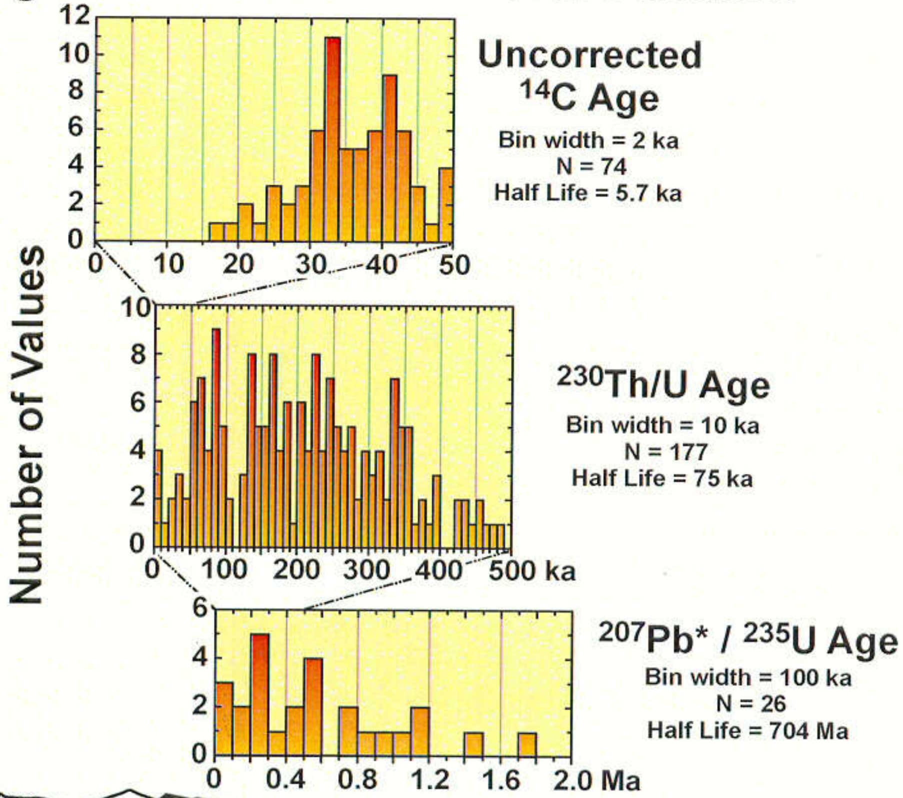


Reference: Work in progress

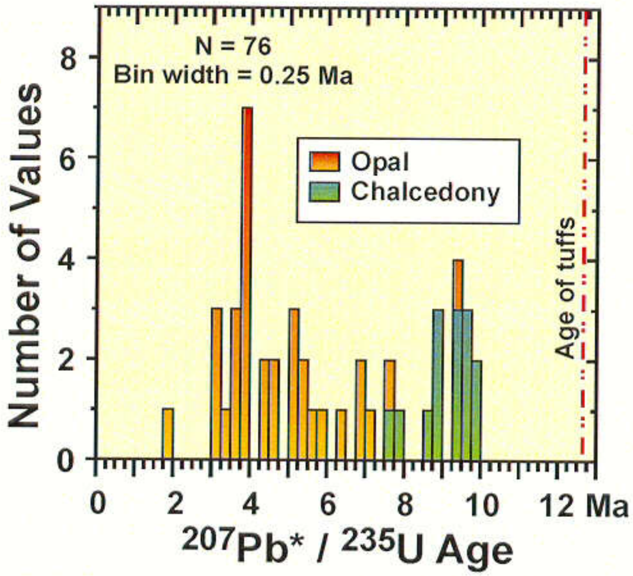
Geochronology

- **Ages of outer surfaces of both calcite and opal in the deep Unsaturated Zone (below PTn) range from <10 ka to <2 Ma**
- **Ages of interior opal and chalcedony layers are commonly 3 to 10 Ma**

Ages of outermost mineral surfaces



Ages of interior and basal layers



Reference: Work in progress

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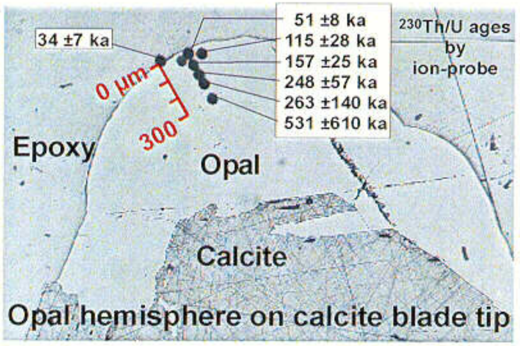
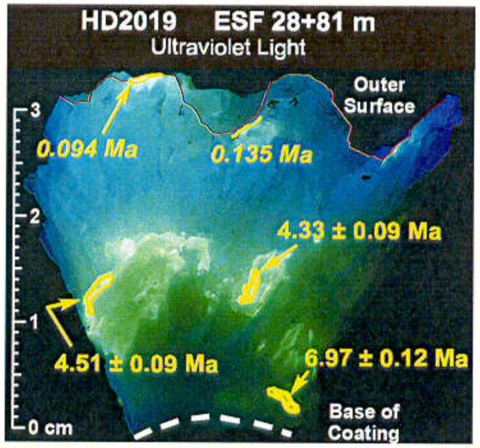
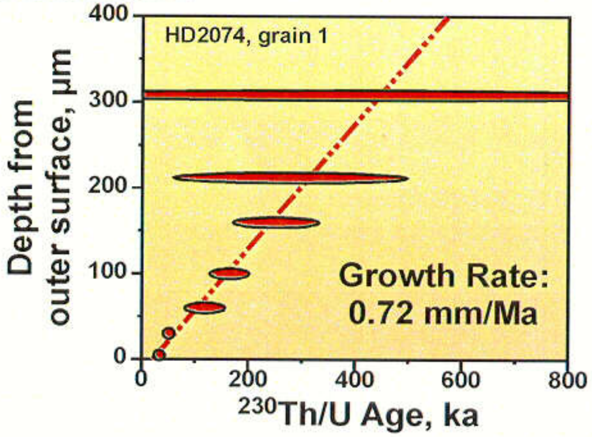
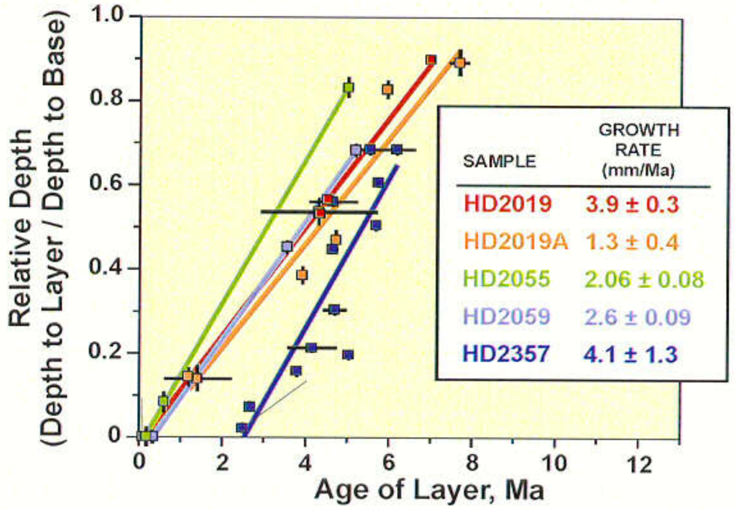
Growth Rates

- **Rates of deposition are very slow, on scale of mm/Ma. Long-term deposition rates in deep Unsaturated Zone coatings are remarkably similar from Tertiary to Pleistocene**









- **Slow, uniform growth rates are consistent with continuous downward percolation of fracture water and are inconsistent with sporadic episodes of inundation by upwelling ground water**

- **Slow, uniform growth rates also imply that deposition rates (and fracture flow) have remained buffered from large variations in surface hydrology (i.e., climate change)**

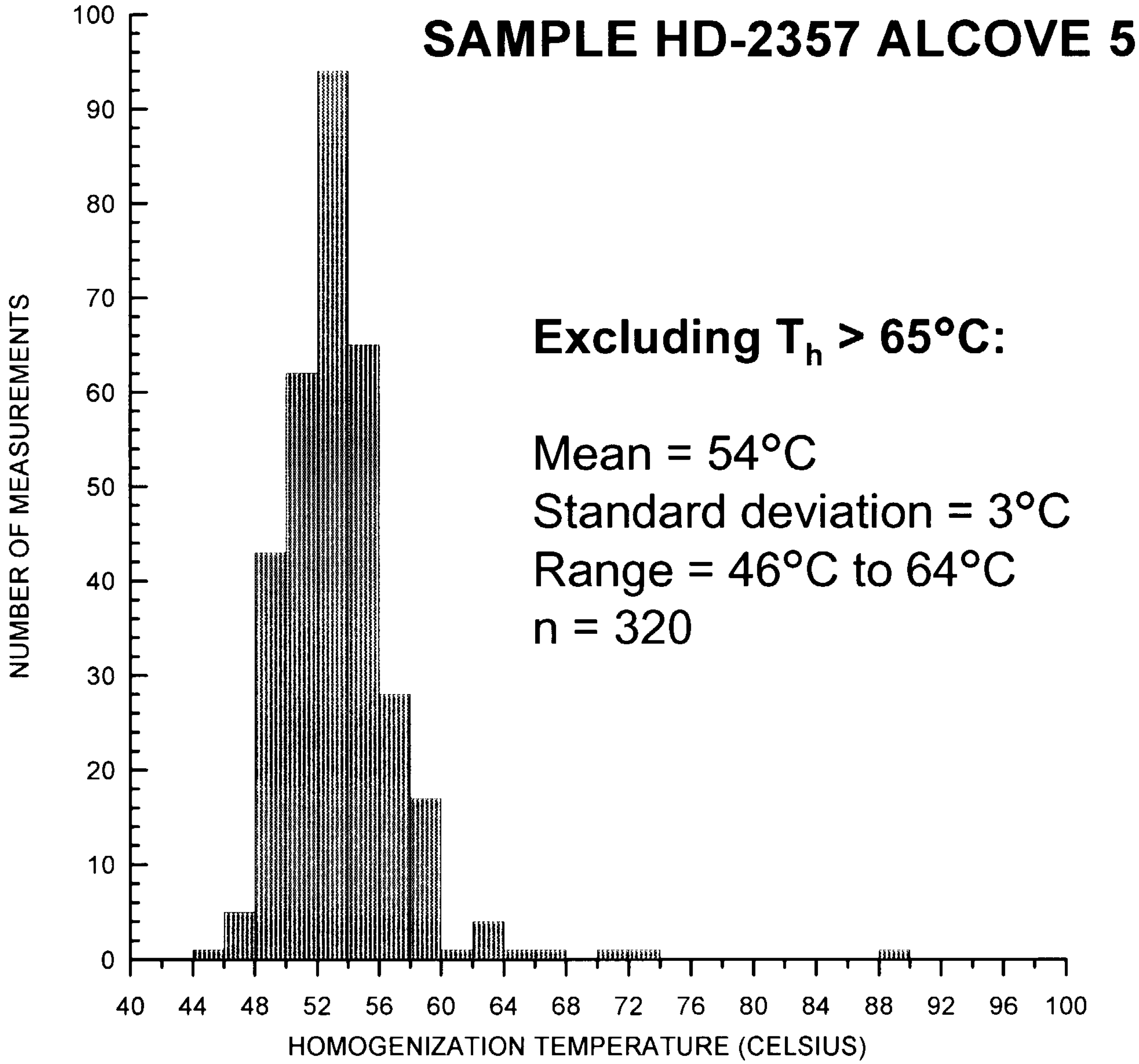
Fluid Inclusion Studies

- **Tiny voids in minerals that trap fluids**
- **With certain key assumptions, can be used to reconstruct fluid temperature and chemistry**
- **Unsaturated Zone calcite in Yucca Mountain contains three types:**
  - Single-phase, liquid-filled
  - Two-phase, with large and variable vapor-liquid ratios
  - Two-phase, with small and consistent vapor-liquid ratios
- **Two-phase inclusions may provide estimates of depositional temperatures of host minerals**

Fluid Inclusion Studies
(Continued)

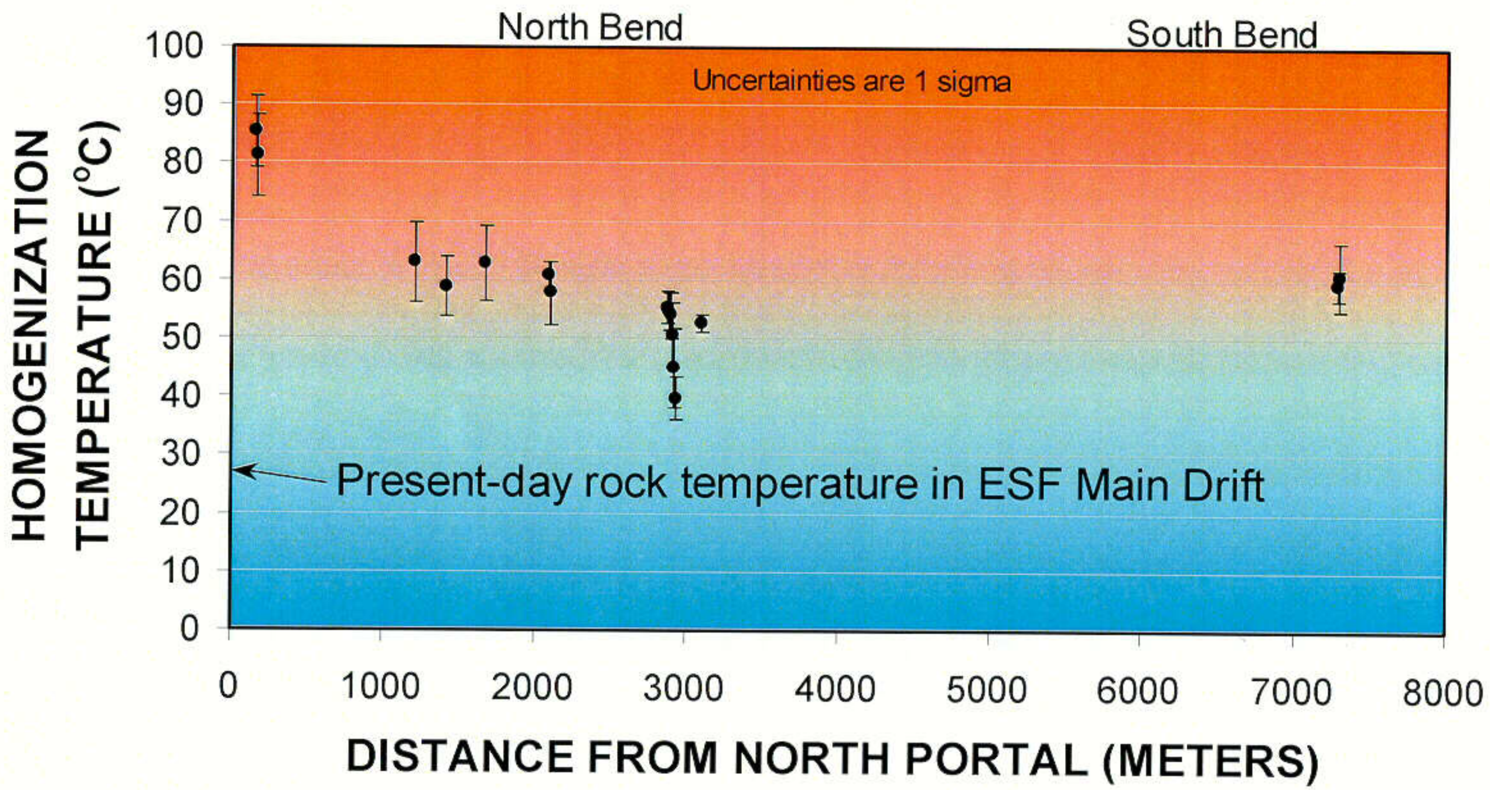
- ~50% of calcite deposits contain fluid inclusions indicating slightly elevated (40° - 80°C) depositional temperatures
- Most of these are in the earliest calcite stage, a few appear to be in intermediate stage, none have been found in latest calcite stage
- This fluid inclusion assemblage is consistent with calcite formation under vadose conditions, but at slightly elevated temperatures

Example Temperature Distribution



Reference: Work in progress

Fluid Inclusion Homogenization Temperatures



Reference: Work in progress

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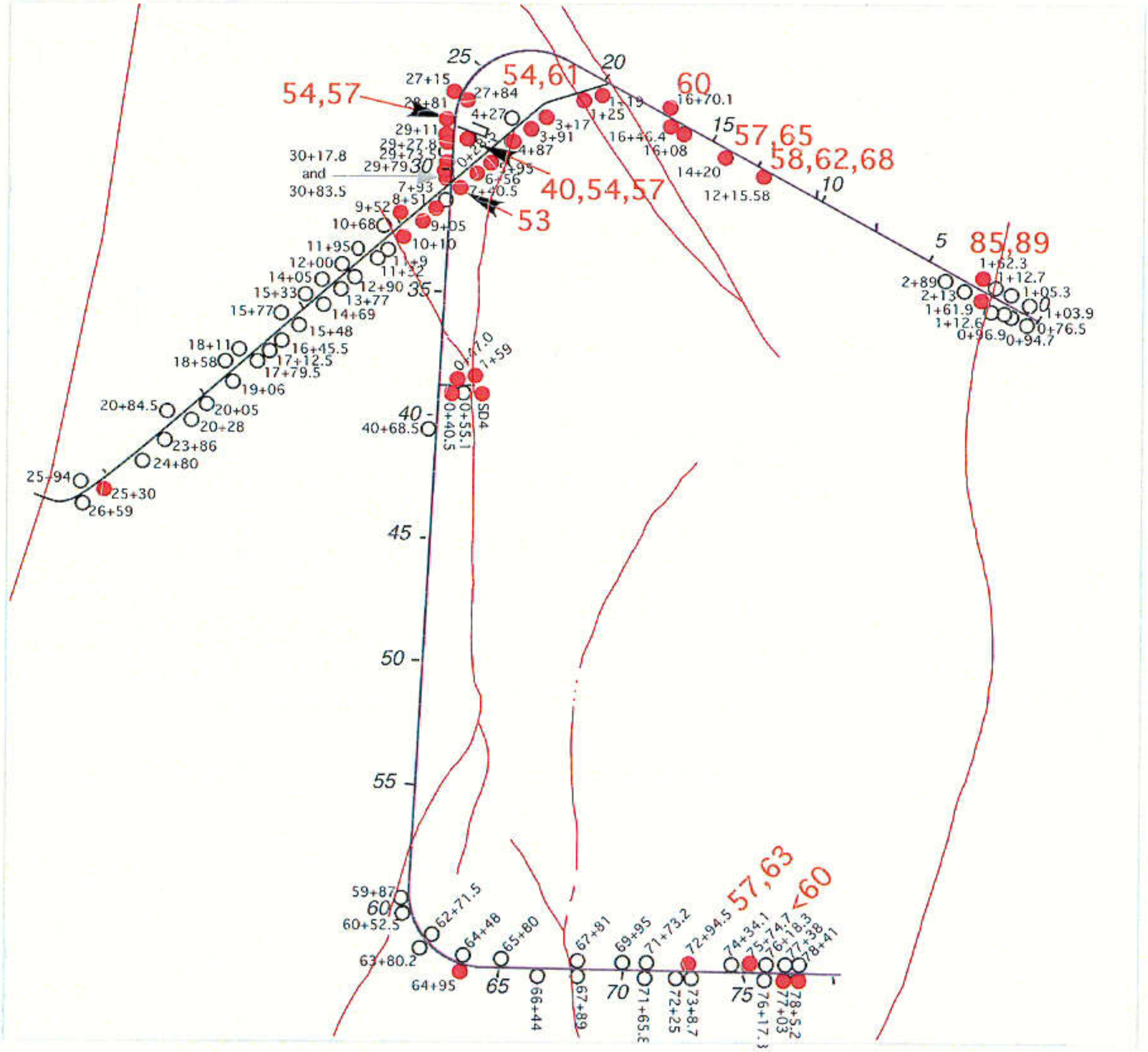
Distribution of Fluid Inclusion Temperatures in the Exploratory Studies Facility



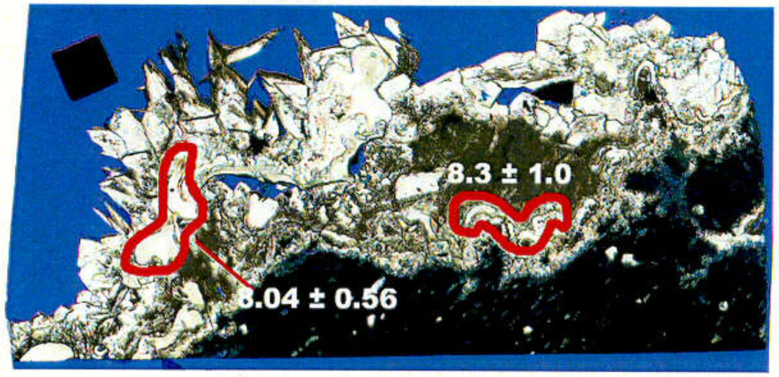
Reference: Work in progress

C71

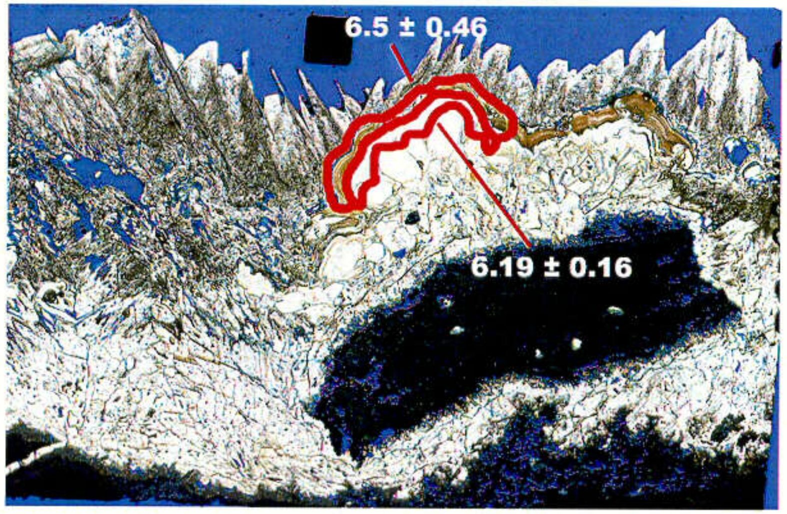
Constraining Ages of Fluid Inclusions

- U-Pb ages of opal constrain the timing of formation of calcite hosting two-phase fluid inclusions to at least >1.9 Ma
- Most bounding ages are much older than 1.9 Ma
- No evidence of elevated temperatures in late-stage calcite

ESF 72+94.5



ESF AL#5 0+28.5



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Potential Geothermal and Seismic Effects on Water Table and Update on Fluid Inclusion Study (Continued)

- **References**
  - *Saturated Zone Flow and Transport Process Model Report* (TDR-NBS-HS-000001 REV 00 ICN 01), Section 3.8
  - *Yucca Mountain Site Description* (TDR-CRW-GS-000001 REV 01), Section 4.4.5

Potential Geothermal and Seismic Effects on Water Table and Update on Fluid Inclusion Study (Continued)

- A large and comprehensive body of data shows that low-temperature fracture minerals formed from meteoric water percolating downward through the rock mass during the past 10 million years or longer
- University of Nevada, Las Vegas and U.S. Geological Survey work to be completed in the near future is expected to provide constraints on the time-temperature history of the rock mass in the unsaturated zone

Conclusions

- **This criterion has been addressed and should be closed**
  - The DOE has extensively investigated deposits that have been interpreted as providing evidence of potential geothermal and seismic effects on the ambient Saturated Zone flow system and the alternative models resulting from this interpretation. Detailed discussions of these investigations, interpretations, published reports, and reviews are provided in Section 4.4.5 of Rev. 1 of the *Yucca Mountain Site Description* and Section 3.8 of the *Saturated Zone Flow and Transport PMR*
  - The upwelling water alternative model is neither consistent with site data nor scientifically credible and the multiple independent reviews support this conclusion. In response to a Nuclear Waste Technical Review Board recommendation, U.S. Geological Survey and University of Nevada, Las Vegas investigations of fluid inclusions were initiated. Final results are expected in 2001

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Features, Events, and Processes in Saturated Zone Flow and Transport

Presented to:
DOE/NRC Technical Exchange on the Key Technical Issue Subissues Related to Saturated Zone Flow

Presented by:
Theresa Brown, Ph.D.
Civilian Radioactive Waste Management System Management and Operating Contractor

October 31 - November 2, 2000
Albuquerque, NM

YUCCA MOUNTAIN PROJECT

Outline

- Presentation Objective
- Scope of Revisions
- Status
- Summary of Results
- Conclusions

Presentation Objective

- **Describe the basis for revision to the *Saturated Zone Features, Events, and Processes Analysis and Model Report* and results of the analysis**

Scope of Revision

- **Add two new secondary Saturated Zone Features, Events, and Processes**
  - Soil leaching following ashfall (1.2.04.07.01)
  - Soil leaching to groundwater (2.3.02.02.10)
- **Update for results of other Rev. 00 Features, Events, and Processes Analysis and Model Reports**
- **Additional documentation of secondary Features, Events, and Processes analyses**
- **Add related NRC Issue Resolution Status Reports, treatment of Secondary Features, Events, and Processes and related Primary Features, Events, and Processes fields**
- **Address informal review comments**

Status

- Scope of Analysis and Model Report revised
- One “To Be Verified” assumption (water table rise included)
- Rev. 01 scheduled for completion December 2000

Summary of Results

YMP FEP Database ID#	FEP Description	TSPA Screening Decision
1.2.02.01.00	Fractures	Included (existing), Excluded (changes) –low consequence
1.2.02.02.00	Faulting	Included (existing), Excluded (changes in existing) – low consequence, Excluded (new) – low probability
1.2.03.01.00	Seismic Activity	Excluded – low consequence
1.2.04.02.00	Igneous Activity Causes Changes to Rock Properties	Excluded – low consequence
1.2.04.07.00	Ashfall	Excluded – low consequence

YMP = Yucca Mountain Project
FEP = Feature, event, or process
TSPA = Total System Performance Assessment

Summary of Results
(Continued)

YMP FEP Database ID#	FEP Description	TSPA Screening Decision
1.2.06.00.00	Hydrothermal Activity	Excluded – low consequence
1.2.09.02.00	Large-Scale Dissolution	Excluded – low consequence
1.2.10.01.00	Hydrologic Response to Seismic Activity	Excluded (effects of new faults) low probability Excluded (effects of existing fauluts) – low consequence
1.2.10.02.00	Hydrologic Response to Igneous Activity	Excluded – low consequence
1.3.07.01.00	Drought/Water Table Decline	Excluded – low consequence
1.3.07.02.00	Water Table Rise	Included (preliminary)
1.4.07.01.00	Water Management Activities	Included (existing), Excluded (changes) – regulatory guidance
1.4.07.02.00	Wells	Included
2.1.09.21.00	Suspension of Particles Larger than Colloids	Included

Summary of Results
(Continued)

YMP FEP Database ID#	FEP Description	TSPA Screening Decision
2.2.03.01.00	Stratigraphy	Included
2.2.03.02.00	Rock Properties of Host Rock and Other Units	Included
2.2.06.02.00	Changes in Stress Produce Change in Permeability of Faults	Excluded – low consequence
2.2.06.03.00	Changes in Stress Alter Perched Water Zones	Included
2.2.07.12.00	Saturated Groundwater Flow	Included
2.2.07.13.00	Water-Conducting Features in the Saturated Zone	Included
2.2.07.14.00	Density Effects on Groundwater Flow (Concentration)	Excluded – low consequence
2.2.07.15.00	Advection and Dispersion	Included
2.2.07.16.00	Dilution of Radionuclides in Groundwater	Included
2.2.07.17.00	Diffusion in the Saturated Zone	Included
2.2.08.01.00	Groundwater Chemistry/Composition in Unsaturated Zone and Saturated Zone	Included
2.2.08.02.00	Radionuclide Transport Occurs in a Carrier Plume in the Geosphere	Included

Summary of Results
(Continued)

YMP FEP Database ID#	FEP Description	TSPA Screening Decision
2.2.08.03.00	Geochemical Interactions in the Geosphere	Included
2.2.08.06.00	Complexation in the Geosphere	Included
2.2.08.07.00	Radionuclide Solubility Limits in the Geosphere	Included
2.2.08.08.00	Matrix Diffusion in Geosphere	Included
2.2.08.09.00	Sorption in the Unsaturated Zone and Saturated Zone	Included
2.2.08.10.00	Colloid Transport in the Geosphere	Included
2.2.08.11.00	Distribution And Release of Nuclides from the Geosphere	Included
2.2.09.01.00	Microbial Activity in Geosphere	Included
2.2.10.01.00	Repository Induced Thermal Effects in the Geosphere	Excluded – low consequence
2.2.10.02.00	Thermal Convection Cell Develops in Saturated Zone	Excluded – low consequence
2.2.10.03.00	Natural Geothermal Effects	Included
2.2.10.06.00	Thermo-Chemical Alteration	Included
2.2.10.07.00	Thermo-Chemical Alteration of the Calico Hills Unit	Excluded – low consequence

Summary of Results
(Continued)

YMP FEP Database ID#	FEP Description	TSPA Screening Decision
2.2.10.08.00	Thermo-Chemical Alteration of the Saturated Zone	Excluded – low consequence
2.2.10.13.00	Density Driven Groundwater Flow (Thermal)	Excluded (repository) – low consequence, Included (geothermal)
2.2.11.01.00	Naturally-Occurring Gases in the Geosphere	Excluded – low consequence
2.2.12.00.00	Undetected Features	Included
2.3.02.02.00	Radionuclide Accumulation in Soils	Included
2.3.11.04.00	Groundwater Discharge to Surface	Excluded – low consequence
3.1.01.01.00	Radioactive Decay and Ingrowth	Included
3.2.07.01.00	Isotopic Dilution	Included

Conclusions

- **Forty-seven Primary Saturated Zone Features, Events, and Processes**
  - Twenty-six included (one "To be Verified")
  - Four partially included/excluded
  - Seventeen excluded (based on low probability, low consequence and regulatory guidance)
- **New Features, Events, and Processes treated as follows:**
  - Soil leaching following ashfall - excluded due to low consequence
  - Soil leaching to groundwater - excluded due to low consequence

Conclusions
(Continued)

- **Secondary Features, Events, and Processes addressed explicitly**
- **Analysis and Model Report *Features Events and Processes in Saturated Zone Flow and Transport* Rev. 01 (ANL-NBS-MD-000002 REV 01) scheduled for completion December 2000**

Analysis of the Resolution of the Key Technical Issue on Unsaturated and Saturated Zone Flow Under Isothermal Conditions

Subissue 2: Hydrologic Effects of Climate Change

Importance to system performance: Overview: The wetter climates in the past suggest that more groundwater flowed beneath Yucca Mountain, compared to the modern climate. Several studies, discussed in CRWMS M&O (2000a, Section 9.4.2), show that the water table has risen less than 115 m in the past. To account for future changes in the water table elevation beneath Yucca Mountain, TSPA simulations use a water-table rise of 120 m for both the monsoon and glacial transition climates. Other hydrologic effects of climate change are incorporated in TSPA through the use of appropriate flow fields. Preliminary TSPA sensitivity and barrier importance analyses show no significant impact from hydrologic effects of climate change on expected performance for more than 10,000 years. Therefore, the hydrologic effects of climate change have been evaluated and preliminarily determined not to be principal factors in the postclosure safety case.		
Acceptance Criterion 1: If bounding analyses are used to predict climate-induced effects (water table rise, for example) the analyses are based on a reasonably complete search of paleoclimate data pertinent to water-table rise and other effects (for example, changes in precipitation and geochemistry), including, at a minimum, information contained in Paces, et al. (1996), Szabo, et al. (1994), Forester, et al. (1996).		
NRC Staff Analysis	**DOE Status**	**DOE-Proposed Path Forward**
Acceptance criterion status: **closed**. The staff could not find a reference to Paces et al. (1996) in the TSPA-VA. The treatment of water-table rise is, however, consistent with the conclusions in this reference. Future licensing documents should reference this article. (NRC 1999) The Hydrologic Effects of Climate Change (of which this acceptance criterion is a part) was statused as closed by the NRC in the UZ KTI meeting of August 16 and 17, 2000.	The DOE believes this criterion is **closed**. The implementation of the water table rise for future climates is discussed in the AMR: *Abstraction of Flow Fields for RIP* (CRWMS M&O 2000b, Section 6.2) and is based on several of the recommended literature sources.	No further action is needed. Current analyses satisfy this criterion.

Analysis of the Resolution of the Key Technical Issue on Unsaturated and Saturated Zone Flow Under Isothermal Conditions

Subissue 2: Hydrologic Effects of Climate Change

Acceptance Criterion 2: Regional and sub-regional models for the SZ that are used to predict climate-induced consequences are calibrated with the paleohydrology data, and are consistent with evidence that the water-table rise during the late Pleistocene was up to 120 m.

NRC Staff Analysis	DOE Status	DOE-Proposed Path Forward
Acceptance criterion status: **closed**. Data from Nye County's drilling program shows that the water table occurs about 16 m below the surface at well NC-EWDP-1D and about 30 m below the surface at well NC-EWDP-9S, indicating that groundwater has lowered by these amounts since the Wisconsin glacial maximum, about 20 ky before present. DOE has assumed a greater amount of water table rise, and therefore this criterion appears to be reasonably met. Finally, DOE's probabilistic treatment of climate and infiltration induces water-table rise at an expected future time 5 kyr hence. (NRC 1999) The Hydrologic Effects of Climate Change (of which this acceptance criterion is a part) was statused as closed by the NRC in the UZ KTI meeting of August 16 and 17, 2000.	The DOE believes this criterion is **closed**. As noted by the NRC Staff Analysis (NRC 1999) the site evidence no longer supports a water-table rise of up to 120 m during the late Pleistocene and DOE has assumed a water table rise greater than that supported by the evidence. DOE is planning a sensitivity run with the SZ site-scale flow model with a climate-induced water-table rise. As this rise will move the water table under the site into less permeable units, it believed that the adverse effects on performance will be negligible.	No further action is needed. Current analyses satisfy this criterion.

Subissue 2: Hydrologic Effects of Climate Change

Acceptance Criterion 3: DOE has incorporated future climate changes and associated effects in its performance assessments. For example, available information does not support the assumption that present-day climate will persist unchanged for 10 k.y. or more.		
NRC Staff Analysis	**DOE Status**	**DOE-Proposed Path Forward**
Acceptance criterion status: **closed**. Based on their review of TSPA-VA, the staff found that this criterion has been reasonably met. (NRC 1999) The Hydrologic Effects of Climate Change (of which this acceptance criterion is a part) was statused as closed by the NRC in the UZ KTI meeting of August 16 and 17, 2000.	The DOE believes this criterion is **closed**. For TSPA-SR, DOE continues to incorporate future climate change and the associated effects in its performance assessments indirectly through the incorporation of the effects of climate change on SZ flow and transport (CRWMS M&O 2000c).	No further action is needed. Current analyses satisfy this criterion.

Subissue 2: Hydrologic Effects of Climate Change

Acceptance Criterion 4: If used, expert elicitations are conducted and documented using the guidance in the Branch Technical Position on Expert Elicitation (NRC, 1996), or other acceptable approaches.

NRC Staff Analysis	DOE Status	DOE-Proposed Path Forward
Acceptance criterion status: **closed**. DOE has not used expert elicitation to refine assumptions about climate change. (NRC 1999) The Hydrologic Effects of Climate Change (of which this acceptance criterion is a part) was statused as closed by the NRC in the UZ KTI meeting of August 16 and 17, 2000.	The DOE believes this criterion is **closed**. The DOE did not use expert elicitation to evaluate the hydrologic effects of climate change.	No additional action is needed.

Subissue 2: Hydrologic Effects of Climate Change

Acceptance Criterion 5: The collection, documentation, and development of data, models, and computer codes have been performed under acceptable Quality Assurance Procedures (QAP). If they were not subject to an acceptable QAP, they have been appropriately qualified.

NRC Staff Analysis	DOE Status	DOE-Proposed Path Forward
Acceptance criterion status: **To Be Determined (TBD).** (NRC 1999) The Hydrologic Effects of Climate Change (of which this acceptance criterion is a part) was statused as closed by the NRC in the UZ KTI meeting of August 16 and 17, 2000.	DOE believes this criterion is **closed, pending.** Current analyses documented in the SZ Flow and Transport PMR (CRWMS M&O 2000c) and supporting AMRs were completed under acceptable quality assurance procedures. The status of technical inputs may be confirmed by review of the Document Input Reference System (DIRS) database. The DIRS database will be updated to indicate changes to the QA status of these data.	80% of the data related to the subject of this KTI have been qualified as of 7/31/00. A list of unqualified data supporting the Site Recommendation consideration Report will be provided to the NRC with the report. These unqualified data will be qualified by 6/25/01.

Subissue 3: Present-Day Shallow Infiltration

Acceptance Criterion 3: DOE has characterized shallow infiltration in the form of either probability distributions or deterministic upper-bound values for performance assessment, and provided sufficient data and analyses to justify the chosen probability distribution or bounding value.

NRC Staff Analysis	DOE Status	DOE-Proposed Path Forward
Acceptance criterion status: **open**. The staff noted an apparent bias in upper bound Mean Annual Infiltration (MAI) multipliers. DOE should assign equal weights to the upper and lower bounds for MAI multipliers or demonstrate that another approach achieves the same result (i.e. resolves the staff concern for the apparent bias).	The DOE believes this criterion is **closed, pending.** DOE has completed a plan to address comments raised at the Unsaturated Zone KTI meeting and transmitted it to the NRC. The work agreed upon in the plan will be completed.	Complete planned work. No further actions needed.

Subissue 5: Saturated Zone Ambient Flow Conditions and Dilution Processes

Importance to system performance: Groundwater flux and sorption including their variation in the volcanic aquifers and the valley fill alluvium along pathways that could transport radionuclides, are factors that can delay transport of radionuclides through the saturated zone. Retardation of radionuclide movement and dilution of radionuclide concentrations during migration are two principal factors that might greatly affect the performance of a potential repository.

Acceptance Criterion 1–DOE has considered conceptual flow and data uncertainties. Uncertainties due to sparse data or low confidence in the data interpretations have been considered by analyzing reasonable conceptual flow models supported by site data or by demonstrating through sensitivity studies that the uncertainties have little impact on repository performance.

NRC Staff Analysis	DOE Status	DOE-Proposed Path Forward
Acceptance Criterion Status: <u>open pending</u> review of future DOE groundwater modeling reports, milestone reports, and other submittals. Luckey et al. (1996) do an excellent job of describing the various conceptual models of site-scale hydrology as they were known at that time. Since then, a great deal of hydraulic and tracer test data have been collected from the C-Holes complex and analyzed. Confidence in characterization of flow in the tuff aquifer system could be improved by publication of final peer-reviewed reports regarding hydraulic and tracer testing at the C-Holes. (NRC 1999)	The DOE believes that this criterion is **<u>closed</u>**. As discussed in the SZFT PMR (CRWMS M&O 2000c) DOE has incorporated conceptual flow and data uncertainties. Enough information is available to incorporate uncertainty and variability into the TSPA (CRWMS M&O 2000c). The AMR: *Uncertainty Distributions for Stochastic Parameters* (CRWMS M&O 2000d) and the SZFT PMR (CRWMS M&O 2000c) consider uncertainty in the parameters used in the SZFT model for the purpose of TSPA. Data uncertainties are included in the stochastic analyses for TSPA for a large number of parameters relevant to groundwater flow and radionuclide transport. The potential existence of horizontal anisotropy in fracture permeability is considered as an alternative conceptual model of the SZ flow system in TSPA analyses. Alluvium Testing Complex (ATC) activities will help reduce uncertainties on groundwater flux and sorption in the valley fill alluvium along pathways. The SZFT PMR (CRWMS M&O 2000c) provides a more detailed discussion of hydraulic and tracer testing at the C-Holes. The C-wells final internally peer-reviewed report on hydraulic and tracer testing is being completed and is planned for publication in FY2001.	No additional work is needed.

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Acceptance Criterion 2: DOE has reasonably delineated possible flow paths from beneath the repository to potential receptor locations based on data that is sufficient to elucidate (i) the relative travel distances through aquifers of differing hydrologic and geochemical properties; (ii) in fractured-rock aquifers, the portions of flow through rock matrix and fractures; (iii) flow directions with respect to the hydraulic gradient, considering the potential effects of horizontal anisotropy; (iv) approximate volume fluxes and pore velocities; and (v) vertical hydraulic gradients, including the potential for flow between the Paleozoic carbonate aquifer and the volcanic tuff aquifer. A sufficient number of wells and exploratory holes should be drilled, and an adequate number of tests conducted, to reasonably bound the hydraulic and transport properties of the units downgradient from the proposed repository.

NRC Staff Analysis	DOE Status	DOE-Proposed Path Forward
Acceptance Criterion Status: **Partly resolved.** Flow paths from the proposed repository to a 20-km distance appear to be bounded within a relatively narrow arc. (NRC 1999)	The DOE believes that this criterion is **closed.** Flow paths from beneath the repository to potential receptor locations have been delineated based upon multiple lines of evidence including areal distributions of chemical and isotopic data, and gradients of measured head (CRWMS M&O 2000c and 2000i). Enough information is available to incorporate uncertainty and variability into the TSPA (CRWMS M&O 2000c). Hydraulic and transport properties downgradient have been bounded (CRWMS M&O 2000d), and additional testing is ongoing to reduce uncertainty. Additional discussions of the subelements of the criterion are provided in the following sections of the DOE Status.	Complete planned Phase III of NCEWDP and ATC.
DOE should continue efforts to fill in data gaps with new wells in the valley fill deposits that lie along the possible flow paths to the exposure group, and to interpret existing data from the tuff aquifer.	New wells (NCEWDP) and the alluvium testing complex (ATC) in the valley fill deposits that lie along the possible flow paths to the exposure group will be used to acquire additional data in the valley fill deposits that lie along the flow paths to the potential exposure group.	No additional work is needed.

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Hydraulic and tracer testing should be conducted on a scale large enough to include a statistically representative elementary volume in the fracture network in tuffs (i.e., latest tests in the C-wells and hydraulic tests at SD-6) and in the valley-fill aquifer.	Multi-well pump testing of the tuffs at the C-wells complex has been performed with monitoring wells at distances of up to approximately 3 km from the pumping well. These tests stress a large enough part of the tuff aquifer to include a statistically representative elementary volume of the fracture network (CRWMS M&O 2000a, Section 9.3.3). Hydraulic and tracer testing is being conducted in the valley fill aquifer at the ATC.	No additional work is needed
Repository performance predictions should be made for a reasonable set of conceptual flow models.	Repository performance assessments are made for reasonable set of conceptual flow models (CRWMS M&O 2000e). Alternative models have been considered (CRWMS M&O 2000c, Section 3.8).	No additional work is needed
DOE has yet to delineate where the water-table transitions from the tuffs to the overlying valley-fill aquifer.	The uncertainty in the northerly extent of the alluvium in the SZ of the site-scale flow and transport model is abstracted as a polygonal region that is assigned radionuclide transport properties representative of the valley-fill aquifer hydrogeologic unit. The dimensions of the polygonal region are stochastically varied in the SZ flow and transport simulations for TSPA calculations (CRWMS M&O 2000d). Efforts are underway to refine the delineation of where the water-table transitions from the tuffs to the overlying valley fill aquifer through the Nye County EWDP and geophysical investigations and interpretations.	No additional work is needed
Another factor that may affect the relative travel distances through tuff and valley-fill aquifer systems is horizontal anisotropy in the fractured tuff aquifer due to preferential north-south orientation of fractures and faults.	Horizontal anisotropy of permeability in fractured tuff units has been included in SZ flow and transport simulations for TSPA-SR as an alternative conceptual model (CRWMS M&O 2000e).	No additional work is needed

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Pore velocity estimates are poorly constrained over the entire flow path due to a wide range of estimates regarding effective flow porosities in the fractured tuff aquifer, and paucity of data for the valley-fill aquifer.	The effective porosity approach for flow in fractured tuffs is not used in SZ flow and transport simulations for TSPA-SR. A dual-porosity approach is used to explicitly account for matrix diffusion in the fractured tuffs (CRWMS M&O 2000d). Porosity estimates are being refined through measurements in the valley-fill aquifer. Cross-hole tracer tests in the valley-fill aquifer will provide direct evidence regarding effective porosity in this unit.	No additional work is needed
The valley-fill aquifer has great potential to retard contaminants that reach that distance. Exploratory drilling and geophysical surveys should be used in addition to the Nye County wells to obtain data within data gaps to delineate where the water table transitions from the tuff aquifer to the overlying valley-fill aquifer, and to reveal lengths of flowpaths in the valley-fill. One location to explore is about 2 km northwest of well 2D, which would confirm the length of a due-south flowpath in valley-fill materials. Another key area to investigate is the data gap between the Washburn 1-X well and JF-3.	The Nye County drilling program has now completed well 19D in saturated alluvium, which is located approximately 2 km to the northeast of well 2D. This well is north of Washburn 1-X well and south of well JF-3 and helps to better define the transition from tuff to valley fill. Additional wells are planned at locations 22S and 20D that will further enhance the confidence in the location of the alluvial contact between the Washburn 1-X well and well JF-3. A borehole west to northwest of Nye County well 19D may be considered in out year planning. However, there is a problem of being able to access this area with a drill rig.	No additional work is needed

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The separation of dissolved organic carbon from groundwater should be applied to samples collected at YM to independently estimate the average groundwater residence time at locations within the saturated zone.	Flow paths and residence times have been evaluated using geochemical and isotopic methods and are discussed in CRWMS M&O (2000i). Measurements of C-14 content in dissolved organic carbon from groundwater samples along the flow path at Yucca Mountain to independently estimate the average groundwater residence time at locations within the saturated zone is included in planning for FY2001.	No additional work is needed
Information about flow conditions in the Paleozoic carbonate aquifer beneath YM is based on only one well, UE-25 p#1. The existence of an upward hydraulic gradient from the carbonate is not incorporated in the current DOE studies. (NRC 1999)	The upward gradient, as observed at well UE-25 p#1, is simulated in the SZ site-scale flow and transport model. Nye County Borehole NC-EWDP-2DB penetrated the top of the carbonates at 2865 feet deep on 8/27/2000 (Source: http://www.nyecounty.com/daily_rpts/Dly_wk08_27.pdf) More Nye County wells are planned to penetrate the carbonate aquifer in 2001. Therefore, more data will be available to refine the upward hydraulic gradient.	No additional work is needed

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Acceptance Criterion 3: DOE has provided an hydrologic assessment to describe likely causes of the "moderate hydraulic gradient" and the "large hydraulic gradients."		
NRC Staff Analysis	**DOE Status**	**DOE-Proposed Path Forward**
Acceptance Criterion Status: **<u>Open pending</u>** submission and staff review of DOE reports on the drilling and testing of wells WT-24 and SD-6. Planned hydraulic testing in well SD-6 should be sufficient to complete characterization of the moderate hydraulic gradient, provided that nearby wells H-6, H-5, and others east of the Solitario Canyon fault are monitored during the testing. Preliminary reports suggest that the well is not highly productive and that the scale of hydraulic testing may therefore be limited. (NRC 1999)	The DOE believes that this criterion is **<u>closed.</u>** The large and moderate hydraulic gradient are represented in the SZ flow and transport model (CRWMS M&O 2000c). An expert elicitation panel on SZ flow and transport convened by DOE addressed the issue of the cause of the large hydraulic gradient, among other issues (CRWMS 1998, pp. 3-5 to 3-6). The panel narrowed the theories to the two most credible hypotheses: flow through the upper volcanic confining unit or semi-perched water; and the consensus of the panel slightly favored semi-perched water. The experts were in agreement that the issue was mainly one of technical credibility, that the probability of any large transient change in the configuration of the large gradient is low, and that long-term transient readjustment of gradients was of low probability (CRWMS 1998, p. 4-3). Borehole USW WT-24 was drilled in the area of the large gradient and reportedly encountered a perched saturated zone at 987 m elevation, then an unsaturated interval to 840 m, where saturated conditions were encountered. However, borehole USW WT-24 was terminated at an elevation 630 m, and this was not deep enough to test conclusively whether the small hydraulic gradient extended that far north.	No additional work is needed.

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	With respect to the cause of the large hydraulic gradient, the drilling of borehole USW WT-24 demonstrated that the previous portrayal of the large gradient (Tucci and Burkhardt 1995, Figure 4) probably included perched water; however, the question of whether perching of water is the cause of the large gradient was not finally resolved. CRWMS M&O (2000f) treats the large hydraulic gradient area as a linear east-west barrier or zone of reduced permeability in the site-scale SZ flow and transport model. Luckey et al. (1996, p. 25) suggest that the Solitario Canyon fault and its splays function as a barrier to flow from west to east due either to the presence of poorly permeable fault gouge (similar to that since noted in the ECRB cross-drift) or because of juxtaposition of more permeable units against less permeable units. Additional information on boreholes USW SD-6 and USW WT-24 is provided in CRWMS M&O 2000j and its supporting documents, and in CRWMS M&O 2000a and CRWMS M&O 2000c; as such, there are no current plans to publish formal reports on these boreholes.	

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Acceptance Criterion 4: DOE has provided maps of approximate potentiometric contours of the regional uppermost aquifer for an area that, at a minimum, includes wells J-11 on the east, VH-1, VH-2, and the GEXA Well on the west, UE-29a#2 to the north, and domestic and irrigation wells south of Amargosa Valley (aka Lathrop Wells). Maps of regional and site-scale recharge and discharge should be provided, along with site-scale hydrostratigraphic cross sections constructed along the paths to the accessible environment, and site-scale flow-net analysis of the SZ.

NRC Staff Analysis	DOE Status	DOE-Proposed Path Forward
Acceptance Criterion Status: **Open pending** review of relevant DOE milestone reports The TSPA-VA analysis included a site scale potentiometric map. However, the map does not include data from irrigation wells south of Amargosa Valley. (NRC 1999)	The DOE believes that this criterion is **closed.** DOE has provided maps of approximate potentiometric contours of the regional uppermost aquifer for an area that, at a minimum, includes wells J-11 on the east, VH-1, VH-2, and the GEXA Well on the west, UE-29a#2 to the north, and domestic and irrigation wells south of Amargosa Valley (Tucci and Burkhardt 1995; Figure 3-5 in SZFT PMR, CRWMS M&O 2000c; and Water Level AMR, USGS 2000).	No additional work needed.
Regional infiltration, evapotrans-piration, spring discharges, and pumping estimates are currently being prepared or are being refined. No flow net analyses were performed by the DOE.	Regional infiltration, evapotranspiration, spring discharges, and pumping estimates are included in the regional model and are being refined for the updated regional model. Flow net analyses were not performed. However it is believed that the 3-D modeling for the site scale model obviates the need for flow net analyses as the 3-D modeling in CRWMS M&O (2000f) provides a more detailed analysis of flow than a 2-D flow net.	No additional work is needed

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Acceptance Criterion 5: DOE estimates of key hydrologic parameters are described in the form of either probability distributions or deterministic bounding values that are reasonably consistent with site data. These parameters should include transmissivity, hydraulic gradient, effective flow porosity, effective immobile porosity, and effective aquifer thickness.

NRC Staff Analysis	DOE Status	DOE-Proposed Path Forward
Acceptance Criterion Status: **<u>Open pending</u>** review of future Nye County reports and DOE milestone reports on testing in the tuffs. DOE should continue efforts to fill in data gaps.	DOE believes that this criterion is **<u>closed, pending</u>**. Enough information is available to incorporate uncertainty and variability into the TSPA (CRWMS M&O 2000c). DOE plans to complete a program of data acquisition at the NCEWDP wells and ATC to reduce uncertainty.	No additional work is needed
Interpretation of existing data from hydraulic and tracer tests in the tuff aquifer should continue, and hydraulic testing should be conducted in the recently completed wells SD-6 and WT-24. DOE should use exploratory boring techniques to help fill in large data gaps between existing and planned Nye County wells. This would help confirm lengths of flowpaths in saturated valley fill.	Flow paths from beneath the repository to potential receptor locations have been delineated based upon multiple lines of evidence including areal distributions of chemical and isotopic data, and gradients of measured head (CRWMS M&O 2000c and 2000i). There is enough information available to incorporate uncertainty and variability into the TSPA (CRWMS M&O 2000c). Wells USW SD-6 and USW WT-24 are discussed in this table under Acceptance Criterion 3 in of Subissue 5. DOE continues to add to the existing data with data gathered through the cooperative agreement with Nye County.	No additional work is needed

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Confidence in estimated parameters for the valley-fill aquifer is low due to the paucity of hydrologic data. Emphasis should be placed on obtaining heads, transmissivity, hydraulic conductivity, effective porosity, and dispersion coefficients for the valley-fill aquifer.	Values of parameters currently used for valley fill aquifer are based upon evaluation of regional values for similar type deposits and are supported by information from expert elicitation (CRWMS M&O 2000d). Enough information is available to incorporate uncertainty and variability into the TSPA (CRWMS M&O 2000e). Planned work for the NCEWDP and at the ATC will continue to refine these values.	No additional work is needed
Considerable uncertainty remains regarding effective flow porosities in the tuff aquifer. Continued interpretation of hydraulic and tracer testing at the C-well complex may result in improved estimates. Preferential fracture and fault orientations in the tuff aquifer may result in aquifer anisotropy, yet transmissivity in DOE flow models has been treated as an isotropic parameter.	DOE model explicitly represents known faults and flowing features that directly influence the calibration of the SZ site-scale flow model (CRWMS M&O 2000f, Section 6.3). Horizontal anisotropy of permeability in fractured tuff units has been included in SZ flow and transport simulations for TSPA-SR as an alternative conceptual model (CRWMS M&O 2000e).	No additional work is needed

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Effective porosity is a critical parameter that has not yet been evaluated for the valley fill. Estimates should be obtained and compared using various methods, such as field tracer tests, lab analyses, borehole geophysics, and specific yield. Field tracer tests are especially needed to estimate effective porosity and dispersivity for the valley fill.	Values of parameters currently used for valley fill aquifer are based upon evaluation of regional values for similar type deposits and are supported by information from expert elicitation (CRWMS M&O 2000d). There is enough information available to incorporate uncertainty and variability into the TSPA (CRWMS M&O 2000c). Additional porosity estimates are being made through measurement in the valley fill aquifer. Cross-hole tracer tests in the valley-fill aquifer will provide direct evidence regarding effective porosity in this unit to further refine estimates.	No additional work is needed
DOE should also perform downhole logging with an accelerator porosity sonde (APS) in any new Nye County wells. This tool, along with other logs, would provide the best borehole logging results for formation porosity in the valley fill, even better than that given by previously developed compensated neutron systems. The neutron logs should be appropriately calibrated, standardized, and corrected to obtain reasonable porosity estimates for valley fill. APS logs should also be obtained for existing Nye wells that can readily be re-entered.	Geophysical logging will be used to provide estimates of total porosity in the valley-fill aquifer. However, geophysical methods are incapable of distinguishing between porosity that is available to groundwater flow and porosity that is inaccessible to groundwater flow due to low permeability. DOE is still evaluating the possible use of APS vs. other methods of data acquisition as it is unclear that APS will provide better results. Cross-hole tracer testing in the valley-fill aquifer will provide more definitive evidence of effective porosity than additional specialized geophysical measurements.	No additional work is needed

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DOE should prepare a report to summarize the resulting porosity data, that also includes analysis of physical and chemical properties of valley fill materials sampled below the water table. Data should include conventional particle size analyses (percentages of clays, silts, sands, gravels, etc.). The report should include x-ray analyses of clay mineral types and abundances. (NRC 1999)	Reports published on the ATC and Nye County wells will include porosity data and evaluations. However, there are no current plans to publish separate reports on properties of valley fill materials.	No additional work is needed

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Acceptance Criterion 6: DOE has used mathematical groundwater model(s) that incorporate site-specific climatic and subsurface information. The models were reasonably calibrated and reasonably represent the physical system. Fitted aquifer parameters compare reasonably well with observed site data. Implicitly- or explicitly-simulated fracturing and faulting are consistent with the data in the 3D geologic model. Abstractions are based on initial and boundary conditions consistent with site-scale modeling and the regional models of the Death Valley groundwater flow system. Abstractions of the groundwater models for use in PA simulations should use appropriate spatial- and temporal-averaging techniques.

NRC Staff Analysis	DOE Status	DOE-Proposed Path Forward
Acceptance Criterion Status: **Open pending** review of future DOE performance assessments.	DOE believes that this criterion is **closed.** As discussed in the SZ PMR (CRWMS M&O 2000c), the mathematical groundwater model incorporates site-specific information and is reasonably calibrated and reasonably represents the physical system. Fitted aquifer parameters compare reasonably well with observed site data; implicitly and explicitly simulated fracturing and faulting are consistent with the data in the 3-D geologic model; and abstractions are based on initial and boundary conditions consistent with site-scale modeling and the regional models of the Death Valley groundwater flow system. Abstractions of the groundwater model used in PA simulations use appropriate spatial- and temporal-averaging techniques.	Update the model with new data gathered by NCEWDP and ATC to further reduce uncertainty

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The hydrogeology framework model needs to be updated to fill the large data gaps south of YM. Also, the model should incorporate horizontal anisotropy. Further calibration of the regional flow model should be performed to better match the range of estimated parameters with observed values and reduce the hydraulic head residuals.	The hydrogeologic framework model has been, and continues to be, updated to incorporate Nye County and new data, new geologic cross sections, and aeromagnetic data. Horizontal anisotropy of permeability in fractured tuff units has been included in SZ flow and transport simulations for TSPA-SR as an alternative conceptual model (CRWMS M&O 2000e).	No additional work is needed
For the climate change effects on regional flow, the top layer of the model should be treated in a manner that accounts for climate-induced water-table rise. Alternatively, DOE can demonstrate that the neglect of water-table rise will be conservative, in terms of SZ transport, due to an increase in length of the flowpath in the valley-fill aquifer.	DOE is planning a sensitivity run with the SZ site-scale flow model with a climate-induced water-table rise. As this rise will move the water table under the site into less permeable units, it believed that the adverse effects on performance will be negligible..	No additional work is needed

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The regional model is based on a hydrogeologic framework model that does not have sufficient information on the hydrogeology of the area downgradient of YM due to lack of borehole or geophysical information. As a result of this lack of site data, the regional flow model is also not adequately calibrated. The regional model does not have a capability to assess effects of the climate-induced water-table rise that is expected to occur under future cooler, wetter climates. A water-table rise would induce flow through hydrostratigraphic units that are presently unsaturated, possibly resulting in altered flow directions and velocities. Thus, the effects of climate-induced changes on regional flow patterns may not be reasonably bounded in the TSPA -VA, which derives estimates of SZ flux and flow direction from the regional flow model.	There is enough information available to incorporate uncertainty and variability into the TSPA (CRWMS M&O 2000c). The regional-scale SZ flow model is being revised to incorporate a hydrogeologic framework model that includes a significantly higher-resolution stratigraphy that is more consistent with the hydrogeologic framework model in the SZ site-scale model. DOE is planning a sensitivity run with the SZ site-scale flow model with a climate-induced water-table rise. As this rise will move the water table under the site into less permeable units, it believed that the adverse effects on performance will be negligible.	No additional work is needed

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The TSPA-VA simulations, using a 3D flow model and a 1D transport model, assume the system as isotropic and homogeneous at large scale. There is ample evidence this may not be the case. Use of a dilution factor approach to incorporate the effects of transverse dispersivity is not supported by analyses. Methods proposed by DOE for future TSPA analyses will not use this dilution factor approach. (NRC 1999)	Horizontal anisotropy of permeability in fractured tuff units has been included in SZ flow and transport simulations for TSPA-SR as an alternative conceptual model (CRWMS M&O 2000e). The dilution factor approach from TSPA-VA is not used in TSPA-SR and transverse dispersion is explicitly simulated in the SZ site-scale flow and transport model (CRWMS M&O 2000e).	No additional work is needed

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Acceptance Criterion 7: If credit for wellbore dilution is taken, a demonstration has been provided that reasonable assumptions have been made about well design, aquifer characteristics, plume geometry, withdrawal rates, and capture zone analysis for the receptor location.		
NRC Staff Analysis	**DOE Status**	**DOE-Proposed Path Forward**
Acceptance Criterion Status: **Resolved**. The staff have no further questions at this time If DOE does not take any explicit credit for wellbore dilution, this is acceptable to the staff. If DOE takes credit for wellbore dilution in future submittals the staff will evaluate the information to determine if the acceptable criterion has been met. (NRC 1999)	DOE believes that this criterion is **closed.** No additional credit for any wellbore dilution specifically due to well pumping is taken in TSPA.	No additional action is needed.

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Acceptance Criterion 8: If credit is taken for dilution due to either dispersion, groundwater mixing below the repository footprint, or mixing of the Yucca Mountain water with water from the north in Fortymile Wash, reasonable assumptions have been made about spatial and temporal variations of aquifer properties and groundwater volumetric fluxes.

NRC Staff Analysis	DOE Status	DOE-Proposed Path Forward
Acceptance Criterion Status: **Open, pending** review of future DOE performance assessments. At that time the use of random walk particle tracking in the overall TSPA will be evaluated. (NRC 1999)	DOE believes that this criterion is **closed.** Dispersion is explicitly simulated as a random-walk process in the site-scale SZ flow and transport model that occurs in the longitudinal and transverse directions. Only longitudinal dispersion is simulated in the one-1-D SZ transport model (CRWMS M&O 2000c). As discussed in the SZ AMR: *Saturated Zone Transport Methodology and Transport Component Integration* (CRWMS M&O 2000g), DOE believes the particle-tracking algorithm used is suitable for performing saturated-zone flow and transport simulations for the TSPA analyses. The model is a considerable improvement over the TSPA-VA model because it allows transport results to be derived directly from the saturated-zone process model rather than through a cumbersome and difficult-to-justify abstraction process. The flow and transport processes determined to be relevant in the site characterization program are captured with the model. These processes include advection, dispersion, sorption, and matrix diffusion. The capability of assigning a small source region and simulating the transport of a plume that has dimensions that are smaller than the size of a grid block are particularly attractive features of the model. To accomplish these goals, a new form of the particle-tracking formulation was	No additional work is needed

	derived to account for anisotropic dispersion—specifically, independent terms for horizontal and vertical transverse dispersivity. In addition, new model development was required to allow for finite spacing between fractures in the matrix-diffusion model. These features were incorporated into FEHM, and extensive validation testing demonstrated that the various processes are adequately captured in the code. Therefore, the particle-tracking model is suitable for use in transport analyses of the saturated zone. In the SZ flow and transport model, the dispersive component of the transport is calculated using the random-walk method (Tompson and Gelhar 1990). This approach is based on the analogy between the mass transport equation and the Fokker-Plank equation of statistical physics. The dispersive displacement of each particle is computed using uniform random numbers, based on the dispersivity tensor and the porous flow velocity field at the particle location. The proper terms in the random-walk algorithm are derived from an anisotropic version of the dispersion coefficient tensor defined by Burnett and Frind (1987). Sorption and diffusion processes are captured using a matrix-diffusion submodel, which delays particles in accordance with a semianalytical solution that includes sorption and diffusion into the rock matrix away from the flowing fractures. Linear equilibrium sorption and diffusion from equally spaced fractures into a stagnant matrix fluid are assumed.	

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Acceptance Criterion 9: DOE has incorporated key conclusions regarding potential geothermal and seismic effects on the ambient SZ flow system (e.g., National Research Council 1992; NWTRB 1998d; Craig 1997).

NRC Staff Analysis	DOE Status	DOE-Proposed Path Forward
Acceptance Criterion Status: **<u>Open pending</u>** review of data on fluid inclusions, and review of future DOE performance assessments The staff await results of a program to collect, date, and analyze mineral fluid inclusions from the underground at YM. (NRC 1999)	DOE believes that this criterion is **<u>closed.</u>** The DOE has extensively investigated deposits that have been interpreted as providing evidence of potential geothermal and seismic effects on the ambient SZ flow system and the alternative models resulting from this interpretation. A detailed discussion of these investigations, interpretations, published reports, and reviews is provided in CRWMS M&O (2000a; Section 4.4.5). The upwelling water alternative model regarding potential geothermal and seismic effects on the ambient SZ flow system has been reviewed by multiple panels and individual reviewers independent of, and external to, the DOE (Powers et al. 1991; Powers, 1991; Archambeau and Price 1991; Evernden 1992; National Research Council 1992; CRWMS M&O 1998; Leslie 1994; and Cohon 1998). With the exception of the authors of the minority report (Archambeau and Price 1991), who were chosen for the review by the proponent of the upwelling water model, the external reviewers and review panels have found little or no basis to support the upwelling water model. Evernden (1992, p. 60) noted that the reports in support of the upwelling model include errors in their interpretations and conclusions. Leslie (1994) found inadequate documentation of supporting assertions and that key components of the model are based on flawed premises. The NWTRB states that the	No additional work is needed

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	reports supporting the upwelling model contain unsubstantiated conclusions; errors of fact and *ex cathedra* statements not supported by any, or dubious, evidence; and *non sequiturs*, special pleadings, reliance on dubious conclusions reported in the earlier reports, and assertions presented as proofs (Cohon 1998, p. 3). The DOE believes that the upwelling water alternative model is neither consistent with site data nor scientifically credible and that the multiple independent reviews support this conclusion. However, in response to the NWTRB recommendation (Cohon 1998), DOE-funded investigations of fluid inclusions by the USGS and the University of Nevada-Las Vegas were initiated. The fluid inclusions studies are continuing with final results expected in 2001.	

Subissue 5: Saturated Zone Ambient Flow Conditions and Dilution Processes

Acceptance Criterion 10: If used, expert elicitations are conducted and documented using the guidance in the Branch Technical Position on Expert Elicitation (NRC, 1996), or other acceptable approaches

NRC Staff Analysis	DOE Status	DOE-Proposed Path Forward
Acceptance Criterion Status: **Resolved.** The staff have no further questions at this time The expert elicitation on SZ flow and transport was conducted and documented in an acceptable way. (NRC 1999)	DOE believes this criterion is **closed.** DOE believes that the process followed in the expert elicitation was consistent with acceptable approaches for eliciting experts (CRWMS M&O 1998, p. 2-2).	No further action needed.

Subissue 5: Saturated Zone Ambient Flow Conditions and Dilution Processes

Acceptance Criterion 11: The collection, documentation, and development of data, models, and computer codes have been performed under acceptable Quality Assurance Procedures (QAP). If they were not subject to an acceptable QAP, they have been appropriately qualified.		
NRC Staff Analysis	**DOE Status**	**DOE-Proposed Path Forward**
Acceptance Criterion Status: **TBD.** (NRC 1999)	The DOE believes this criterion is **closed, pending.** The Saturated Zone Flow and Transport Process Model Report and supporting AMRs were completed under acceptable quality assurance procedures. The status of technical inputs may be confirmed by review of the Document Input Reference System (DIRS) database. The DIRS database will be updated to indicate changes to the QA status of these data.	80% of the data related to the subject of this KTI have been qualified as of 7/31/00. A list of unqualified data supporting the Site Recommendation Consideration Report will be provided to the NRC with the report. These unqualified data will be qualified by 6/25/01.

Subissue 6: Matrix Diffusion

Importance to System Performance: TSPA sensitivity and barrier importance analyses show little sensitivity of estimates of expected performance for more than 10,000 years. However, delay in the migration of radionuclides through the unsaturated zone and saturated can add margin to meeting the postclosure performance objective and is therefore considered to be important in providing reasonable assurance that the performance objective is met. TSPA models indicate that matrix diffusion could contribute to this delay and may therefore be given credit in the postclosure safety case. Additional studies are planned to determine whether this credit can be justified.		
Acceptance Criterion 2: If credit for matrix diffusion in the SZ is taken, rock matrix and solute diffusion parameters must be (i) based on a SZ transport model that reasonably matches the results of the field tracer tests that are conducted over different distance scales and flow rates with multiple tracers of different diffusive properties, and (ii) consistent with laboratory data.		
NRC Staff Analysis	**DOE Status**	**DOE-Proposed Path Forward**
Acceptance criterion status: **open, pending** review of future DOE performance assessments and milestone reports. DOE would have to provide a technical analysis to support the chosen distribution of effective flow porosities used in the TSPA-VA It is the staff's understanding, that for future TSPA analyses, the DOE will adopt a different approach to including matrix diffusion processes in SZ transport models--an approach that explicitly considers aquifer physical properties such as spacing between flowing fractures. As this approach is currently under development by DOE, the methods have yet to be made available for staff review. (NRC 1999)	The DOE believes this criterion is **closed**. The approach used in TSPA-VA has been revised to include consideration of flowing interval spacing (CRWMS M&O 2000h) and this AMR: *Probability Distribution for Flowing Interval Spacing*, has been transmitted to the NRC. The C-wells reactive tracer test demonstrated that models that incorporate matrix diffusion provide more reasonable fits to the tracer-experiment data than those that assume a single continuum. The matrix sorption coefficient that fit the data for the lithium tracer in the C-wells reactive tracer experiment agreed well with the value determined in laboratory sorption tests. This provides confidence that the matrix-diffusion model is appropriate. The fact that the early lithium response had the same timing as that of the nonsorbing tracers, but with a lower normalized peak concentration, is consistent with matrix diffusion coupled with sorption in the matrix (CRWMS M&O 2000c, Sections 3.1.3.2, 3.2.4.2 and 3.2.4.3). DOE plans to complete and publish reports on C-well testing	No additional work is needed

Subissue 6: Matrix Diffusion

Acceptance Criterion 3: If used, expert elicitations are conducted and documented using the guidance in the Branch Technical Position on Expert Elicitation (NRC, 1996), or other acceptable approaches.		
NRC Staff Analysis	**DOE Status**	**DOE-Proposed Path Forward**
Acceptance criterion status: **closed**. The staff is not aware of any plans for DOE to use expert elicitation in the evaluation of matrix diffusion.	The DOE believes this criterion is **closed**. Expert elicitation was not used in the evaluation of matrix diffusion.	No further action needed.

Subissue 6: Matrix Diffusion

Acceptance Criterion 4: The collection, documentation, and development of data, models, and computer codes have been performed under acceptable Quality Assurance Procedures (QAP). If they were not subject to an acceptable QAP, they have been appropriately qualified.		
NRC Staff Analysis	**DOE Status**	**DOE-Proposed Path Forward**
Acceptance criterion status: **TBD**.	The DOE believes this criterion is **closed, pending**. The evaluation of matrix diffusion for the SZ Flow and Transport Process Model Report (CRWMS M&O 2000c) and supporting AMRs was completed under acceptable quality assurance procedures. The status of technical inputs may be confirmed by review of the Document Input Reference System (DIRS) database. The DIRS database will be updated to indicate changes to the QA status of these data.	80% of the data related to the subject of this KTI have been qualified as of 7/31/00. A list of unqualified data supporting the Site Recommendation Consideration Report will be provided to the NRC with the report. These unqualified data will be qualified by 6/25/01.

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