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

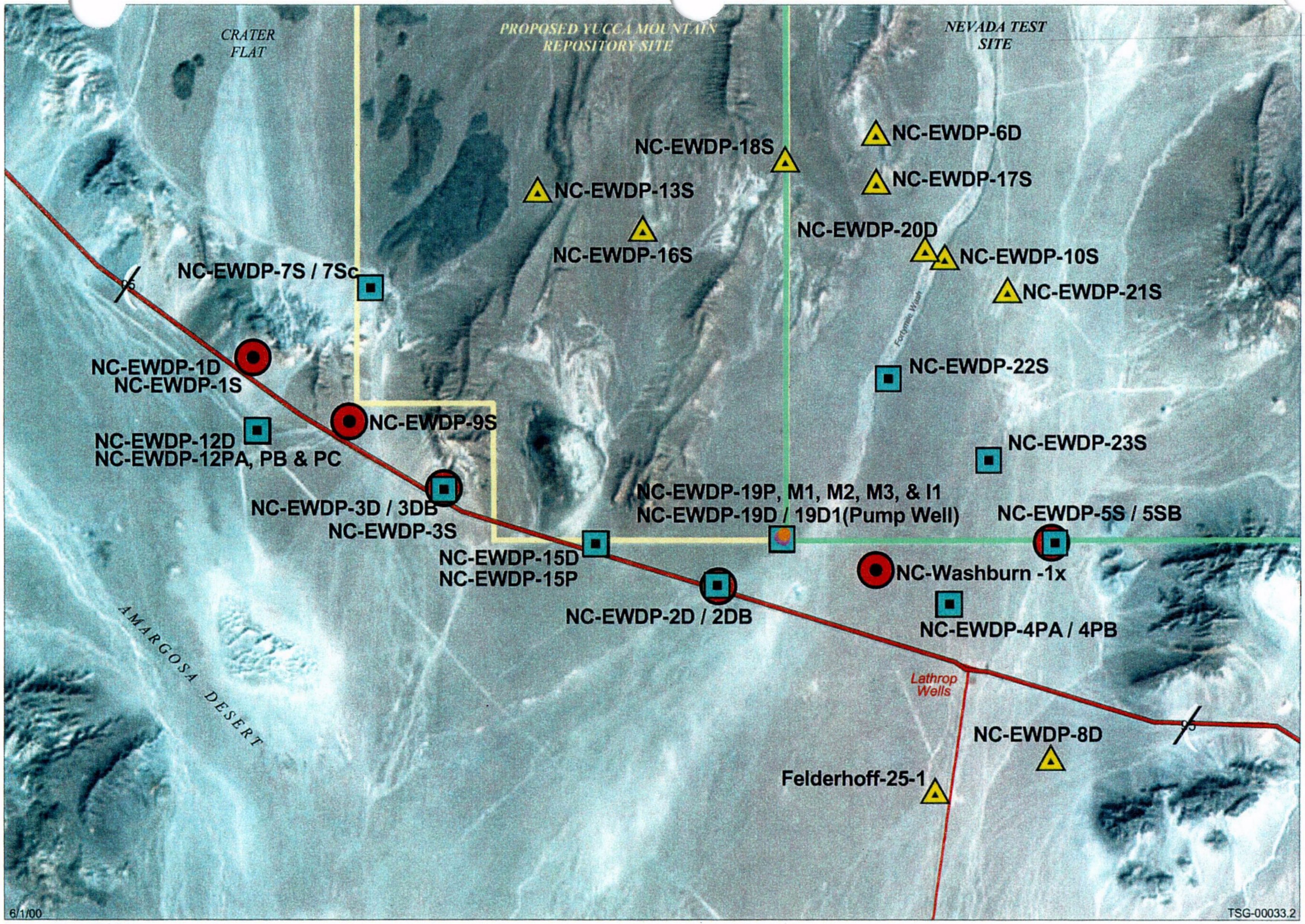
In Memory

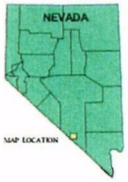
Presented by:

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

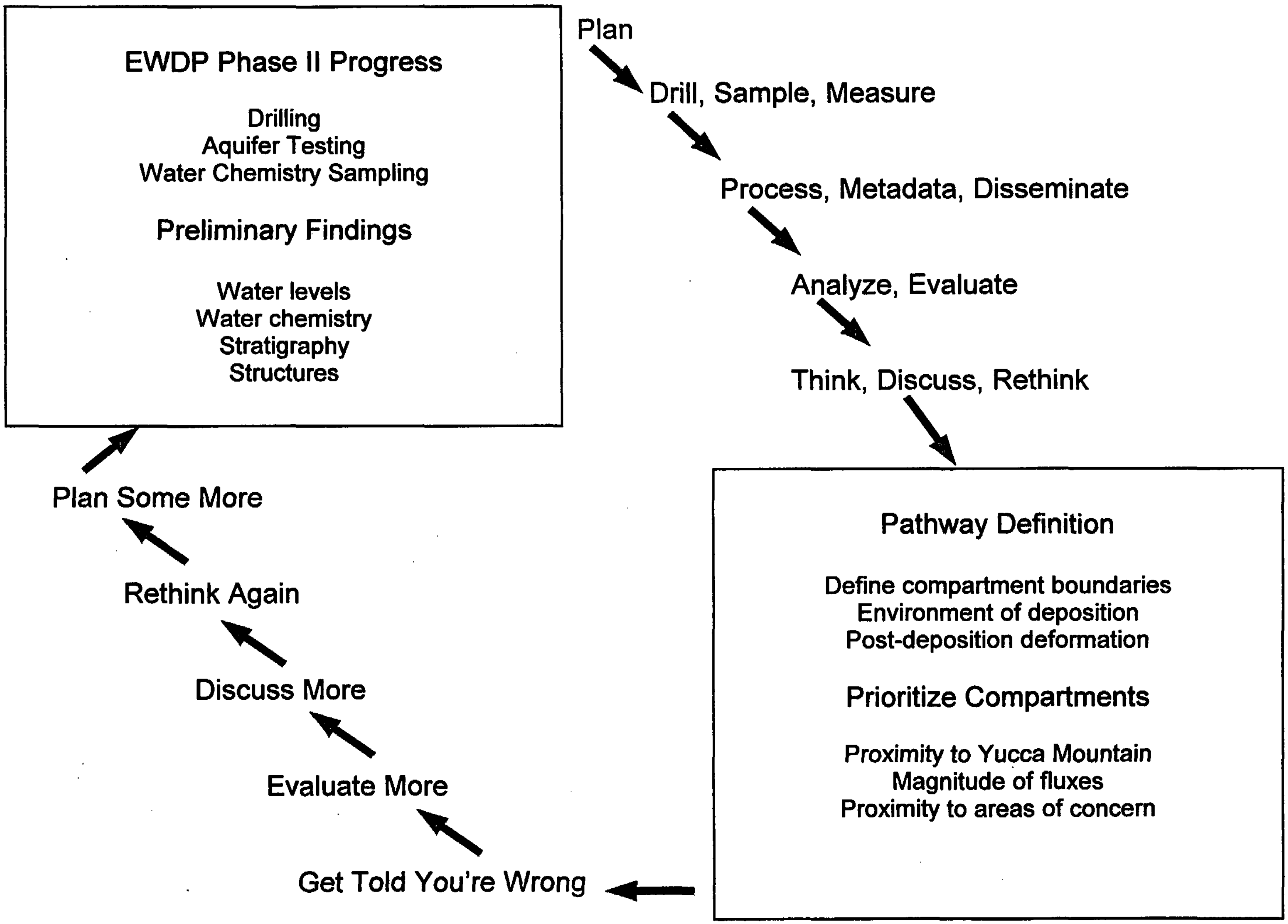
N W E S

5 0 5

Miles

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

C01


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	488 m	312± ft	95 m
NC-EWDO-2DB	3,075 ft	937 m	292± ft	89 m
				5 m
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

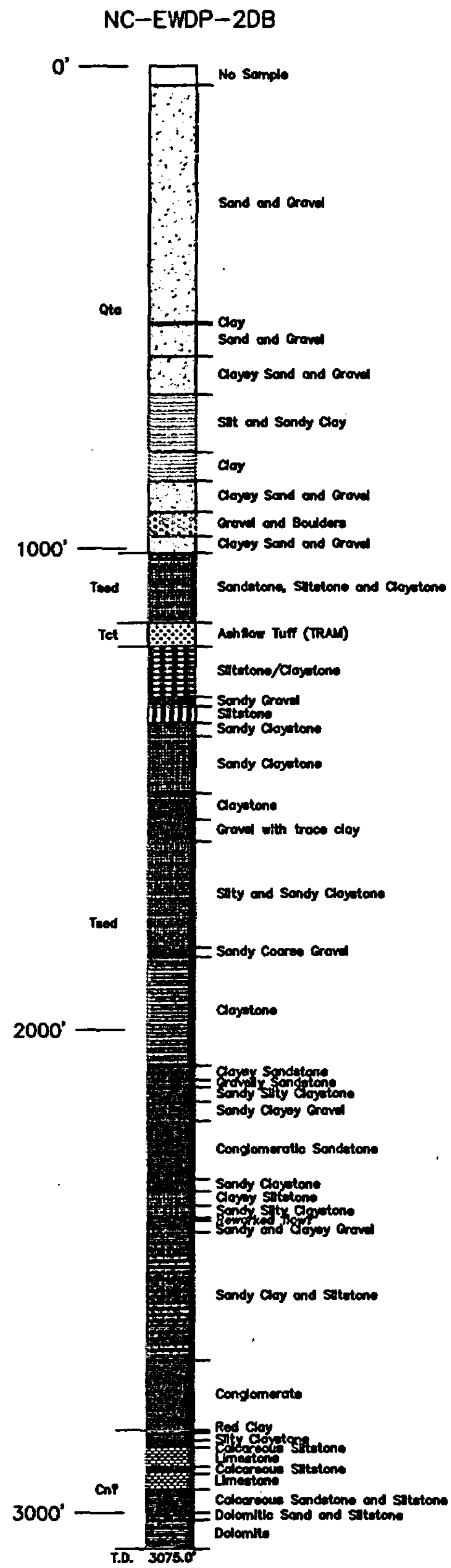
Conductor to 500 ft
Drill/Sample to 3,075 ft
Reamed to 2,690 ft
Set inner conductor to 2,685 ft
Began development
Temperature log to 2,770 ft

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

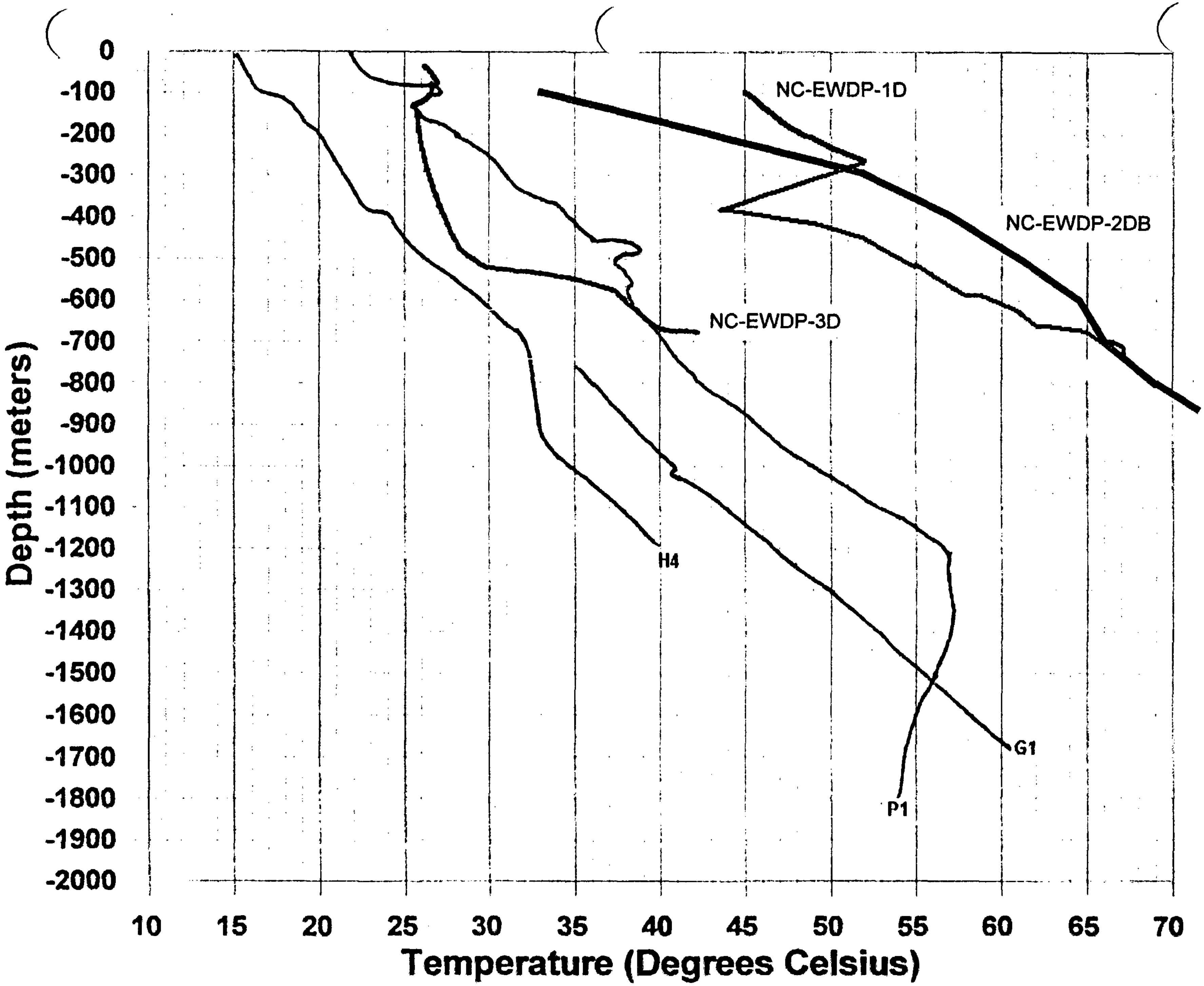
Tram Tuff is predominant volcanic unit present

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.

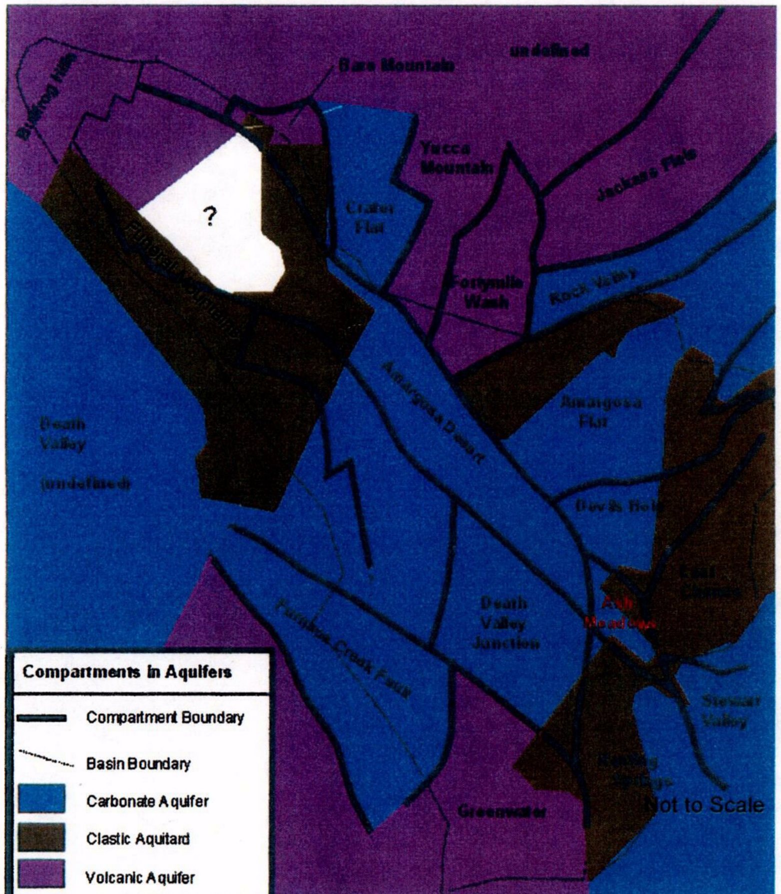
Red clay has been mapped in outcrops in Furneral Range as a detachment.

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

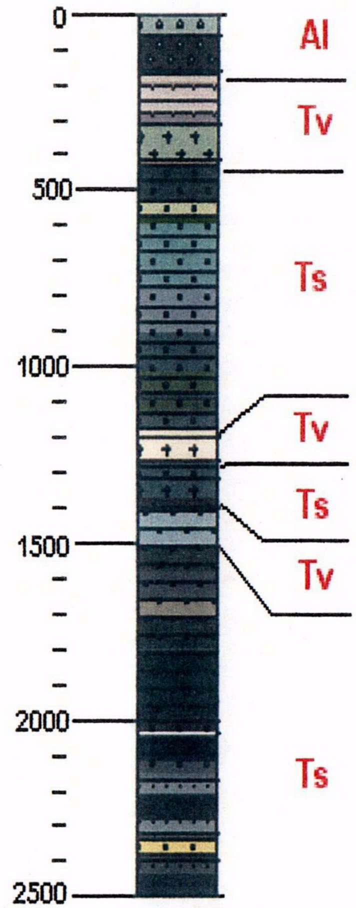


0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-1100
-1200
-1300
-1400
-1500
-1600
-1700
-1800
-1900
-2000
Depth (meters)
10
15
20
25
30
35
40
45
50
55
60
65
70
Temperature (Degrees Celsius)
NC-EWDP-1D
NC-EWDP-2DB
NC-EWDP-3D
H4
G1
P1

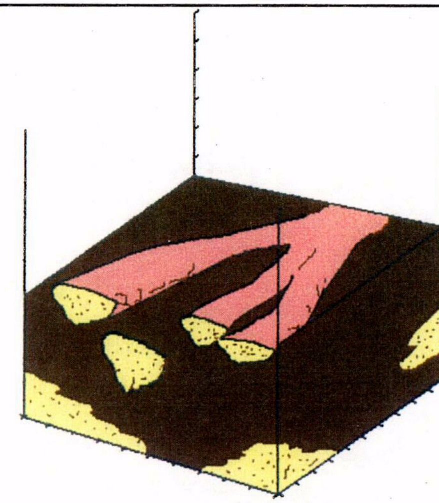
Caldera comlex



Conceptual compartments in pre-Tertiary units



Tertiary sequence NC-EWDP-1D



Conceptual distributary sand channels in Lathrop Wells area

CONCEPTUAL COMPARTMENTS IN AMARGOSA DESERT

C02

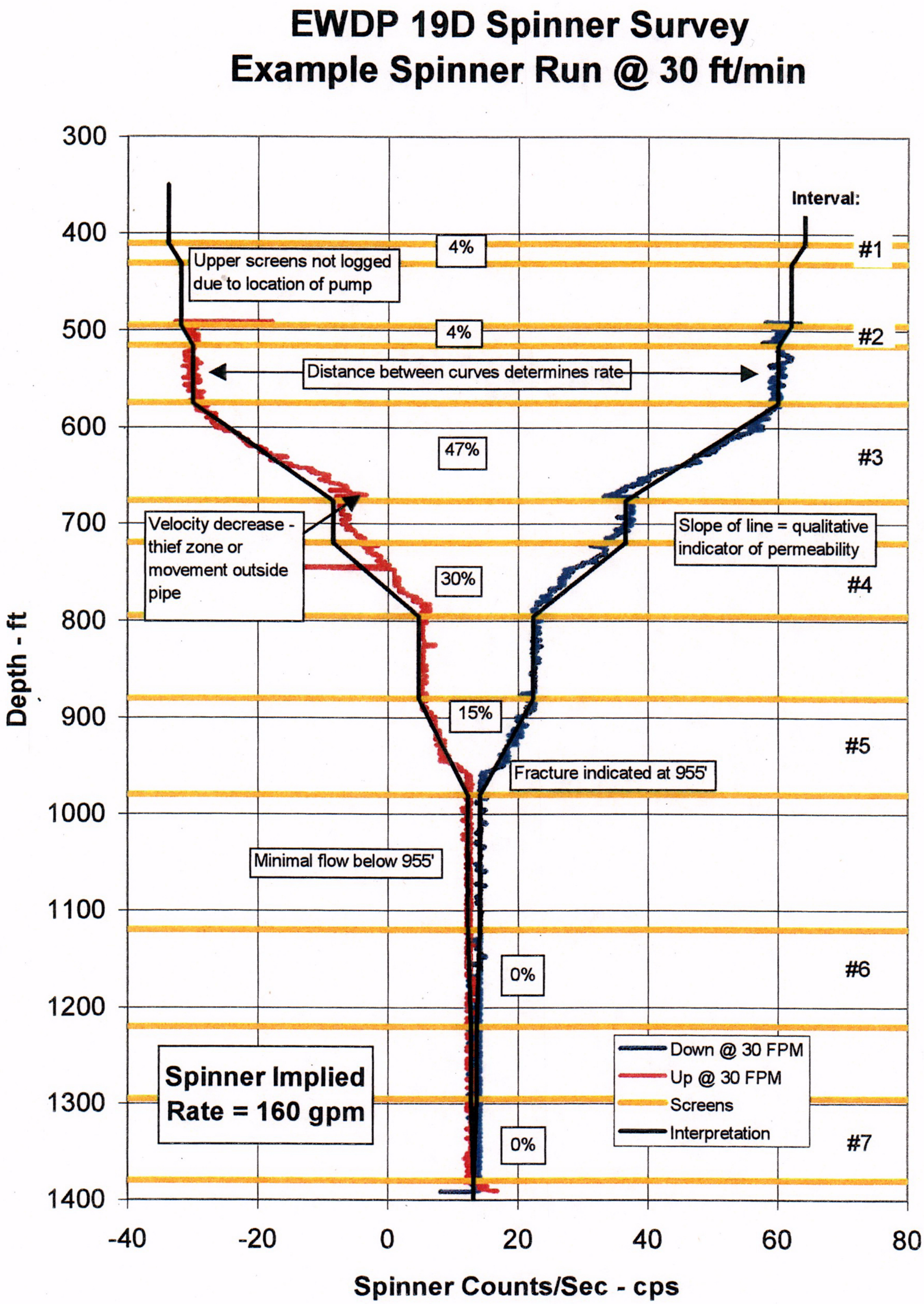
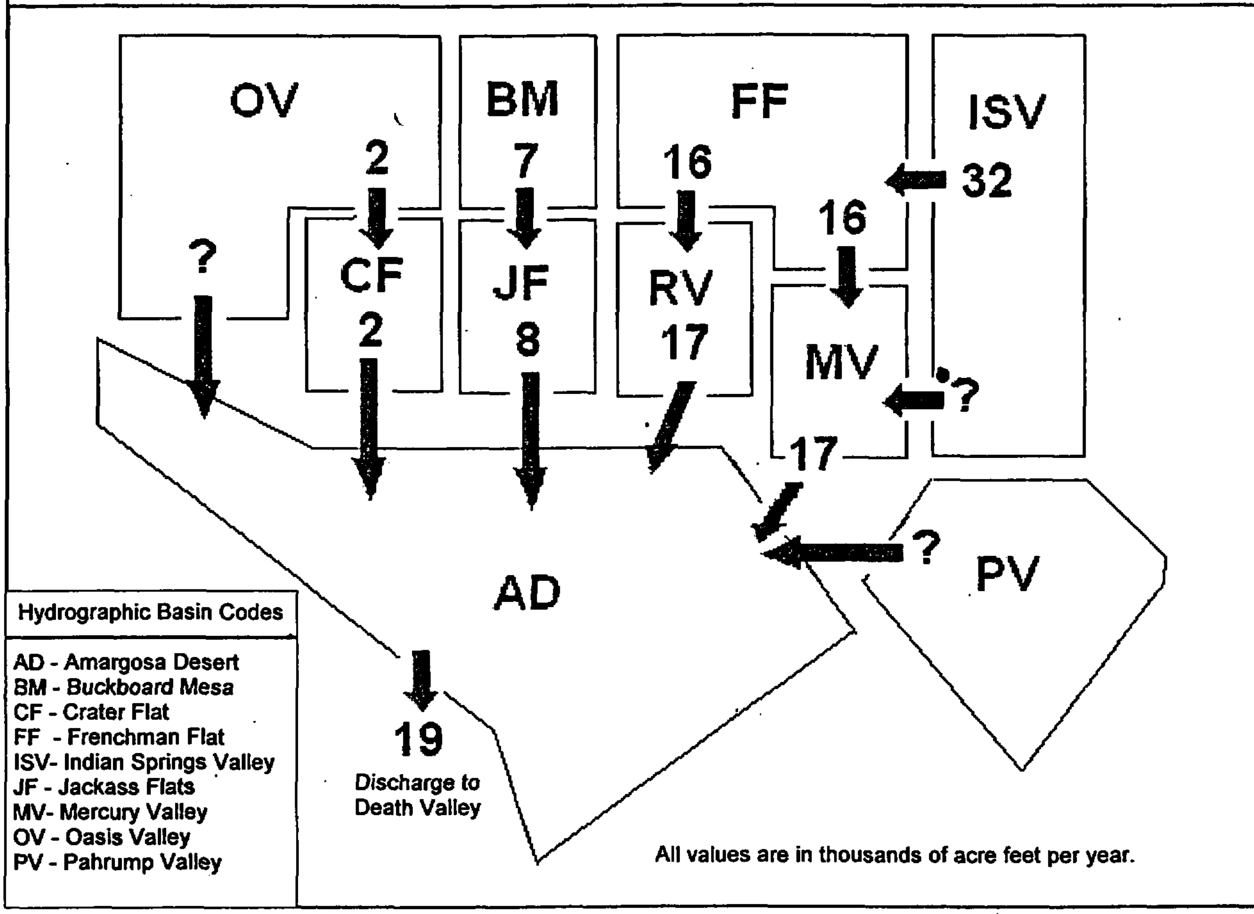

EWDP 19D Spinner Survey
Example Spinner Run @ 30 ft/min
Depth - ft
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
-40
-20
0
20
40
60
80
Spinner Counts/Sec - cps
Interval:
#1
#2
#3
#4
#5
#6
#7
4%
4%
47%
30%
15%
0%
0%
Upper screens not logged due to location of pump
Distance between curves determines 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

Figure 4

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)

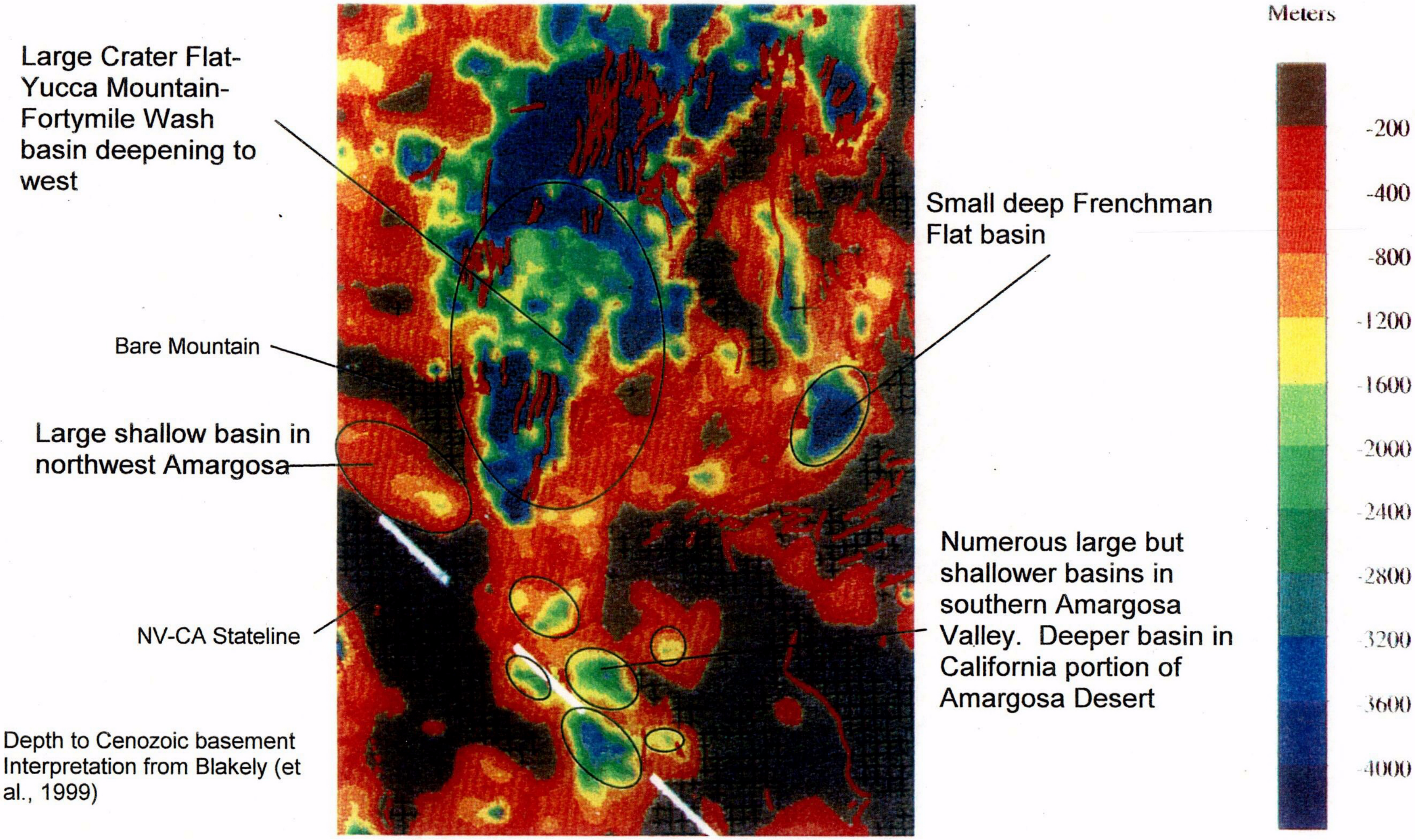
- **hydrostratigraphy within Tertiary basin and bounding Paleozoic highs**
- **structures within these three basins and along boundaries**
- **potentiometrics in each major compartment**

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

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

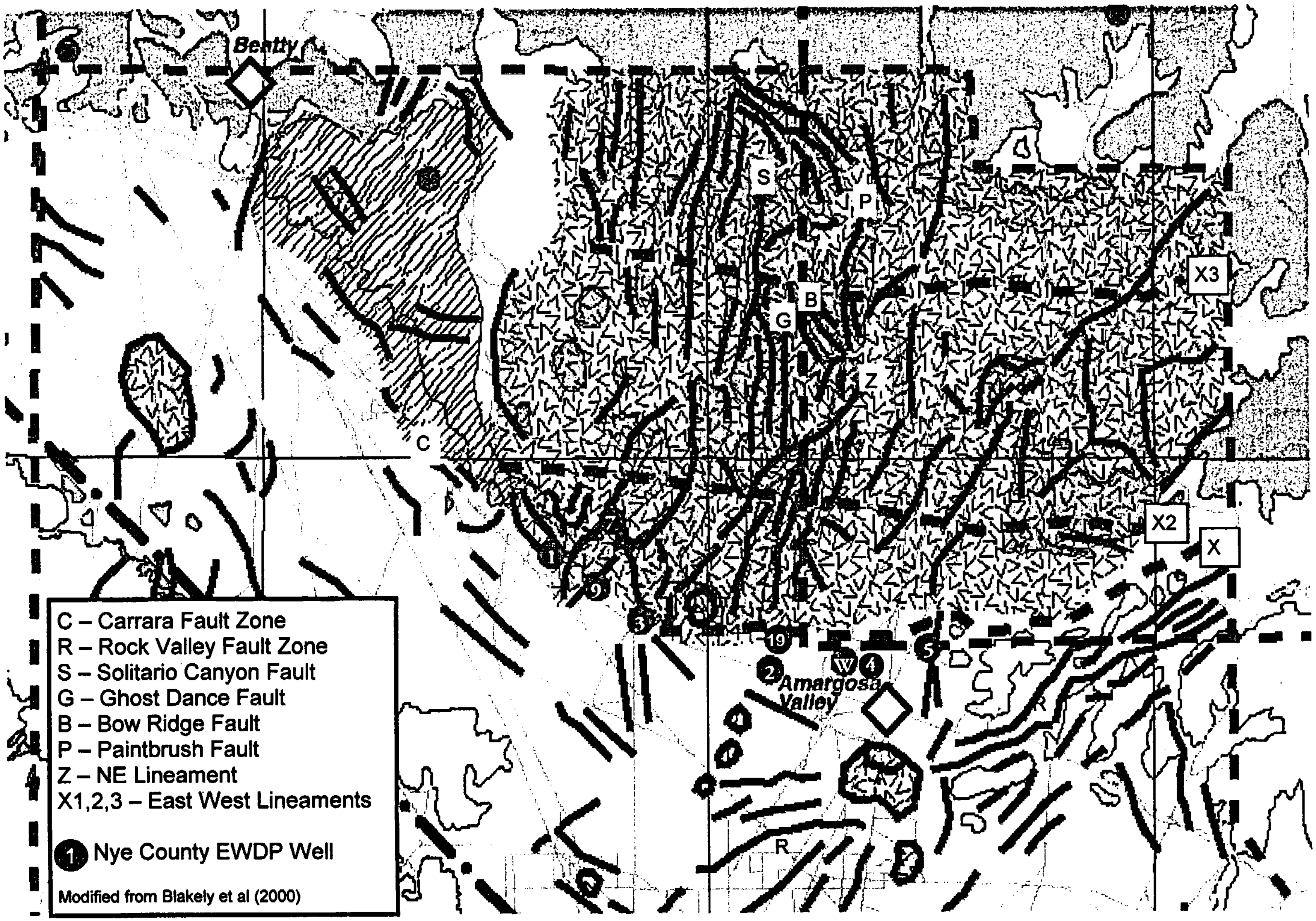
Structural Complexities and Compartmentalization

Separate Early Tertiary Basins



Depth to Cenozoic basement Interpretation from Blakely (et al., 1999)

C04



Beatty
S
P
B
G
Z
C
X3
X2
X
R
R
R
Amargosa Valley
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
Nye County EWDP Well
Modified from Blakely et al (2000)

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.

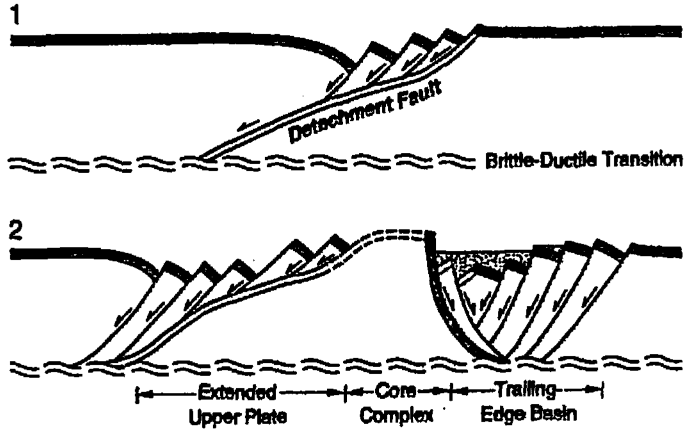
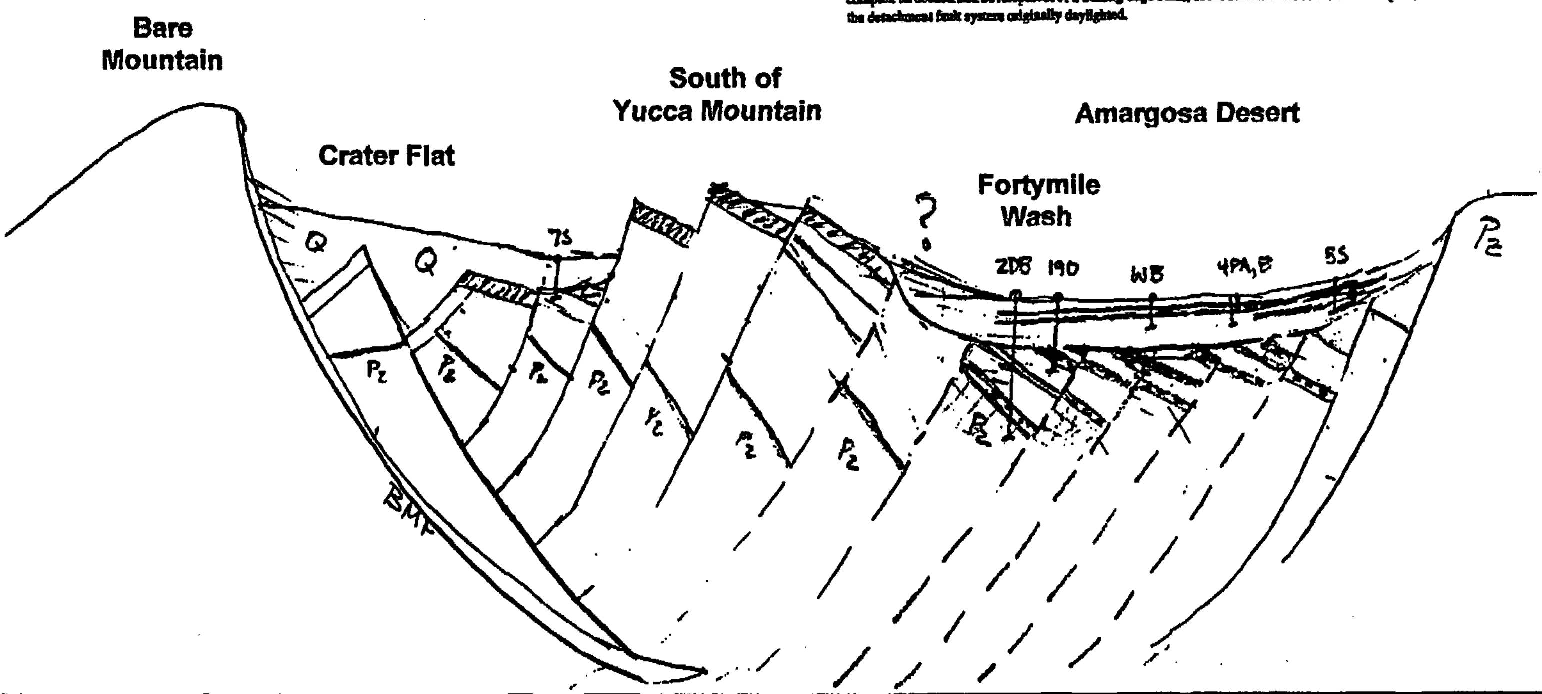
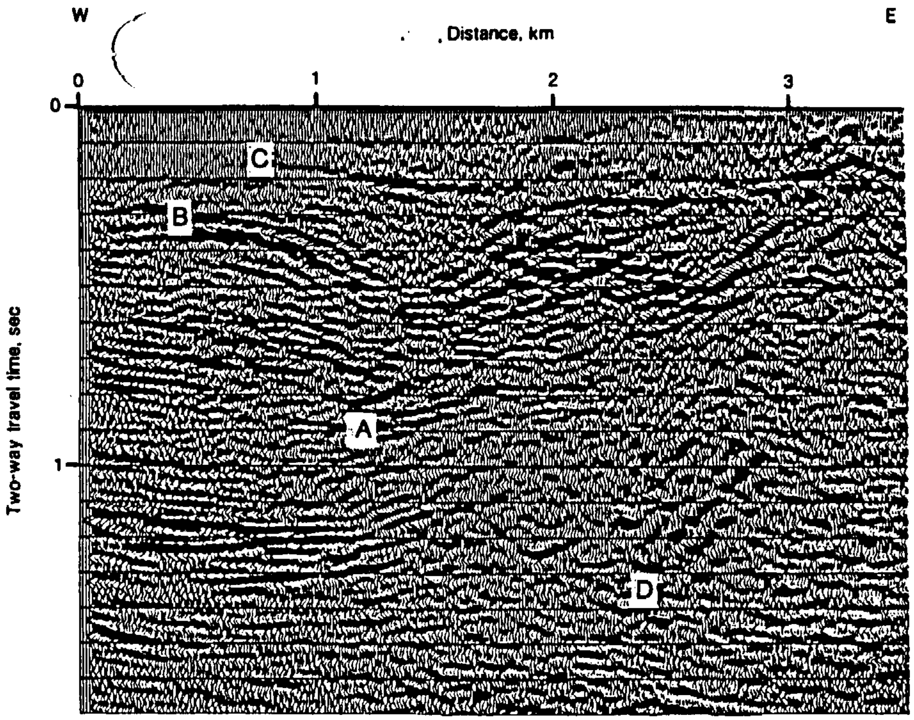
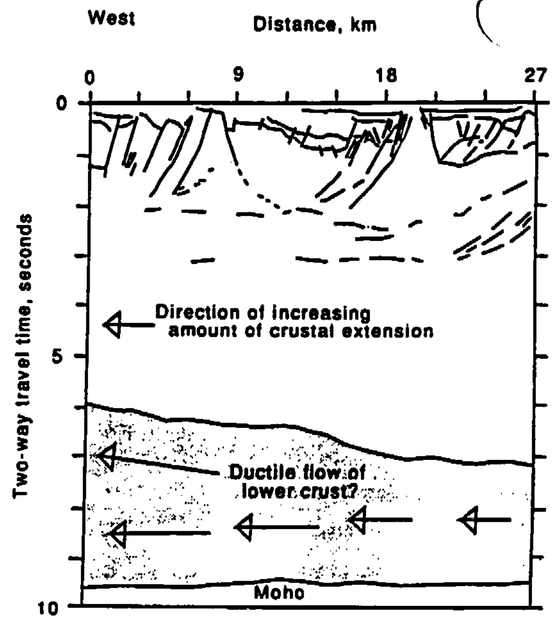
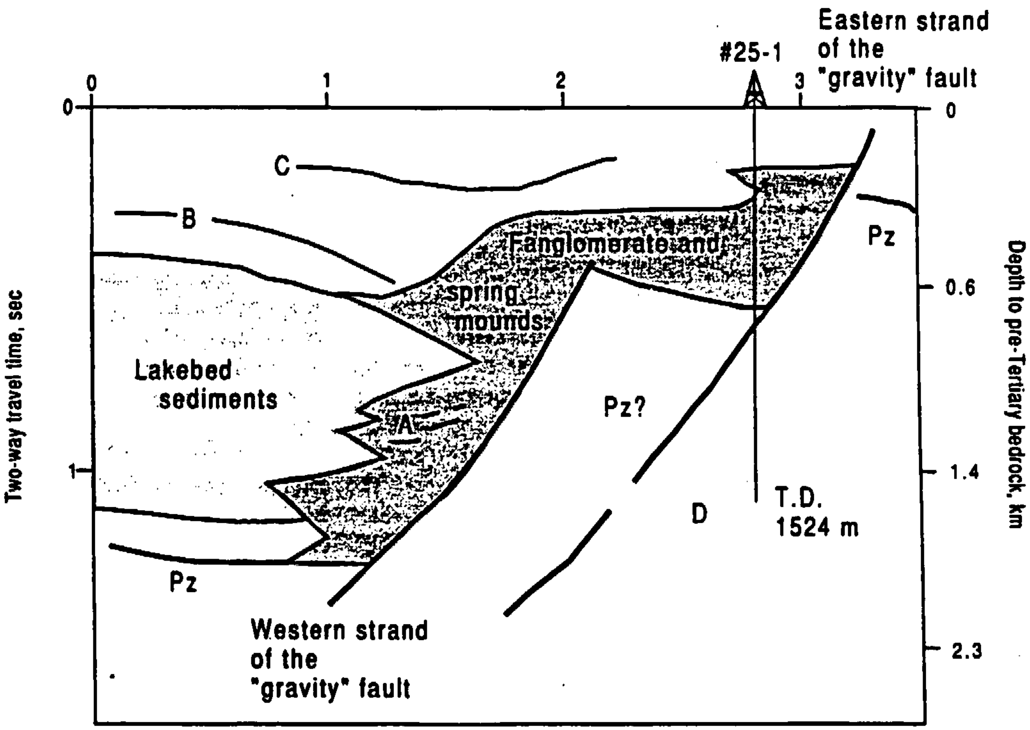


Figure 4. Schematic cross sections drawn in the major direction of extension, showing two stages in the evolution of the detachment fault system: 1, initiation of detachment faulting; 2, exposure of a tectonically denuded metamorphic core complex turtleback and development of a trailing-edge basin, at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

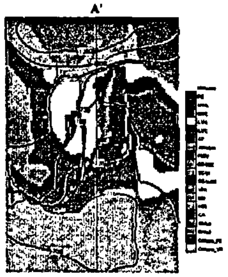
Effects of Recharge and Water Table Variations on Groundwater Flow Paths and Travel Times from Yucca Mountain

Hans D. Arlt • U.S. Nuclear Regulatory Commission • hda@nrc.gov • (301) 415-5845
James Winterle • Center for Nuclear Waste Regulatory Analyses • jwinterle@swri.edu • (210) 522-5249

Abstract: The Center for Nuclear Waste Regulatory Analyses (CNWRA) has developed a three-dimensional, site-scale, saturated-zone flow model for the Yucca Mountain region. This model provides the U.S. Nuclear Regulatory Commission (NRC) a tool to evaluate the effects of parameter uncertainties and alternative conceptual models on estimated flow paths and groundwater fluxes at Yucca Mountain, the site of a proposed high-level nuclear waste repository. Such modeling analyses provide NRC staff with additional insights to assess the adequacy of the U.S. Department of Energy site-scale flow model that is used to support performance assessments of the proposed nuclear waste repository. Present-day groundwater recharge rate estimates are one of the input parameters of the calibrated model presented below. Effects and sensitivities to variations in the recharge rates and boundary/water table levels on potential groundwater flow paths and travel times from Yucca Mountain are also demonstrated. Alternative Case A simulates a future wetter climate which will encompass increased recharge in the model area, including the addition of recharge in the Fortymile Wash area, and a general water table rise. These parameter changes do not substantially affect flow path or travel time calculations. However, the exclusion of recharge over the potential repository area shown in Alternative Case B resulted in shallower flow paths that travel greater distances through higher porosity nonwelded tuffs and *significantly increase groundwater travel time estimates, demonstrating the sensitivity of spatial and temporal* distribution of flow to the occurrence of recharge at source area.

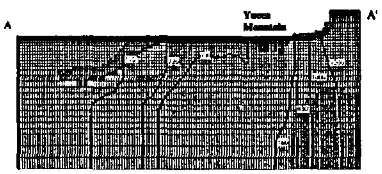
Calibrated Model Results

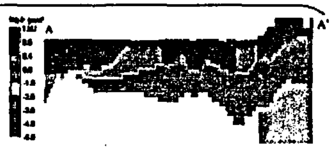
A'



A

The model domain represents a 41-km x 28-km area surrounding Yucca Mountain, NV. Hydrostratigraphic units, as seen for model layer 7 to the left, are assigned to grid cells based on correspondence to aquifers, aquitards, and fault zones. Potentiometric contour lines are in meters above mean sea level (MSL). The model extends from the top of the water table to a depth of 1500 m below MSL. Calculated heads from the steady-state simulation compare favorably to heads recorded in observation wells. Calculated heads also match the upward hydraulic gradient observed between the Paleozoic aquifer and the aquifers above.

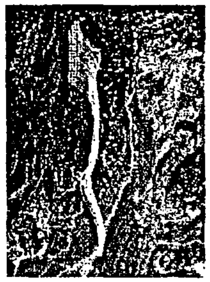


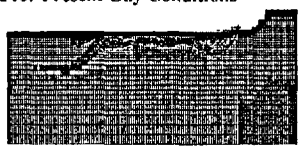


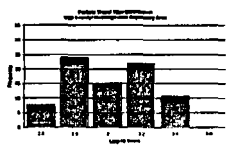
Isotropic hydraulic conductivity values are assigned to the various material types. The K-value figures emphasize the importance of the lower volcanic confining unit (red) on vertical hydraulic gradient, and the relatively high K-values east of the potential repository area (dark blue) on flow paths.

The model uses the confined/unconfined option of the *MODFLOW* Block Centered Flow package for the top seven layers of the numerical grid. This algorithm makes use of an unconfined-flow solution when model cells coincide with the water table and a confined-flow solution for cells entirely below the water table. Model cells entirely above the interpreted water table are assumed dry and treated as inactive.

Calibrated Model Results: Groundwater Flow Paths and Travel Times for Present-Day Conditions

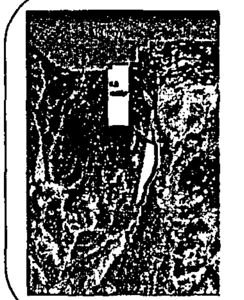






The above figures show horizontal and vertical views of the MODPATH-calculated flow trajectories. Starting locations for 80 particles were assigned to the uppermost active model cells beneath the approximate footprint of the proposed repository. Most of the simulated particles travel east-southeast for a relatively short distance before turning south and continuing southward to the 18-km [11-mi] compliance boundary where particle trajectory calculations were stopped. The locations where the particles turn south coincide with the western edge of the modeled Bow Ridge–Paintbrush Canyon fault zone. When the particles reach this zone of increased permeability, they are swept along the edge of the zone for long distances and do not migrate farther eastward. This process results in a narrow swath of particles with little lateral spreading. The vertical profile of the flow paths tend to follow the topography of the underlying lower volcanic confining unit, which increases the total distance traveled in the volcanic tuff units. While quite small compared to lateral groundwater flux in this area, 5 mm/yr [0.2 in/yr] recharge in the repository area provides enough of a downward flow gradient to drive flow paths to depths exceeding 500m [1,600 ft] below the water table. The distribution of calculated groundwater travel times show that the minimum particle travel time was 360 years and the maximum particle travel time was 2,300 years. The average particle travel time was 950 years.

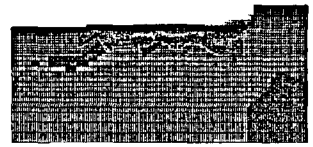
Recharge Areas Considered for Calibrated and Alternative Cases

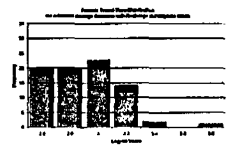


The satellite image of the model domain (left) shows areas of recharge considered for the calibrated model in the northern model area (red) and the Yucca Mountain area (yellow). The 5 mm/yr [0.2 in/yr] recharge rate in the Yucca Mountain area is consistent with estimates of present-day recharge over the potential repository. Recharge of 200 mm/yr [8 in/yr] in Fortymile Wash channel (green) was considered only for the alternative Case A model, which represents future, wetter climate conditions. Recharge rates in the Yucca Mountain and northern model areas were also doubled for Case A. The surface elevation evaporite deposits at the location of Nye County well *EWDP-9S* was used to constrain the elevation of water table rise for the Case A and Case B alternative models.

PRODUCED:
May 22, 2003

Alternative Case A: Increased Recharge and Water Table Rise





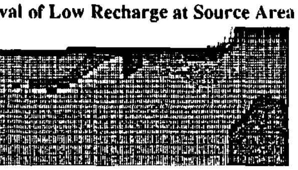
Alternative Case A is intended to evaluate potential effects on flow paths of increased recharge and water table elevation that might follow a future shift to wetter climate conditions in a few thousand years. Several changes from the calibrated reference case include:

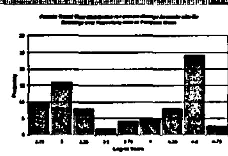
- Constant-head values at the model side boundaries were increased by 5 percent
- Recharge rate in the northern model area was increased to 20 mm/yr [0.8 in/yr]
- Recharge rate in the Yucca Mountain area was increased to 10 mm/yr [0.4 in/yr]
- Recharge rate in the channels of Fortymile Wash set at 200 mm/yr [8 in/yr]

The presence of paleospring evaporite deposits near Well NC–EWDP–9S suggests the water table elevation has risen to the surface level at this location in the past. The MODFLOW Drain package was used to assign a single drain cell at this model location to simulate effects of spring seepage whenever the calculated water table elevation exceeds the drain elevation of 795 m [2,600 ft] above sea level. A calculated head value at this location was 2 mm [0.08 in] above the drain elevation after the constant-head boundary values were increased by 5%.

The horizontal and vertical flow trajectories are similar to those of the calibrated reference model for present-day climate conditions. The minimum particle travel time of 280 years and the average particle travel time of 730 years are also similar in magnitude to those of the reference case. Maximum travel time of 4400 years originates from the northern repository area where water table rise is greatest, and would probably be offset by a decrease in unsaturated zone travel time to the water table.

Alternative Case B: Removal of Low Recharge at Source Area





For Alternative Case B, recharge over Yucca Mountain is removed. Although this recharge rate in the Yucca Mountain area was rather small in Case A, its exclusion in Case B allows an assessment of whether such small influxes are important for calculating groundwater flow paths and travel times. Further changes from Alternative Case A include the removal of any recharge from the Fortymile Wash channels.

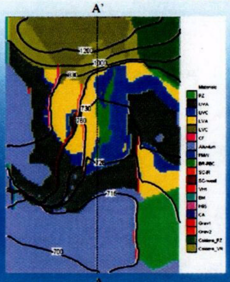
When no recharge is occurring at the proposed repository location, the flow paths generally remain within 100 m [328 ft] of the modeled water table surface. The distribution of calculated groundwater travel times show that the minimum particle travel time is 400 years and the maximum particle travel time is 35,000 years. Although the flow paths are shorter, the average particle travel time of 10,700 years is substantially greater than both the calibrated reference model and Alternative Case A model results. The shallower flow paths travel more distance through the UVC layer (Calico Hills formation), which has a higher assigned porosity. The results show that it is important to consider even relatively small amounts of recharge in the potential repository area when evaluating saturated zone flow paths and groundwater travel times.

Effects of Recharge and Water Table Variations on Groundwater Flow Paths and Travel Times from Yucca Mountain

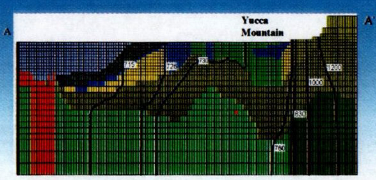
Hans D. Arlt • U.S. Nuclear Regulatory Commission • hda@nrc.gov • (301) 415-5845
James Winterle • Center for Nuclear Waste Regulatory Analyses • jwinterle@swri.edu • (210) 522-5249

Abstract: The Center for Nuclear Waste Regulatory Analyses (CNWRA) has developed a three-dimensional, site-scale, saturated-zone flow model for the Yucca Mountain region. This model provides the U.S. Nuclear Regulatory Commission (NRC) a tool to evaluate the effects of parameter uncertainties and alternative conceptual models on estimated flow paths and groundwater fluxes at Yucca Mountain, the site of a proposed high-level nuclear waste repository. Such modeling analyses provide NRC staff with additional insights to assess the adequacy of the U.S. Department of Energy site-scale flow model that is used to support performance assessments of the proposed nuclear waste repository. Present-day groundwater recharge rate estimates are one of the input parameters of the calibrated model presented below. Effects and sensitivities to variations in the recharge rates and boundary/water table levels on potential groundwater flow paths and travel times from Yucca Mountain are also demonstrated. Alternative Case A simulates a future wetter climate which will encompass increased recharge in the model area, including the addition of recharge in the Fortymile Wash area, and a general water table rise. These parameter changes do not substantially affect flow path or travel time calculations. However, the exclusion of recharge over the potential repository area shown in Alternative Case B resulted in shallower flow paths that travel greater distances through higher porosity nonwelded tuffs and significantly increase groundwater travel time estimates, demonstrating the sensitivity of spatial and temporal distribution of flow to the occurrence of recharge at source area.

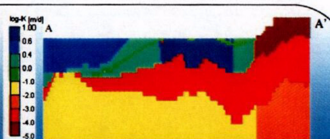
Calibrated Model Results



The model domain represents a 41-km × 28-km area surrounding Yucca Mountain, NV. Hydrostratigraphic units, as seen for model layer 7 to the left, are assigned to grid cells based on correspondence to aquifers, aquitards, and fault zones. Potentiometric contour lines are in meters above mean sea level (MSL). The model extends from the top of the water table to a depth of 1500 m below MSL. Calculated heads from the steady-state simulation compare favorably to heads recorded in observation wells. Calculated heads also match the upward hydraulic gradient observed between the Paleozoic aquifer and the aquifers above.



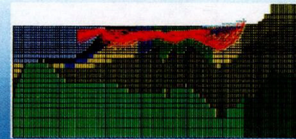
Calibrated hydraulic conductivity values (log10 m/d)

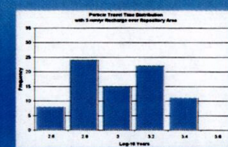


Isotropic hydraulic conductivity values are assigned to the various material types. The K-value figures emphasize the importance of the lower volcanic confining unit (red) on vertical hydraulic gradient, and the relatively high K-values east of the potential repository area (dark blue) on flow paths.

The model uses the confined/unconfined option of the MODFLOW Block Centered Flow package for the top seven layers of the numerical grid. This algorithm makes use of an unconfined-flow solution when model cells coincide with the water table and a confined-flow solution for cells entirely below the water table. Model cells entirely above the interpreted water table are assumed dry and treated as inactive.

Calibrated Model Results: Groundwater Flow Paths and Travel Times for Present-Day Conditions





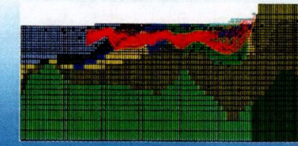
The above figures show horizontal and vertical views of the MODPATH-calculated flow trajectories. Starting locations for 80 particles were assigned to the uppermost active model cells beneath the approximate footprint of the proposed repository. Most of the simulated particles travel east-southeast for a relatively short distance before turning south and continuing southward to the 18-km [11-mi] compliance boundary where particle trajectory calculations were stopped. The locations where the particles turn south coincide with the western edge of the modeled Bow Ridge–Paintbrush Canyon fault zone. When the particles reach this zone of increased permeability, they are swept along the edge of the zone for long distances and do not migrate farther eastward. This process results in a narrow swath of particles with little lateral spreading. The vertical profile of the flow paths tend to follow the topography of the underlying lower volcanic confining unit, which increases the total distance traveled in the volcanic tuff units. While quite small compared to lateral groundwater flux in this area, 5 mm/yr [0.2 in/yr] recharge in the repository area provides enough of a downward flow gradient to drive flow paths to depths exceeding 500m [1,600 ft] below the water table. The distribution of calculated groundwater travel times show that the minimum particle travel time was 360 years and the maximum particle travel time was 2,300 years. The average particle travel time was 950 years.

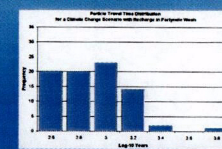
Recharge Areas Considered for Calibrated and Alternative Cases

The satellite image of the model domain (left) shows areas of recharge considered for the calibrated model in the northern model area (red) and the Yucca Mountain area (yellow). The 5 mm/yr [0.2 in/yr] recharge rate in the Yucca Mountain area is consistent with estimates of present-day recharge over the potential repository. Recharge of 200 mm/yr [8 in/yr] in Fortymile Wash channel (green) was considered only for the alternative Case A model, which represents future, wetter climate conditions. Recharge rates in the Yucca Mountain and northern model areas were also doubled for Case A. The surface elevation evaporite deposits at the location of Nye County well EWDP-9S was used to constrain the elevation of water table rise for the Case A and Case B alternative models.

PRODUCED:
May 22, 2003

Alternative Case A: Increased Recharge and Water Table Rise





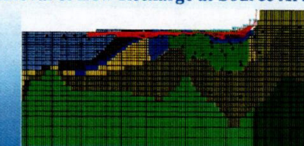
Alternative Case A is intended to evaluate potential effects on flow paths of increased recharge and water table elevation that might follow a future shift to wetter climate conditions in a few thousand years. Several changes from the calibrated reference case include:

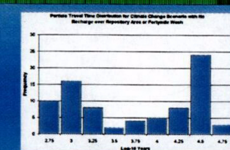
* Constant-head values at the model side boundaries were increased by 5 percent
* Recharge rate in the northern model area was increased to 20 mm/yr [0.8 in/yr]
* Recharge rate in the Yucca Mountain area was increased to 10 mm/yr [0.4 in/yr]
* Recharge rate in the channels of Fortymile Wash set at 200 mm/yr [8 in/yr]

The presence of paleospring evaporite deposits near Well NC–EWDP–9S suggests the water table elevation has risen to the surface level at this location in the past. The MODFLOW Drain package was used to assign a single drain cell at this model location to simulate effects of spring seepage whenever the calculated water table elevation exceeds the drain elevation of 795 m [2,600 ft] above sea level. A calculated head value at this location was 2 mm [0.08 in] above the drain elevation after the constant-head boundary values were increased by 5%.

The horizontal and vertical flow trajectories are similar to those of the calibrated reference model for present-day climate conditions. The minimum particle travel time of 280 years and the average particle travel time of 730 years are also similar in magnitude to those of the reference case. Maximum travel time of 4400 years originates from the northern repository area where water table rise is greatest, and would probably be offset by a decrease in unsaturated zone travel time to the water table.

Alternative Case B: Removal of Low Recharge at Source Area





For Alternative Case B, recharge over Yucca Mountain is removed. Although this recharge rate in the Yucca Mountain area was rather small in Case A, its exclusion in Case B allows an assessment of whether such small influxes are important for calculating groundwater flow paths and travel times. Further changes from Alternative Case A include the removal of any recharge from the Fortymile Wash channels.

When no recharge is occurring at the proposed repository location, the flow paths generally remain within 100 m [328 ft] of the modeled water table surface. The distribution of calculated groundwater travel times show that the minimum particle travel time is 400 years and the maximum particle travel time is 35,000 years. Although the flow paths are shorter, the average particle travel time of 10,700 years is substantially greater than both the calibrated reference model and Alternative Case A model results. The shallower flow paths travel more distance through the UVC layer (Calico Hills formation), which has a higher assigned porosity. The results show that it is important to consider even relatively small amounts of recharge in the potential repository area when evaluating saturated zone flow paths and groundwater travel times.

C05