Ground-Water Flow in the Mojave Desert – Examples from Death Valley and the Mojave River Regional Flow Models

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TOPICS OF DISCUSSION

- Death Valley
  - Conceptual Model
  - Geologic emphasis
  - Groundwater flow model description
  - Transient portion of model
  - Potential uses of model
- Mojave River
  - Human effect on ecosystem – movie
- Questions and discussion

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DVRFS Team project

- Wayne Belcher (WRD/NV)
- Joan Blainey (WRD/AZ)
- Claudia Faunt (WRD/CA)
- Mary Hill (WRD/NRP)
- Randy Laczniak (WRD/NV)
- Carma San Juan (WRD/YMP)
- Don Sweetkind (GD)

Main players, many other contributors

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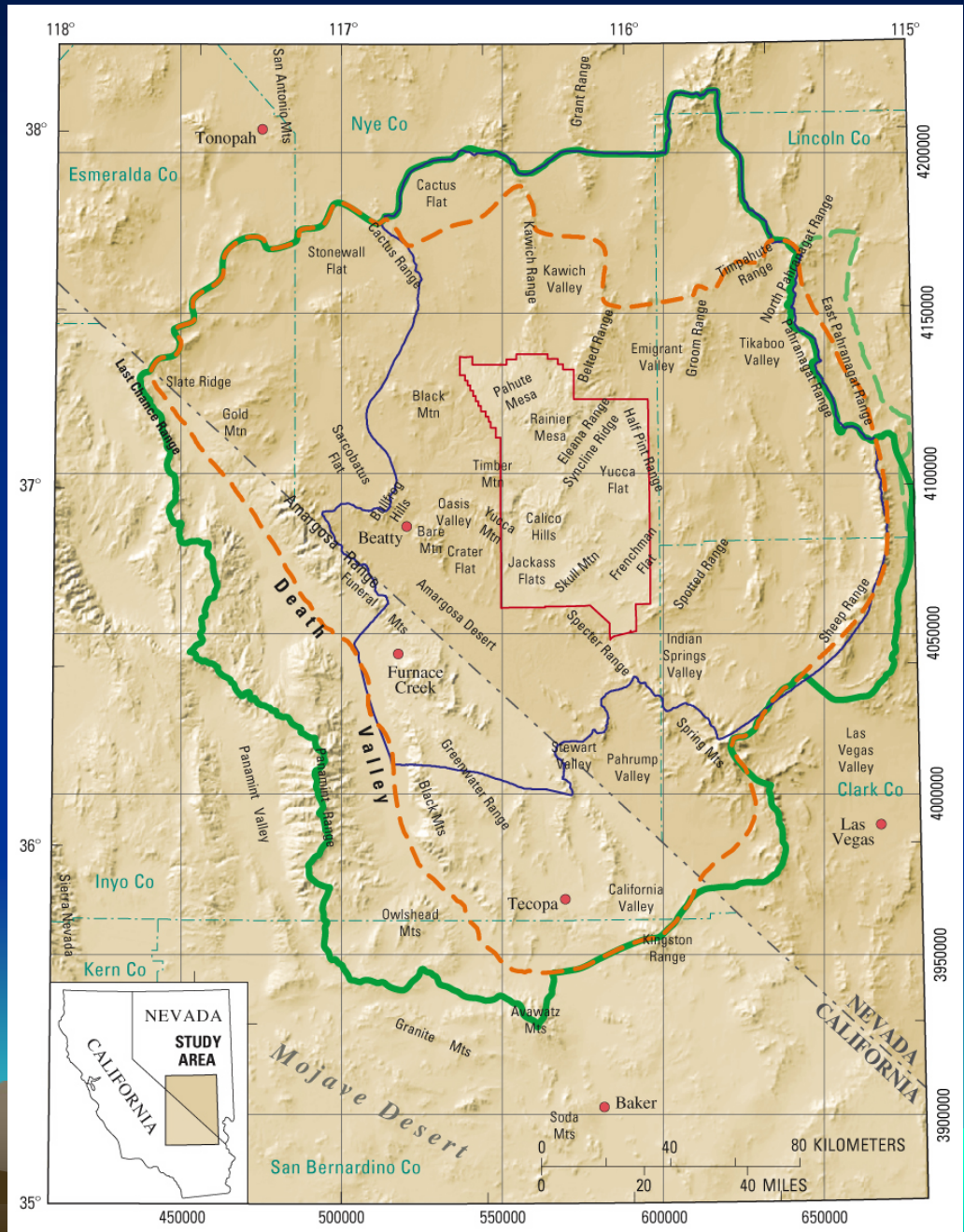
Death Valley regional flow model area

- Large area with complex geology
- Potential high-level nuclear waste repository, Yucca Mountain, Nevada
- Groundwater flow paths from Nevada Test Site
- Constructed using MODFLOW-2000
- Update of previous modeling efforts (thick green line is current boundary)
- Time period 1913-1998



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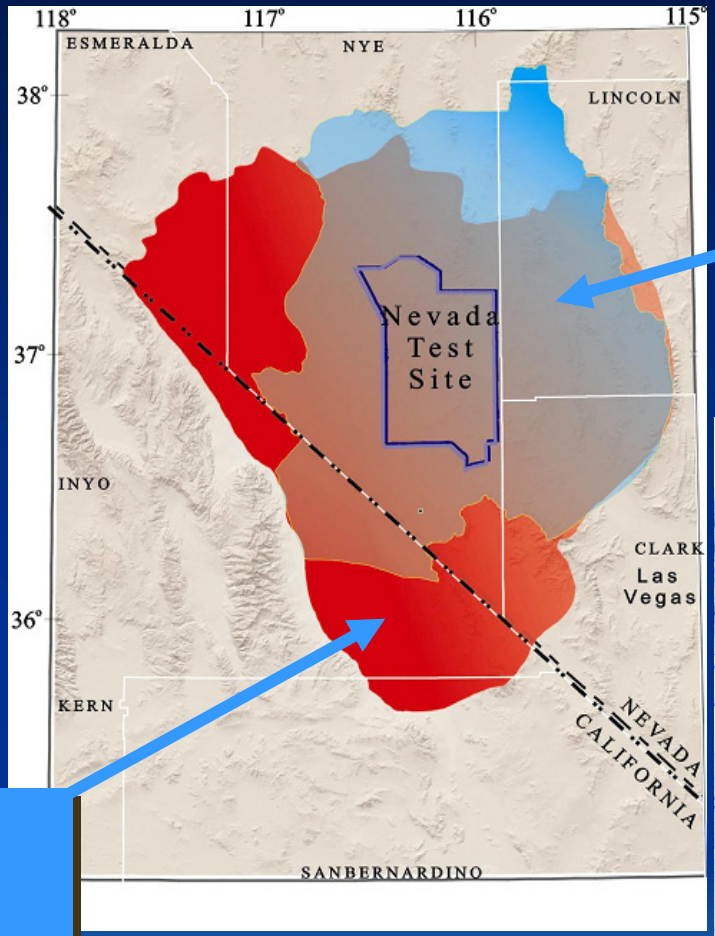
Flow models in the vicinity of the Nevada Test Site

Yucca Mountain



UGTA
Underground Test Areas
Define regional flow paths; boundary conditions for site-scale models

Yucca Flat

YMP/HRMP
Yucca Mountain
Define regional flow paths and discharge areas

- **Different geologic, hydrologic data sets**

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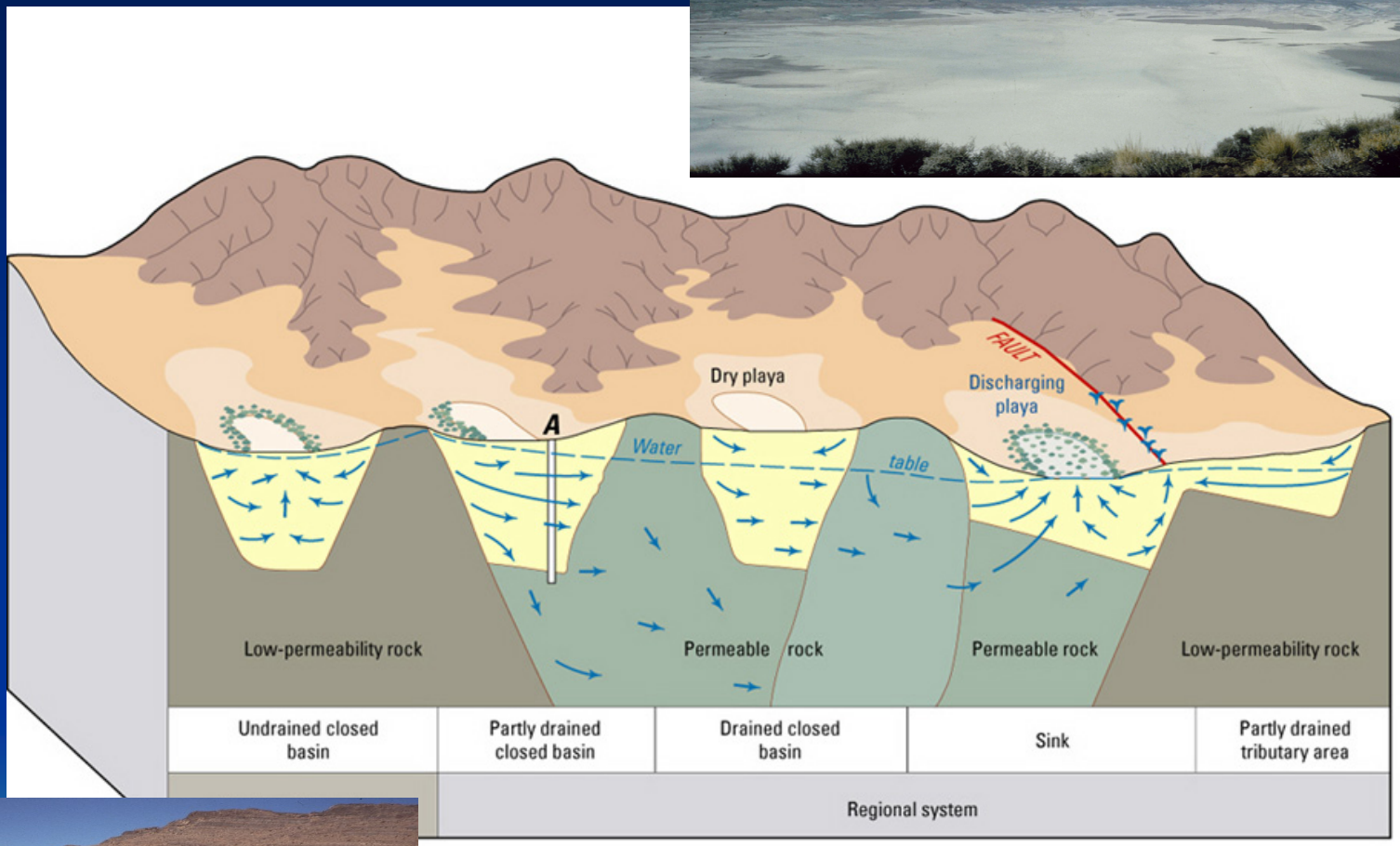
Conceptual model(s) of groundwater flow system

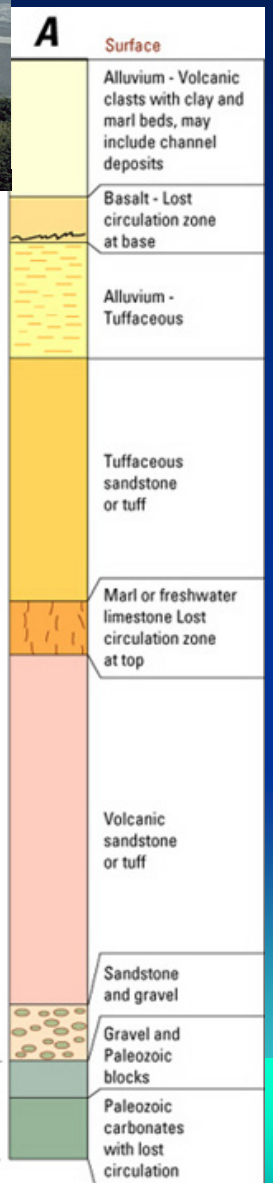


EXPLANATION

Areas of ground-water evapotranspiration

Phreatophytes

Discharging playa



GEOLOGY IS HALF THE EQUATION

$KA = Q/(dh/dl)$

- Framework
  - Unit geometry/truncation
  - Location of high K zones
  - Ground-water barriers
  - Heterogeneity/Anisotropy
  - ***Actually doesn't provide K***

$Q/(dh/dl) = KA$

- Hydrology
  - Model observations (hydraulic heads and discharge rates)
  - Weighting/Error factors for calibration
  - ***Constrains K***

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Comprehensive geologic interpretation in support of the regional flow model

- Compilation of geologic maps
- Interpretation of regional tectonics
- Regional geologic cross-sections
- Geophysical interpretations
- Stratigraphic analysis of Tertiary basins
- Hydrologic significance of structural and stratigraphic elements

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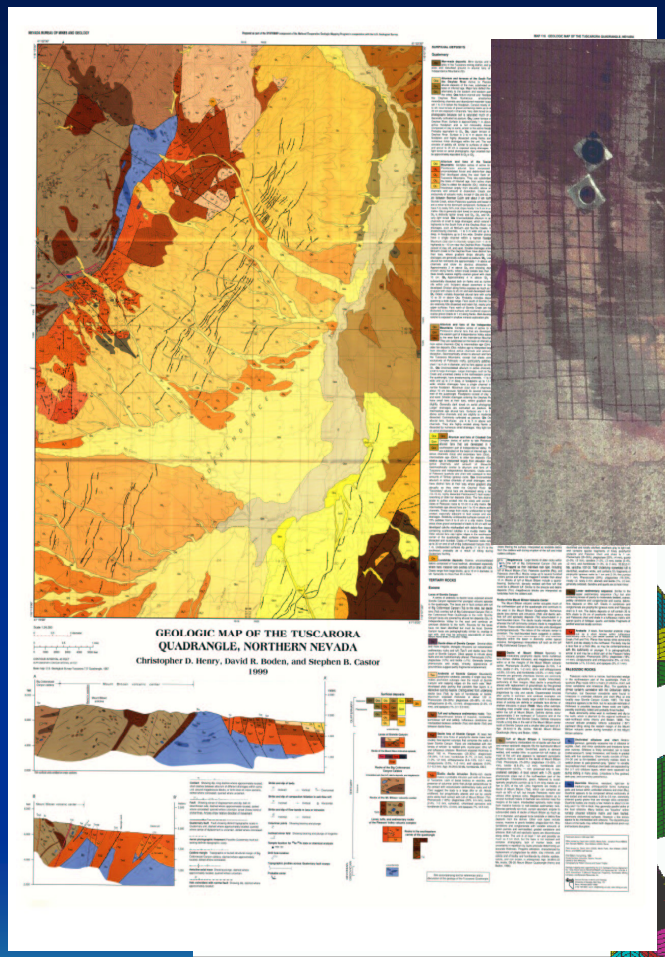
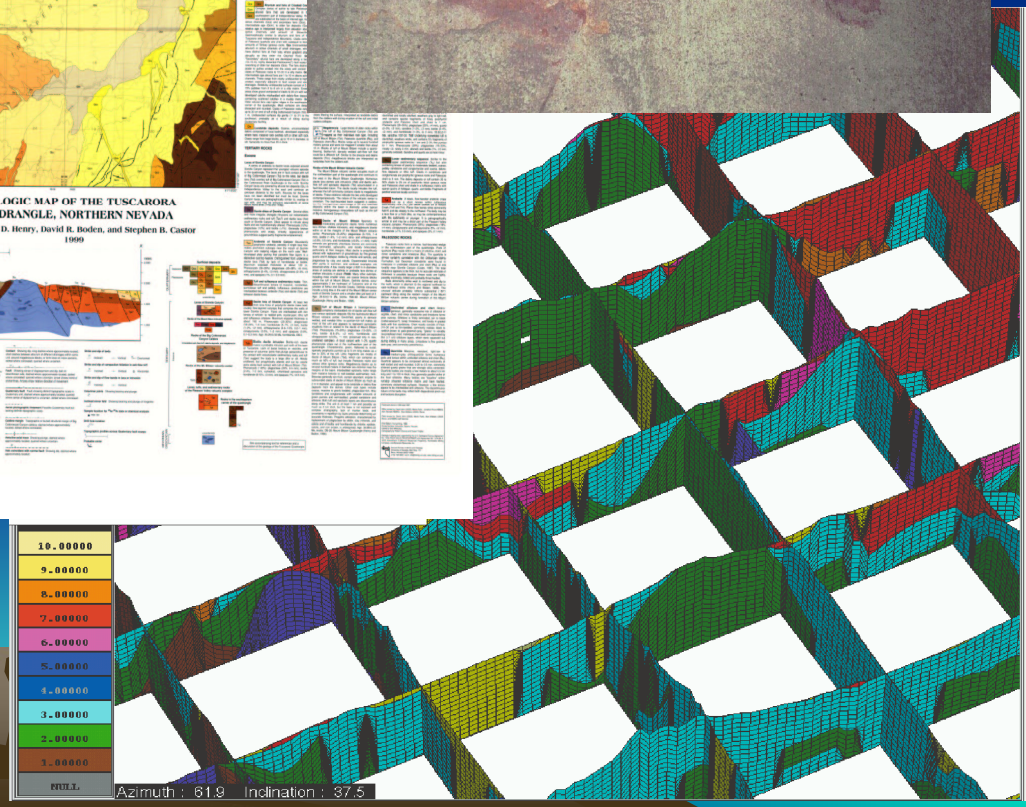
Role of geology in framework and flow models

- Framework
- Juxtaposition of units
- Heterogeneity
- Anisotropy
- Barriers
- Conduits





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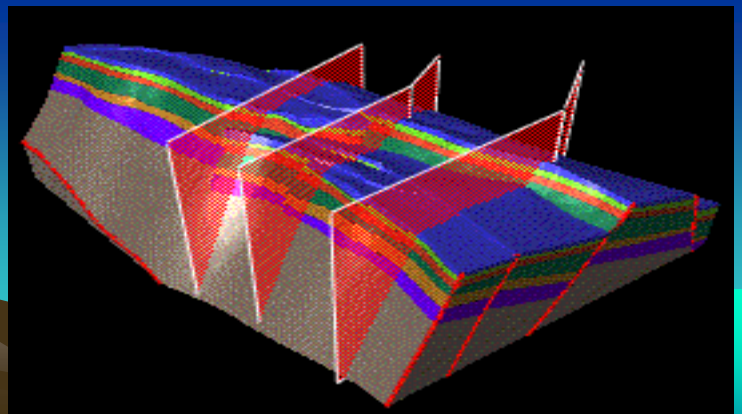
Geologic data needs for framework and flow models

3D framework models

- **Digital geologic map**
- **Top and thickness of each HGU**
  - Structure contour and isopach maps
  - Cross sections and borehole data
- **Faults used in model**
  - Dip, truncation

Flow models

- **Spatially varying material properties**
- **Fault zone properties**
- **Ranking of units, features by K**



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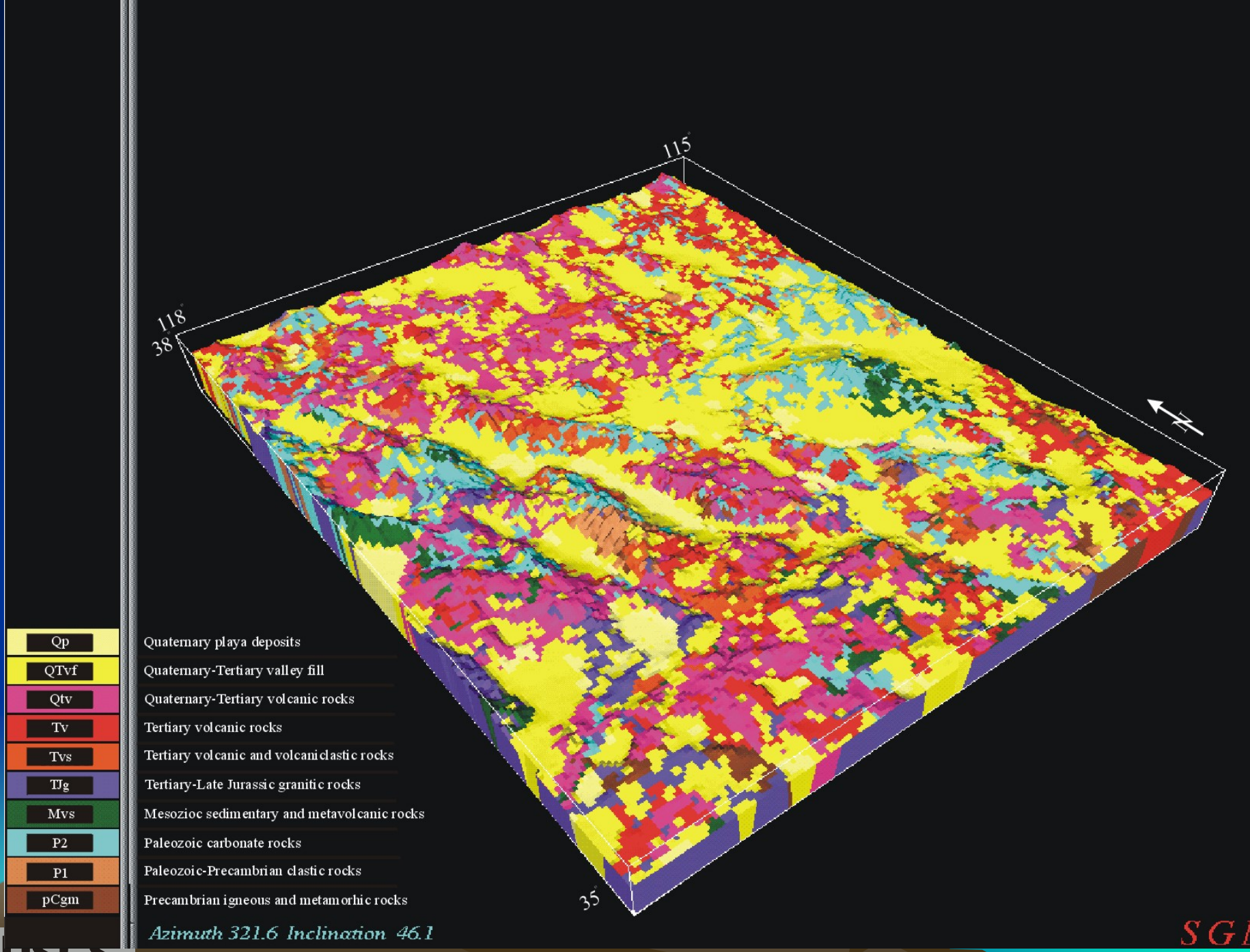
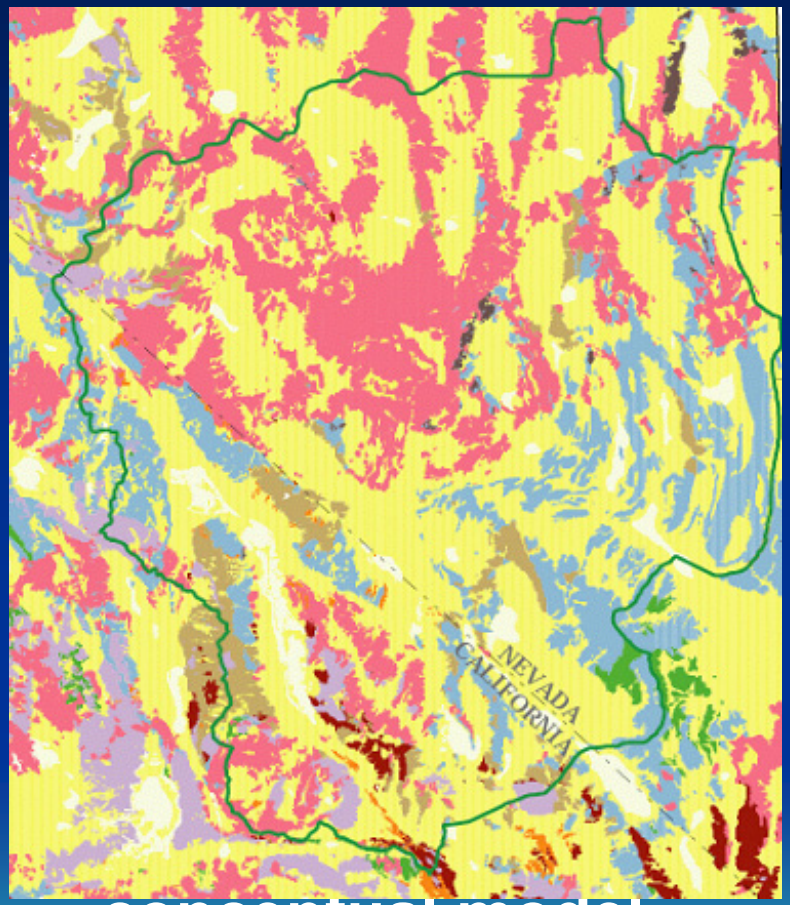
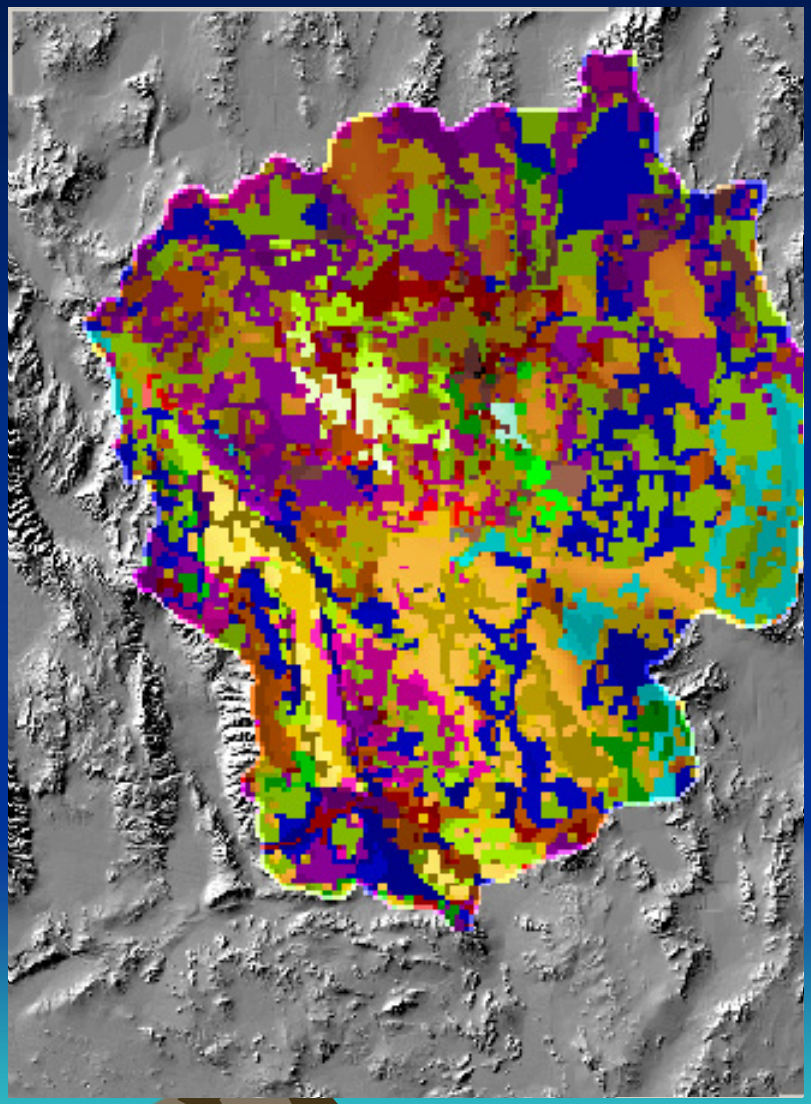

115°
118°
38°
35°
N
Qp
Quaternary playa deposits
QTvf
Quaternary-Tertiary valley fill
Qtv
Quaternary-Tertiary volcanic rocks
Tv
Tertiary volcanic rocks
Tvs
Tertiary volcanic and volcaniclastic rocks
TJg
Tertiary-Late Jurassic granitic rocks
Mvs
Mesozioc sedimentary and metavolcanic rocks
P2
Paleozoic carbonate rocks
P1
Paleozoic-Precambrian clastic rocks
pCgm
Precambrian igneous and metamorhic rocks
Azimuth 321.6 Inclination 46.1

“Looks geologic” – 3D framework



conceptual model



Insert movies

Does complex geology *demand* a complex flow model?

- **Ultimately depends on flow model**
  - Availability of hydrologic data
  - Justified level of geologic detail
- **Need to understand regional framework**
  - Cross section interpretations
  - Representation of structural zones
- **Complexity is required in Death Valley region**
  - Scale of geologic features
  - Previous modeling experience

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Incorporation of geology into flow model

- **Framework model provides geometry of units**
  - Extent and thickness of unit
  - Juxtaposition of units
- **Properties vary spatially**
  - Zonations based on geologic property changes
- **Structures**
  - Conduits through zonations
  - Barriers through HFB package

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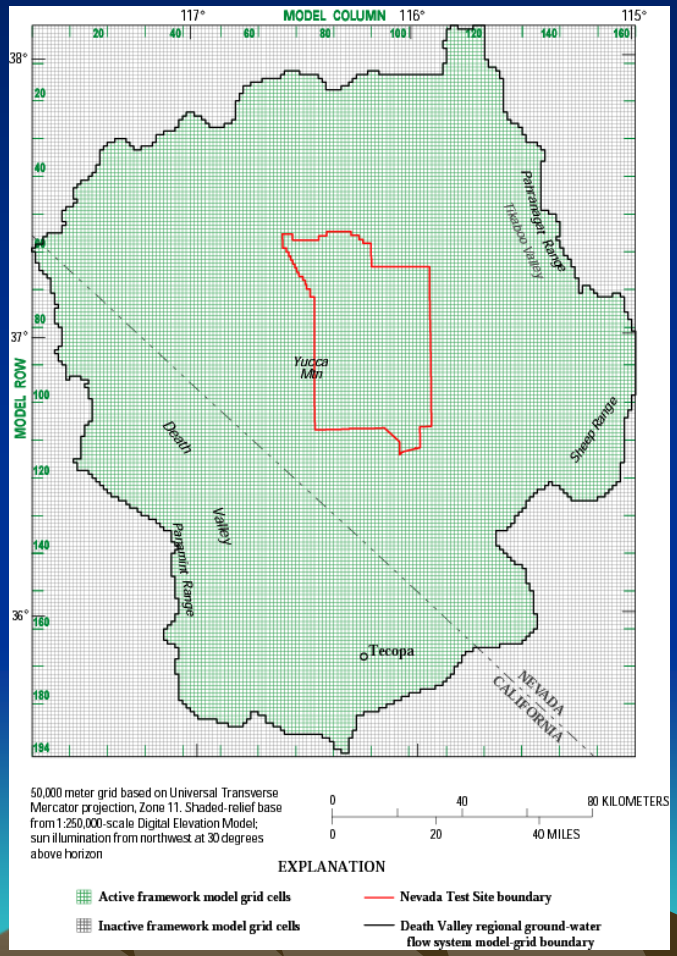
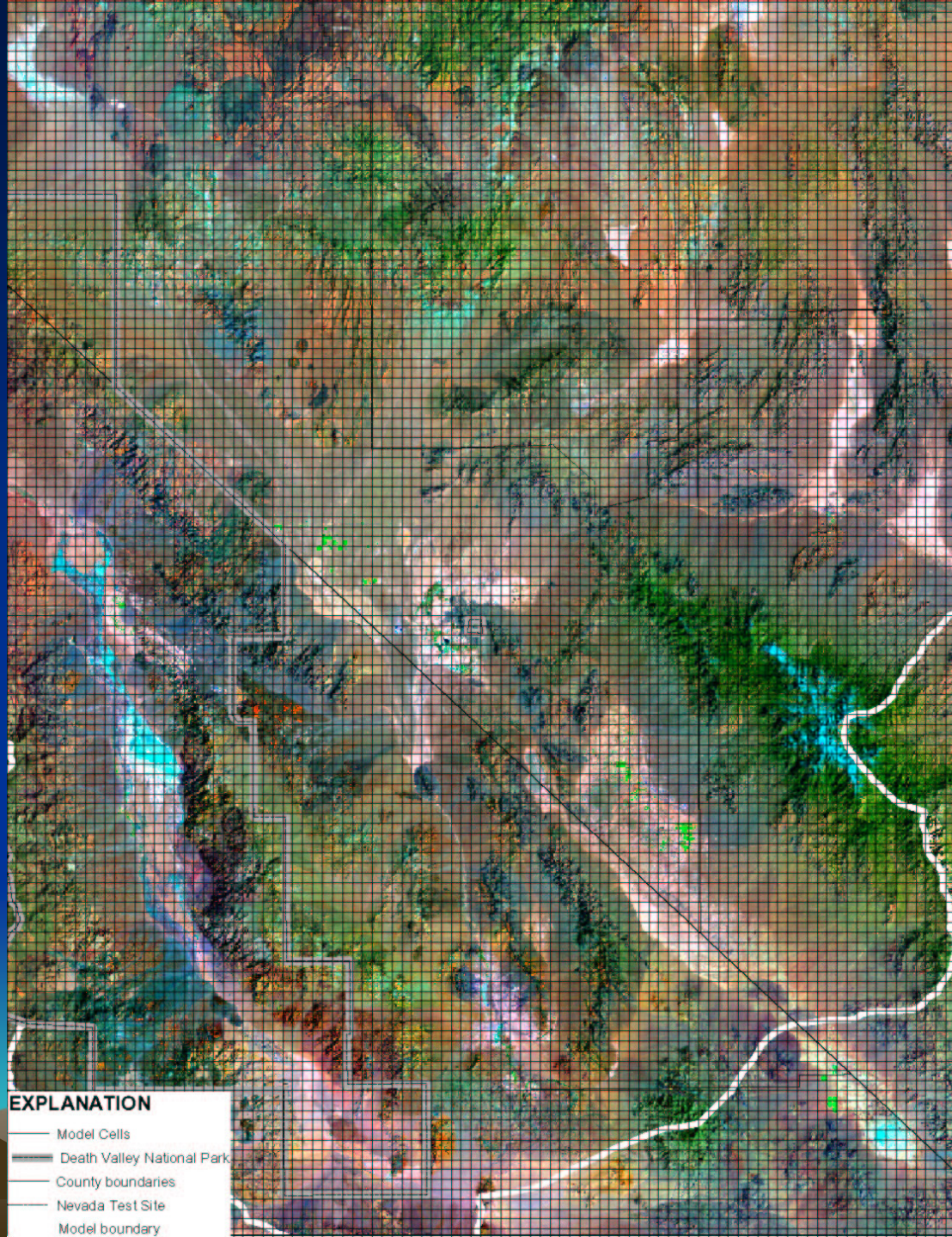
Model discretization

- 1500 m grid cell spacing

194 rows
160 columns





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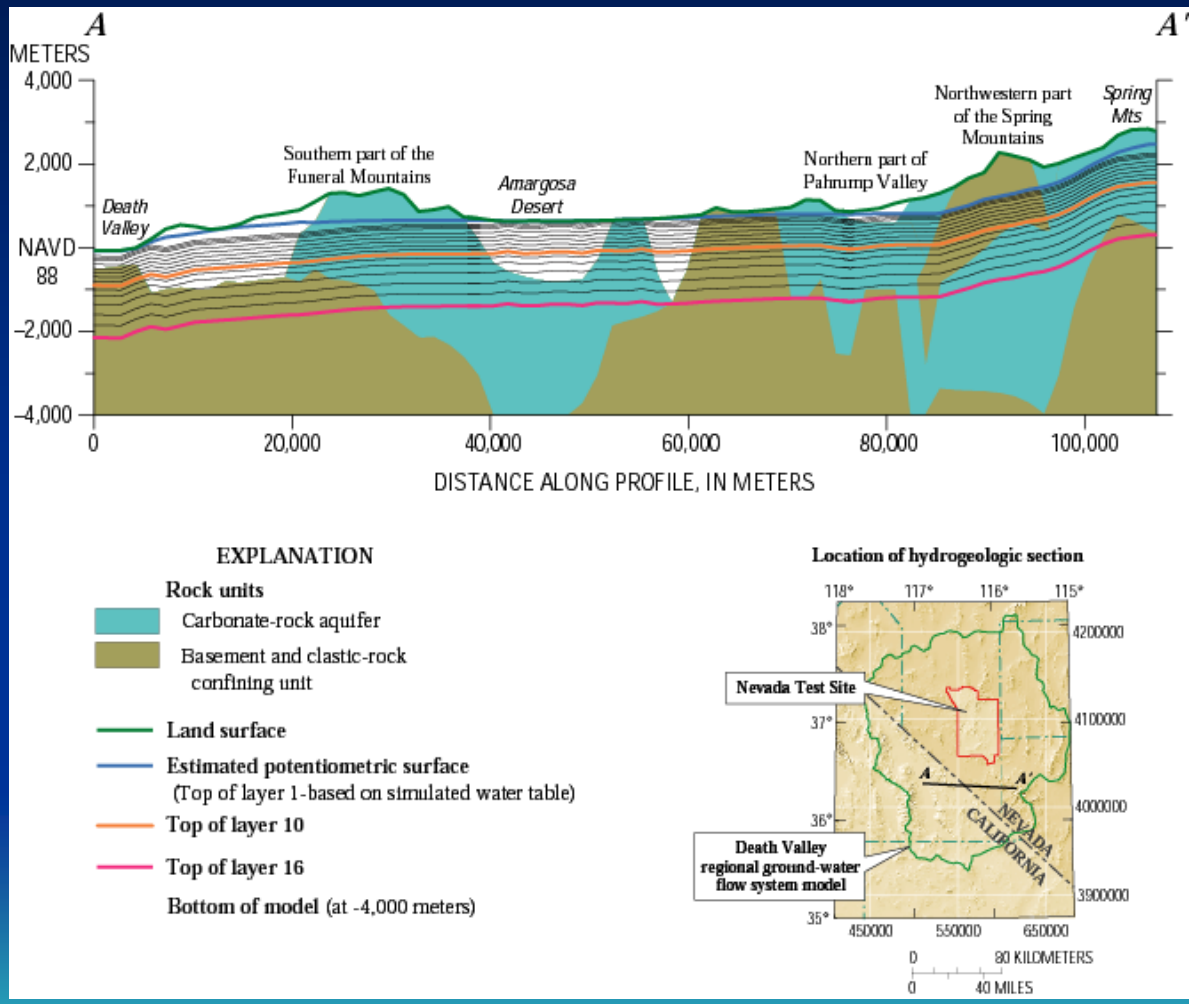
Model layers

- 16 layers
  - top layer is simulated water table
  - remaining layers at smoothed version
  - uniform thickness per layer
  - layers get thicker with depth



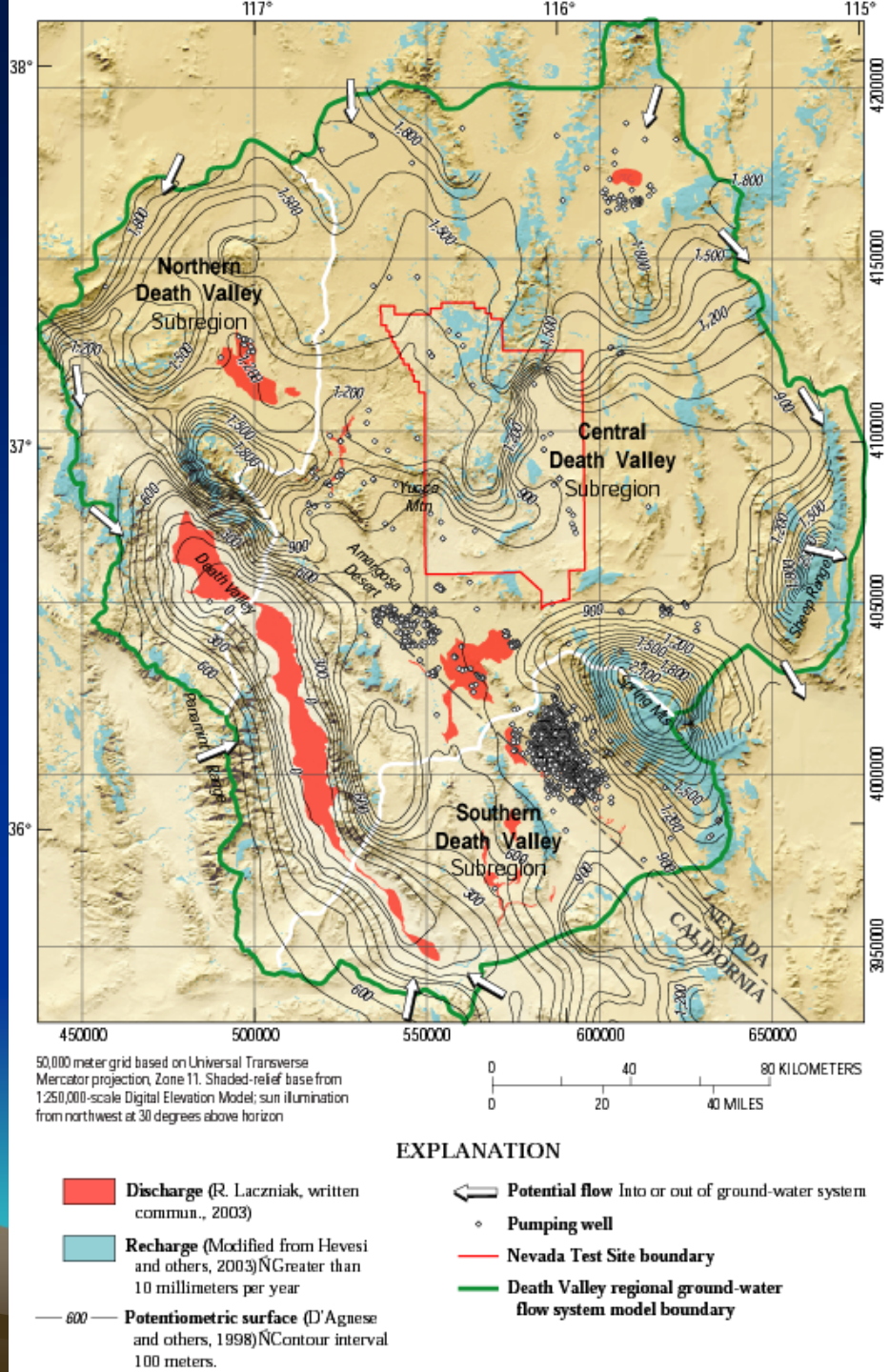
Fluxes and observations

Boundary conditions
- significant change

Recharge
- infiltration model

Discharge
- multi-node well package
- drains (simulating
  - spring flow
  - evapotranspiration

Hydraulic head observations



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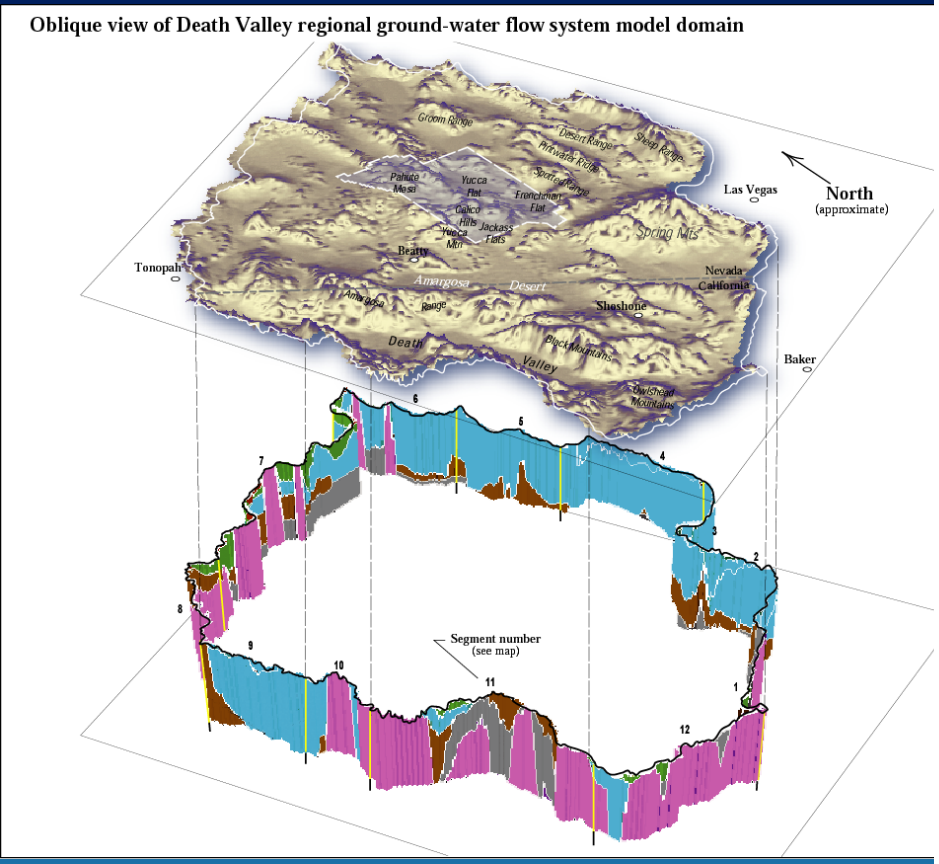
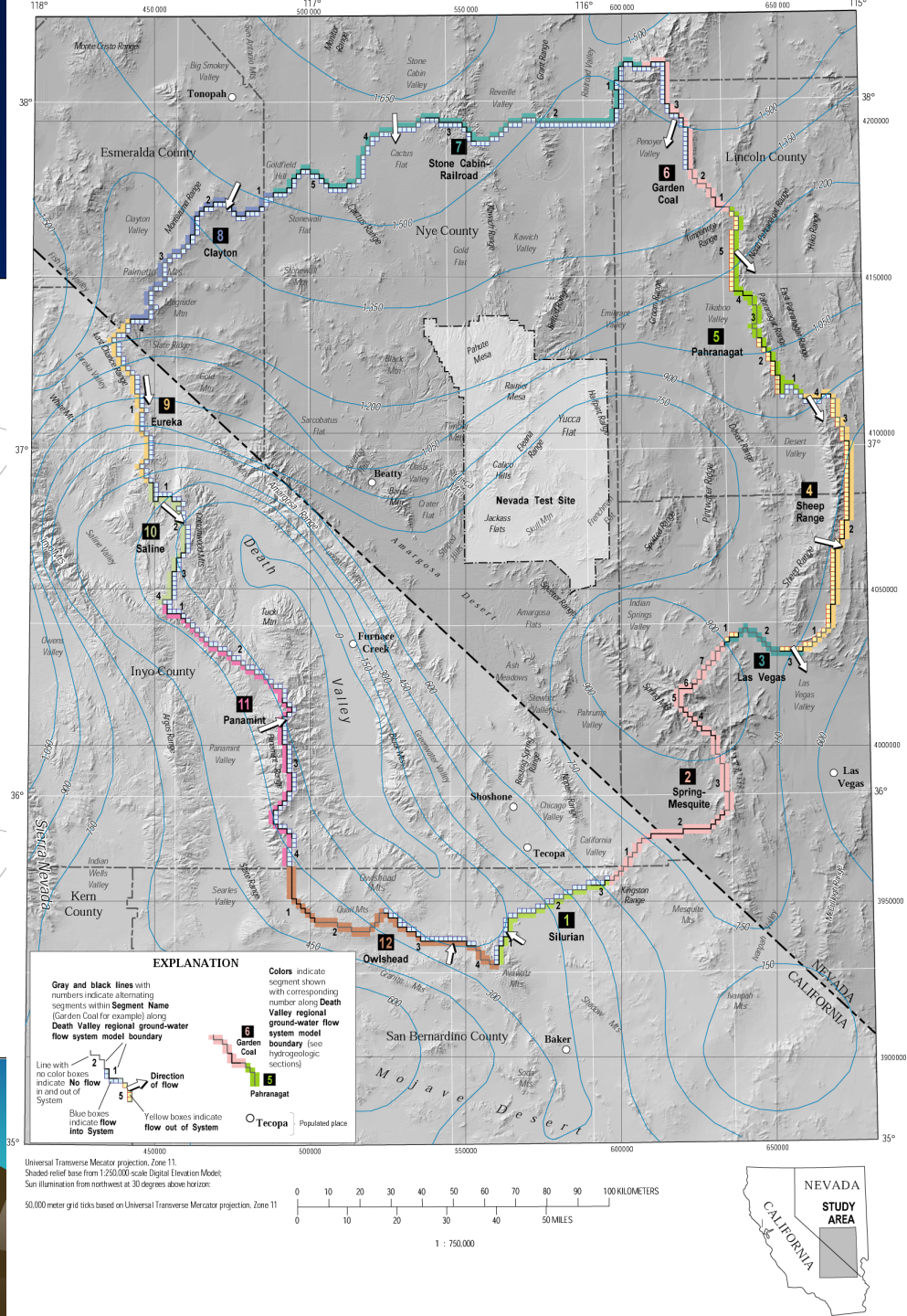
Boundary conditions





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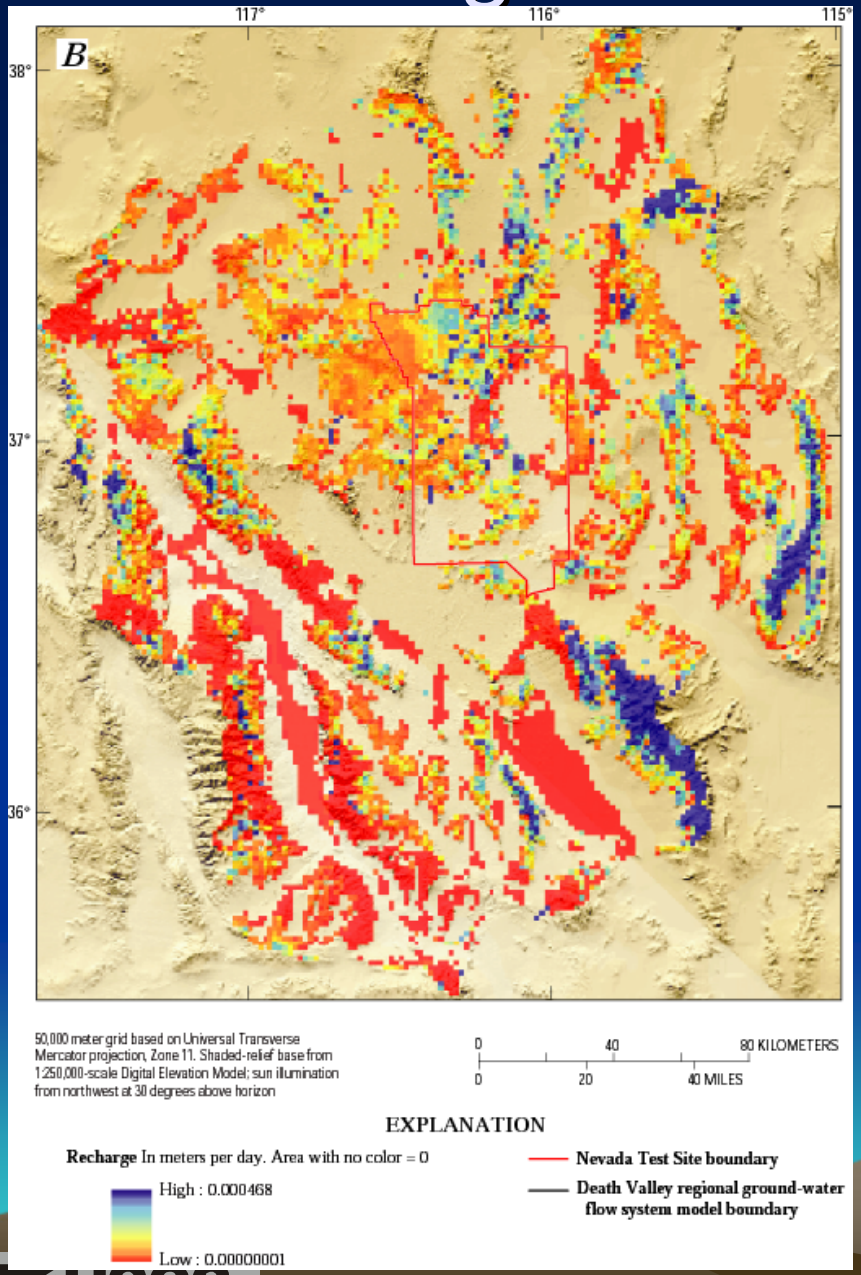
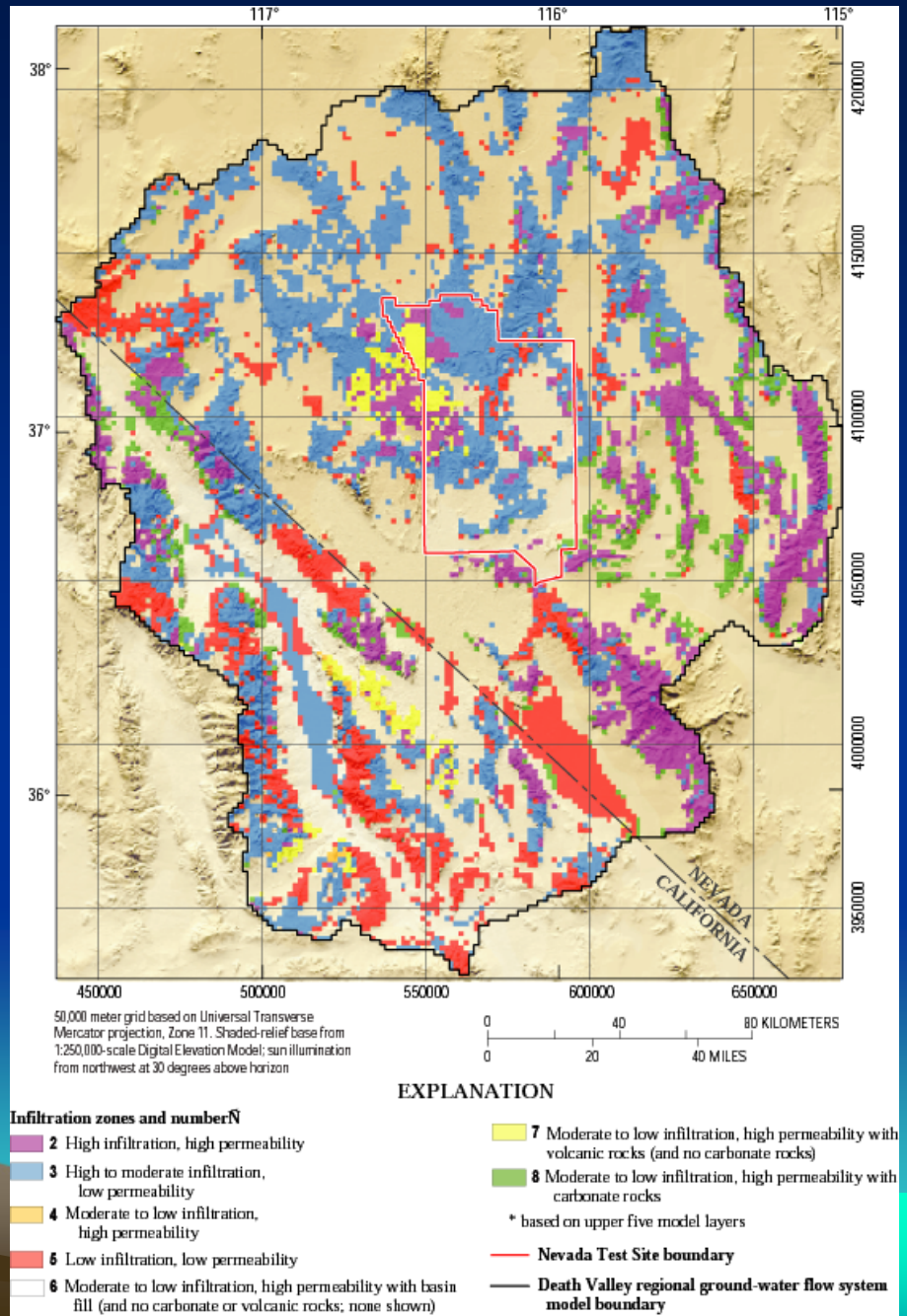
Recharge based on infiltration model





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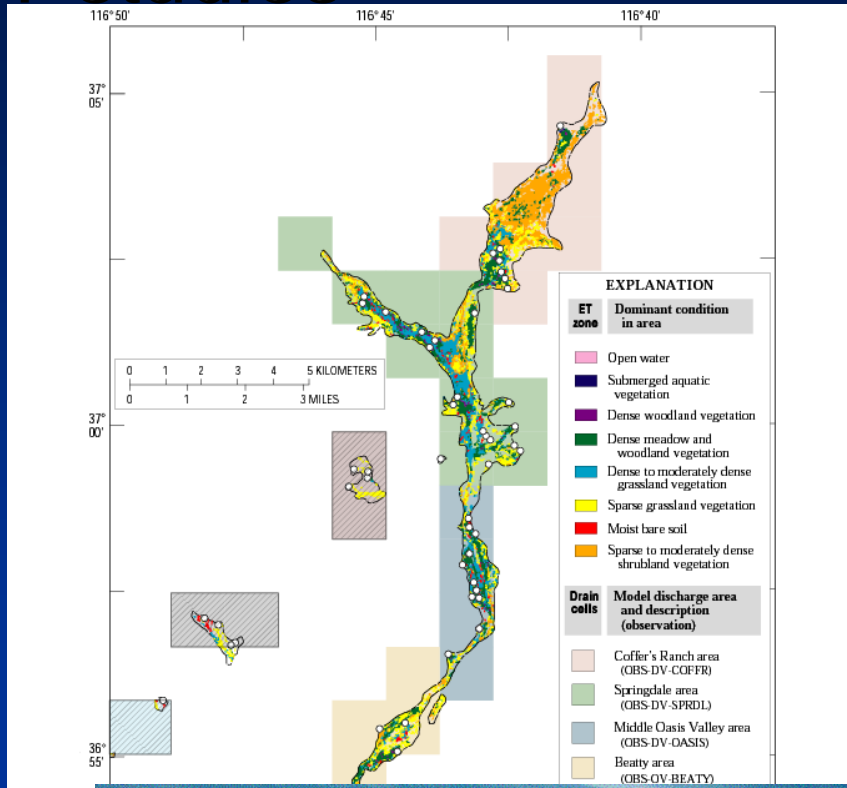
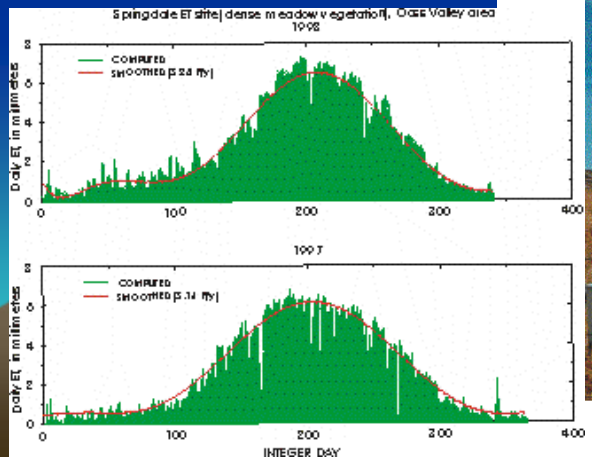
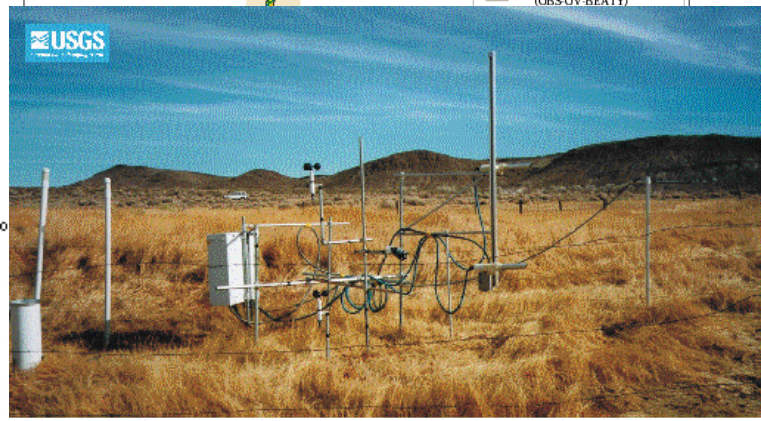
Discharge represented by drains based on comprehensive ET studies

- Activities:
  - Delineation ET areas with remote sensing
  - Monitor microclimate
- Products:
  - Up-to-date natural ground-water discharge rates
  - Uncertainty
- Use in model:
  - Flow observations with uncertainty
  - Constraints on system flux







ET Site over dense meadow vegetation, Oasis Valley area

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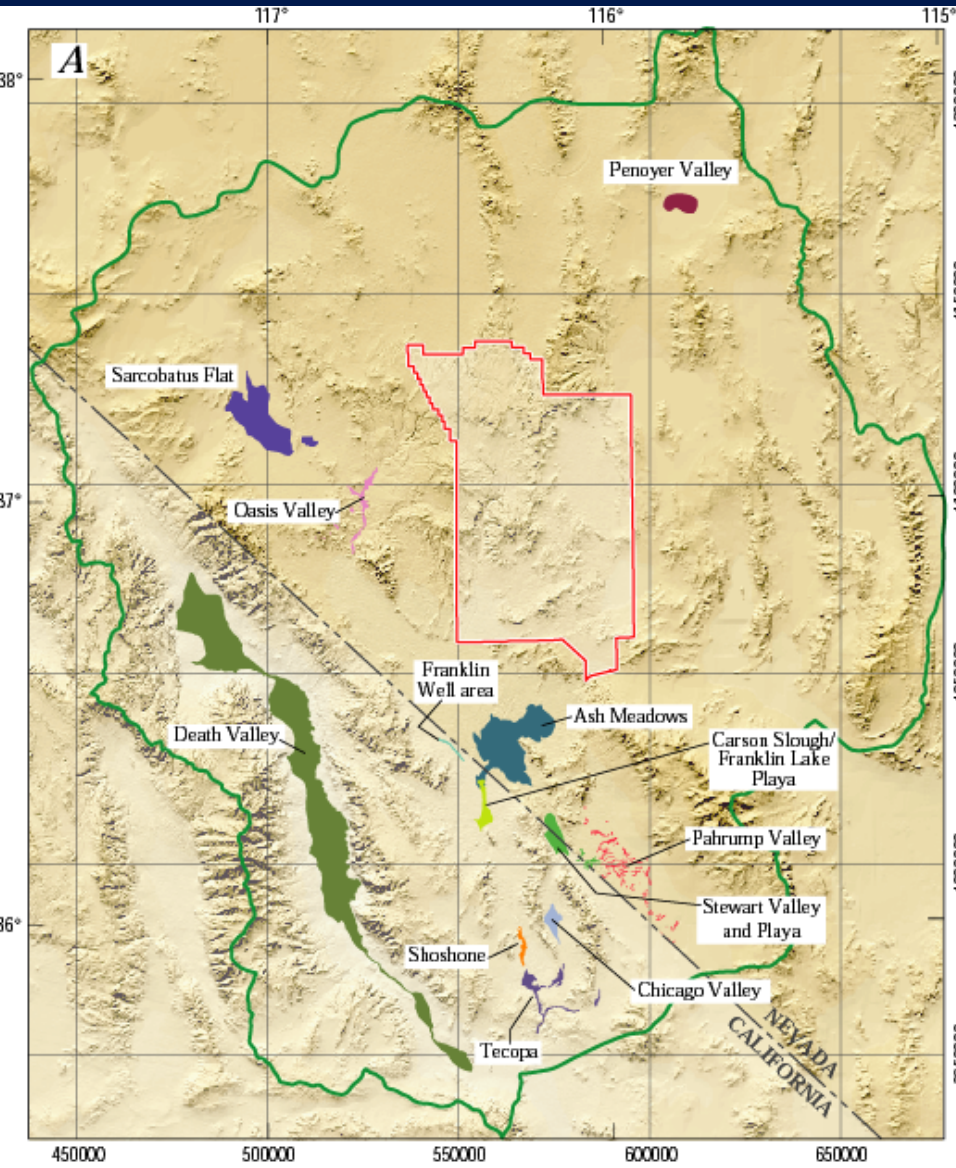
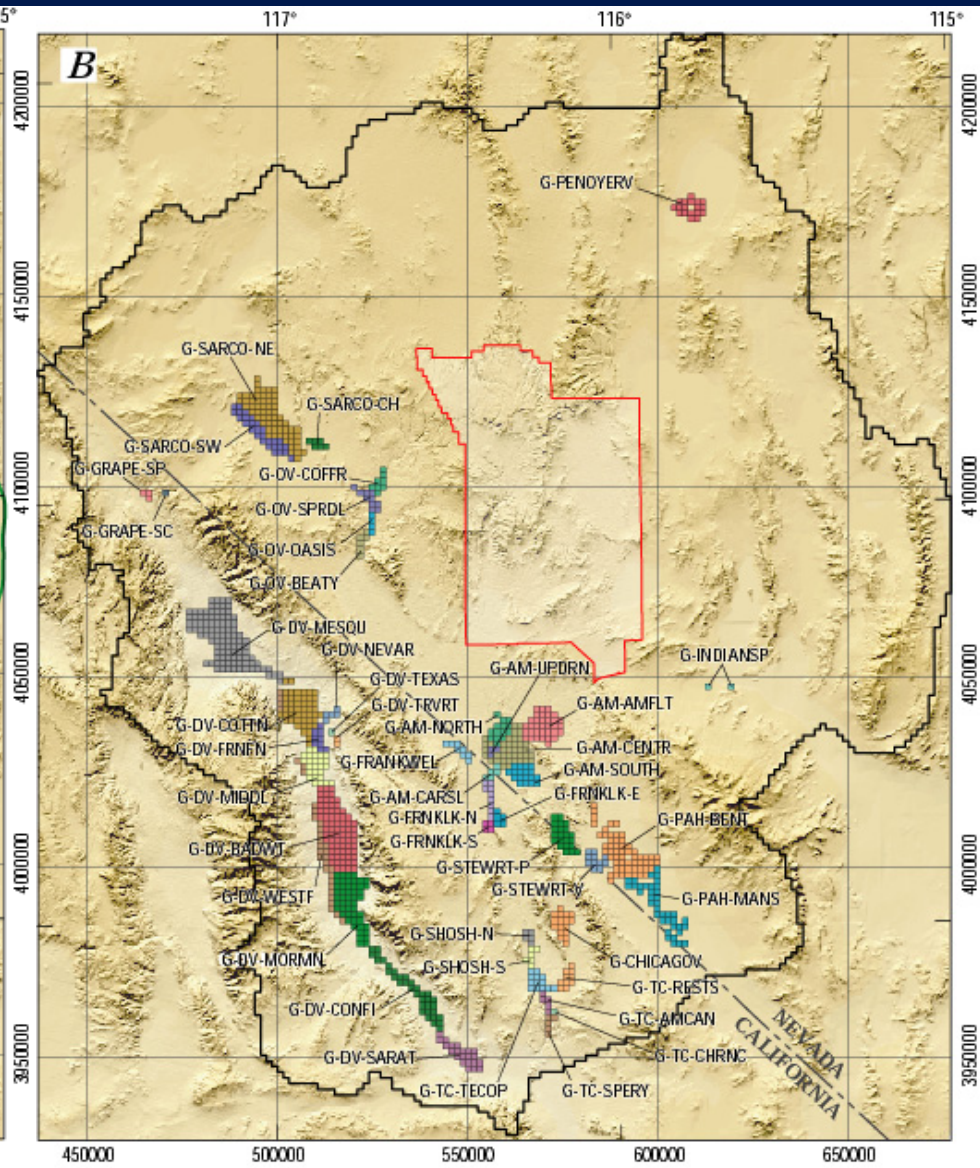
Discharge represented by drains



50,000 meter grid based on Universal Transverse Mercator projection, Zone 11. Shaded-relief base from 1:250,000-scale Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

0 40 80 KILOMETERS

0 20 40 MILES



50,000 meter grid based on Universal Transverse Mercator projection, Zone 11. Shaded-relief base from 1:250,000-scale Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

0 40 80 KILOMETERS

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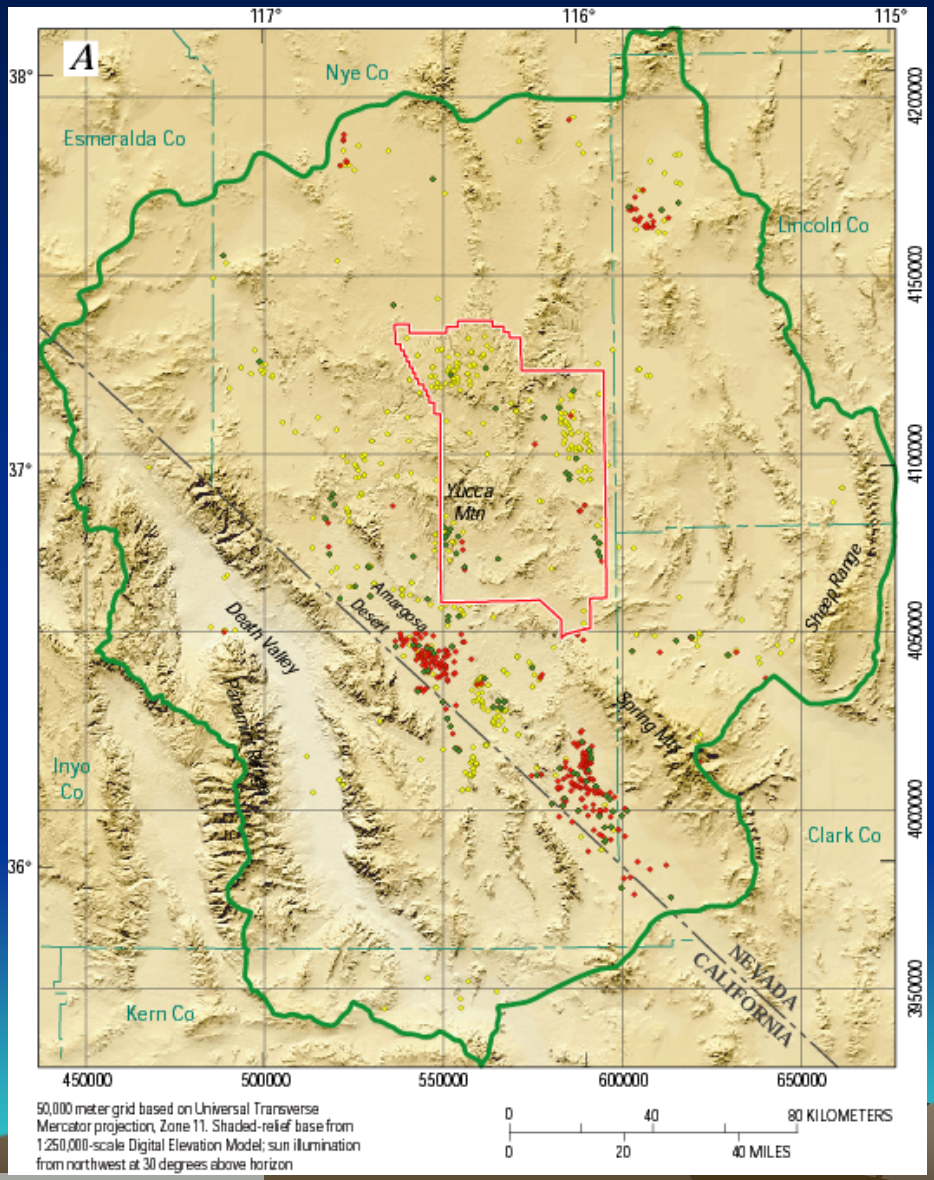
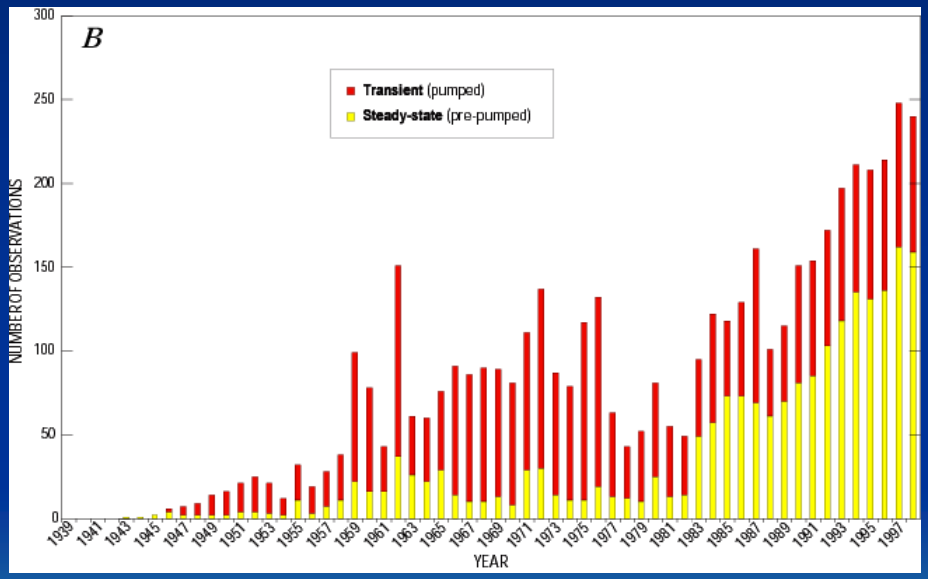
Hydraulic head observations



- Hydraulic head information (2,227 observations)
- Drawdown information (2,672 observations)



Hydraulic-head observation

- Steady state (pre-pumped) stress period
- Transient and steady state-stress periods
- Transient (pumped) stress period

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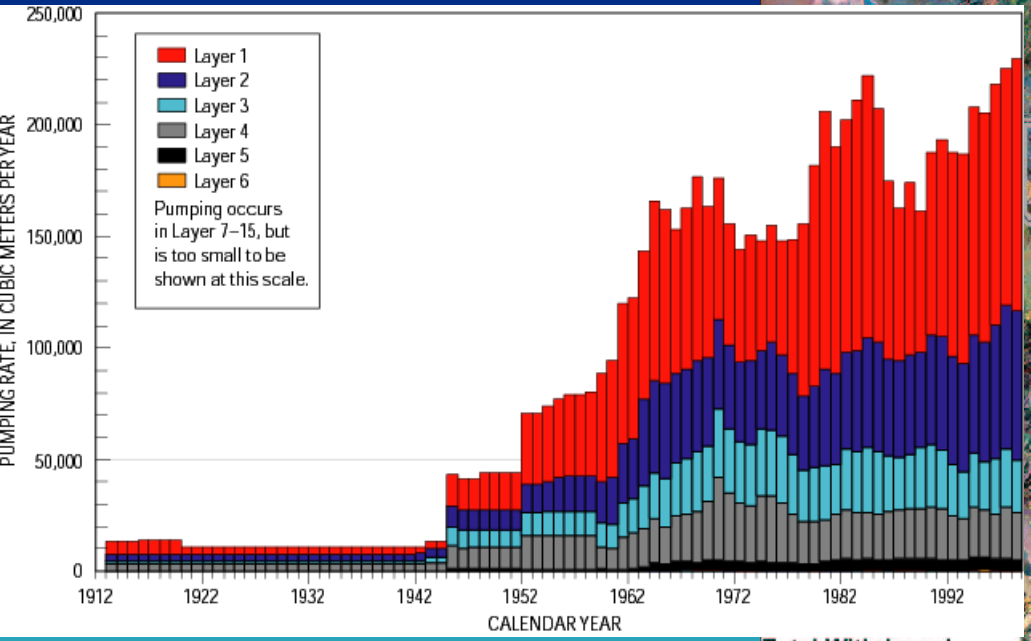
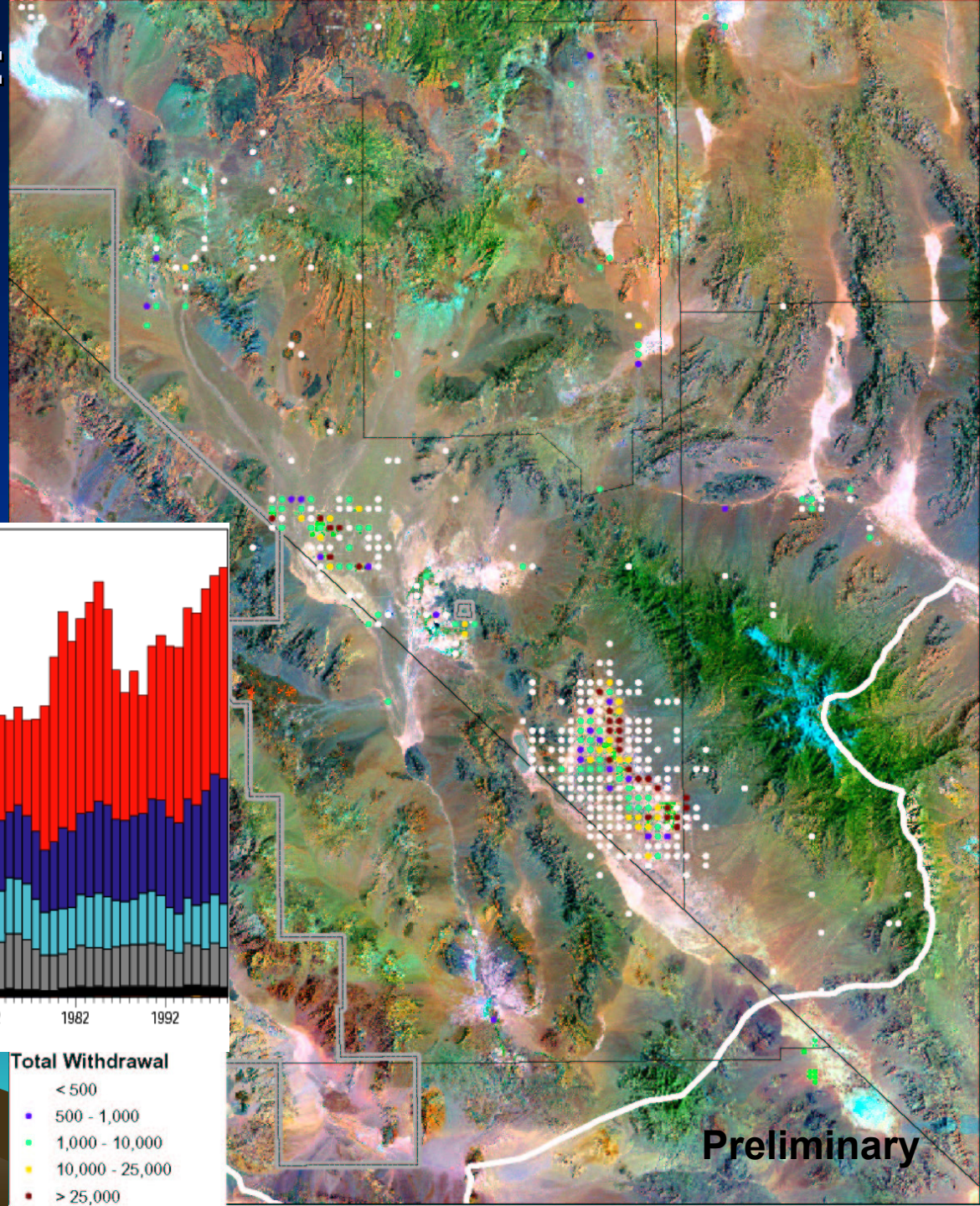
Transient simulation: Pumping

- Multi-Node Well Package Distribution of simulated wells
  - One well combined pumpage per cell





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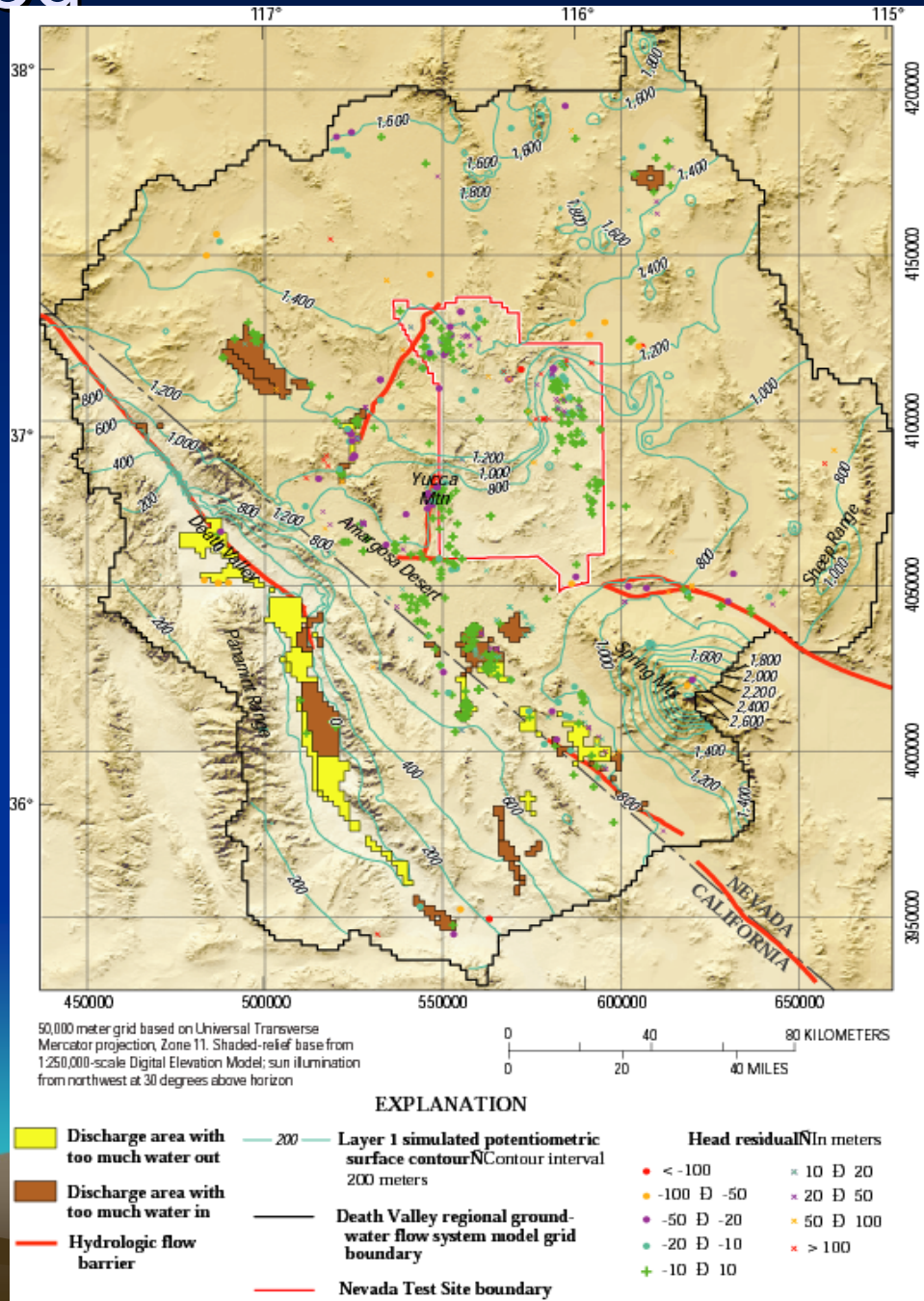
Residuals and simulated potentiometric surface

- Calibrated with the aid of parameter-estimation
- Pre-development conditions
  - Calibrated to hydraulic head information
- Transient conditions with pumping (1913-1998) calibrated to:
  - Hydraulic head information (2,227 observations)
  - Drawdown information (2,672 observations)
  - Discharge information (49 observations)
  - ONLY to changes in discharge at Pahrump Valley (3 uncertain observations)
  - Hydraulic head errors typically greater than measured drawdown



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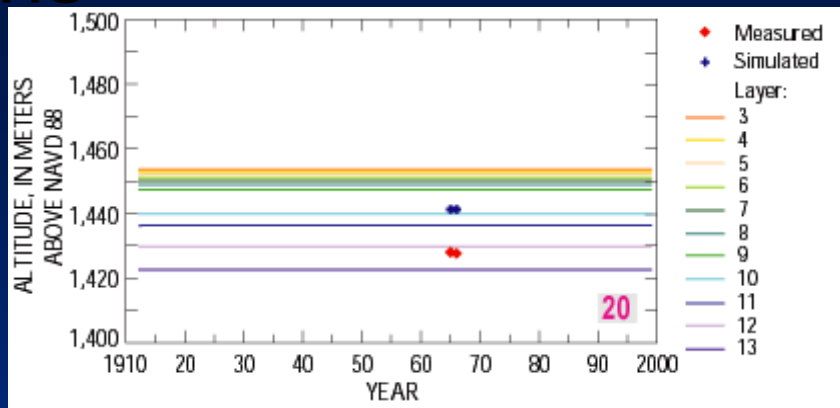
Hydrographs

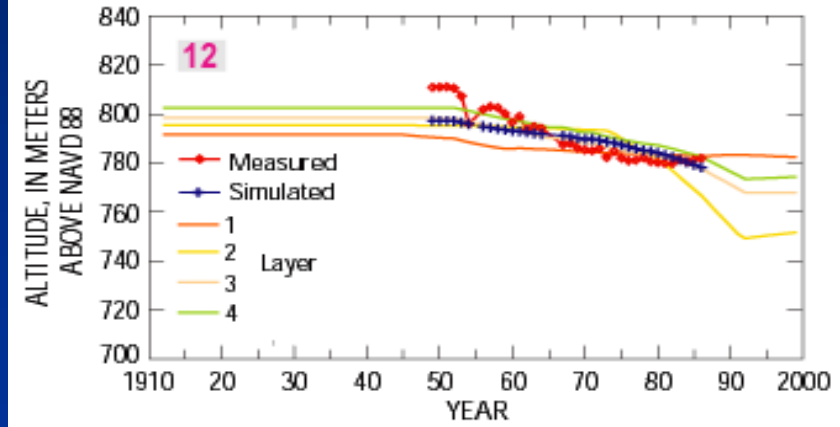
Useful for examining
- gradients
- affects of pumping
- changes through time

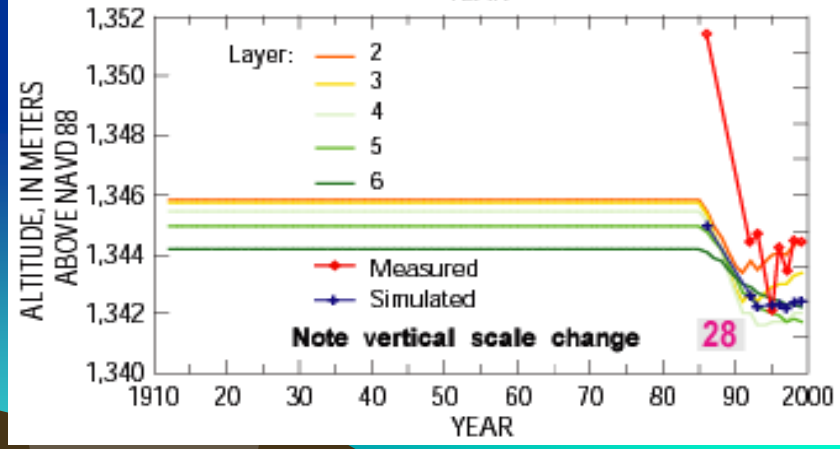
Downward gradient

Upward gradient and pumping
With gradients reversing

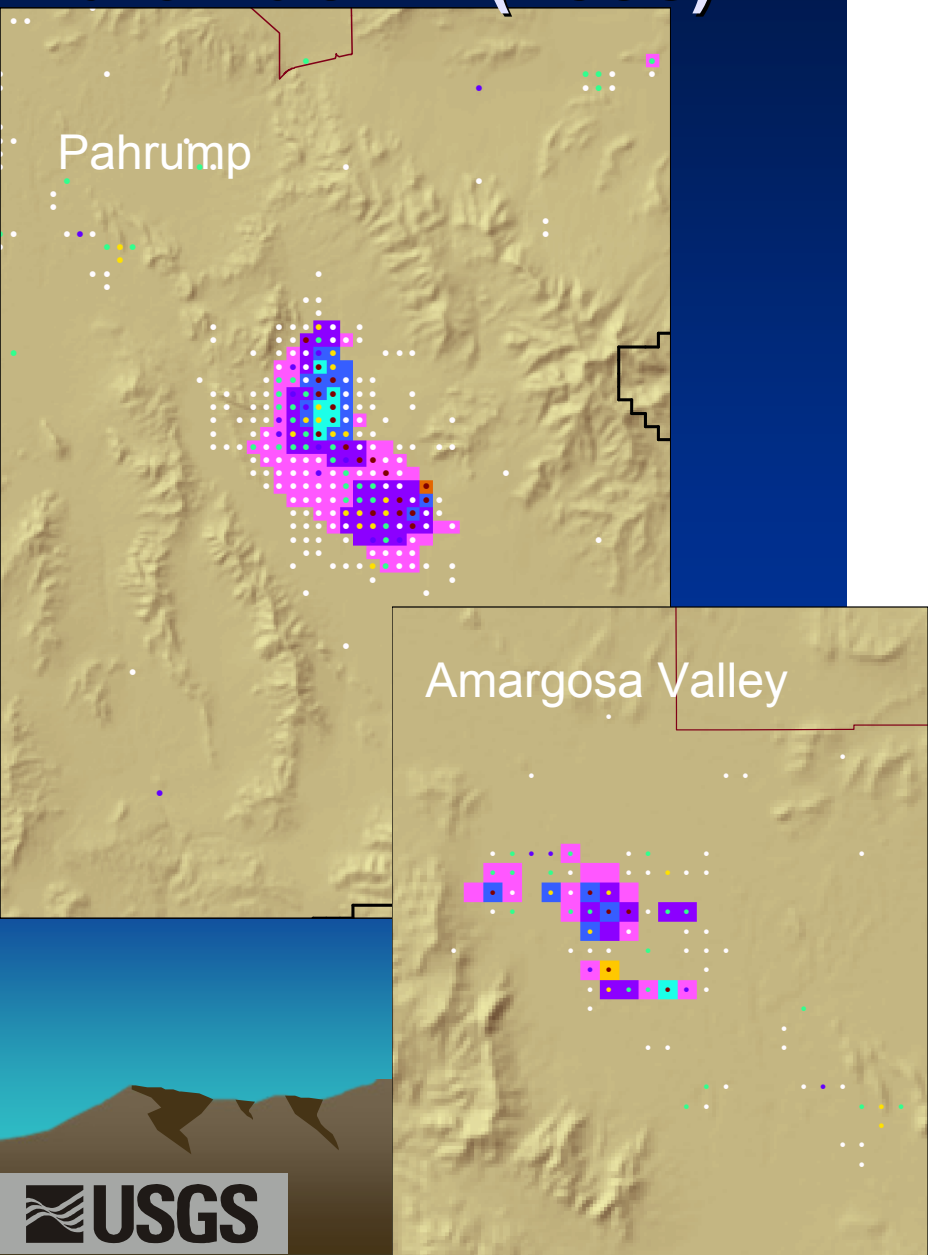
Local pumping on NTS

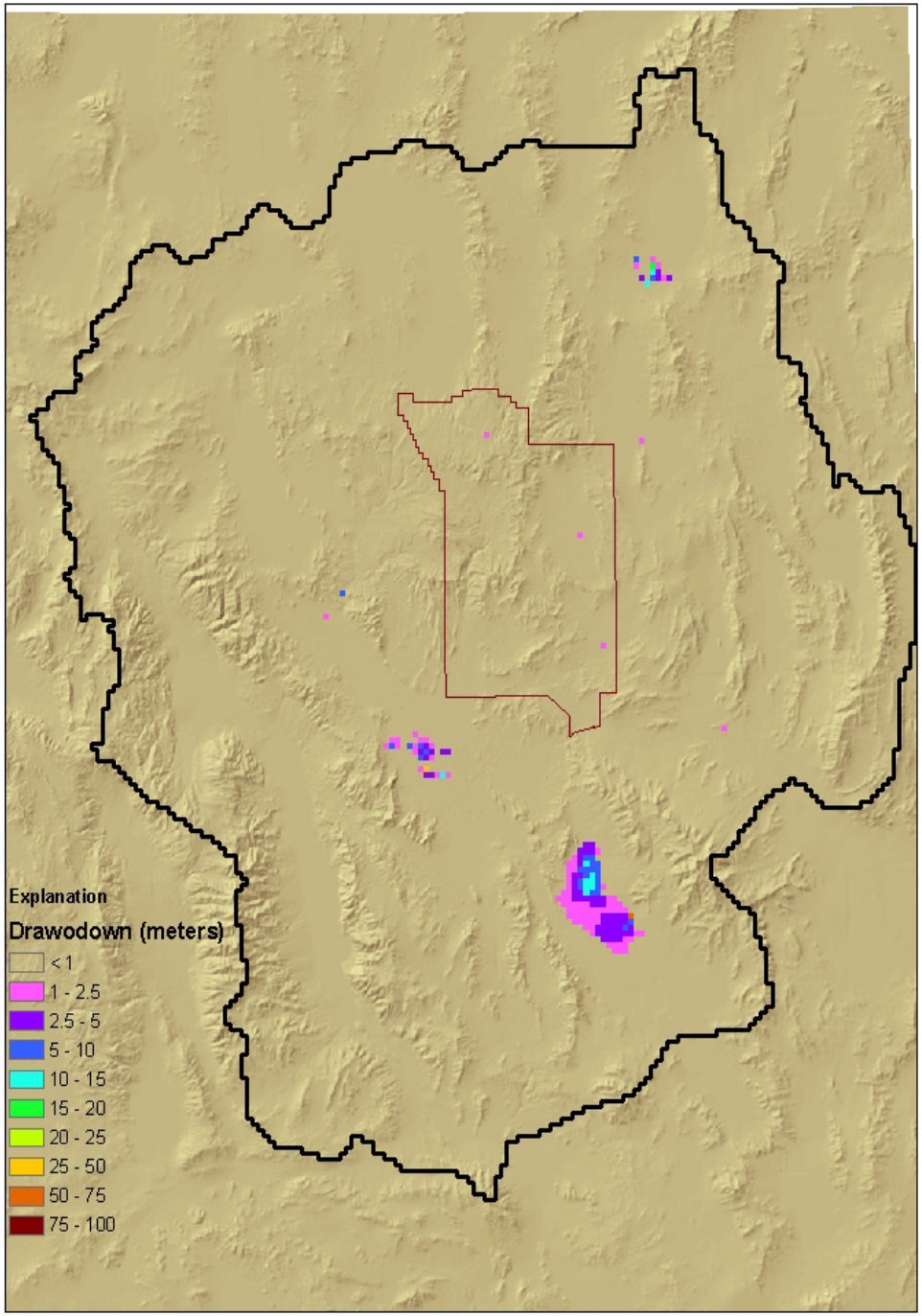






Simulated drawdown (1998)





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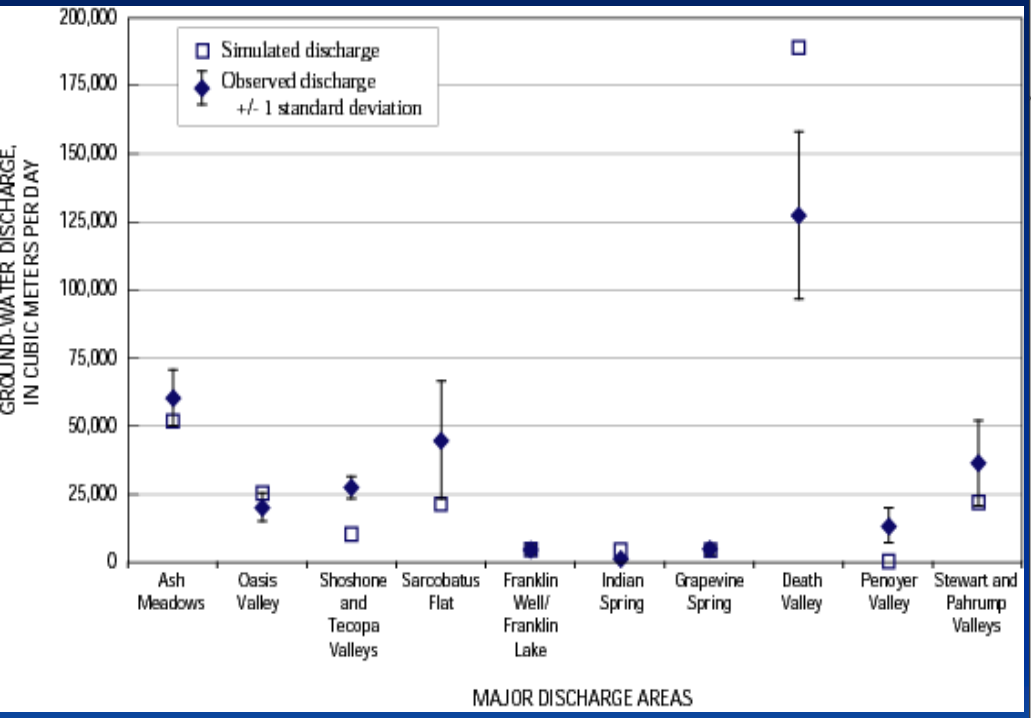
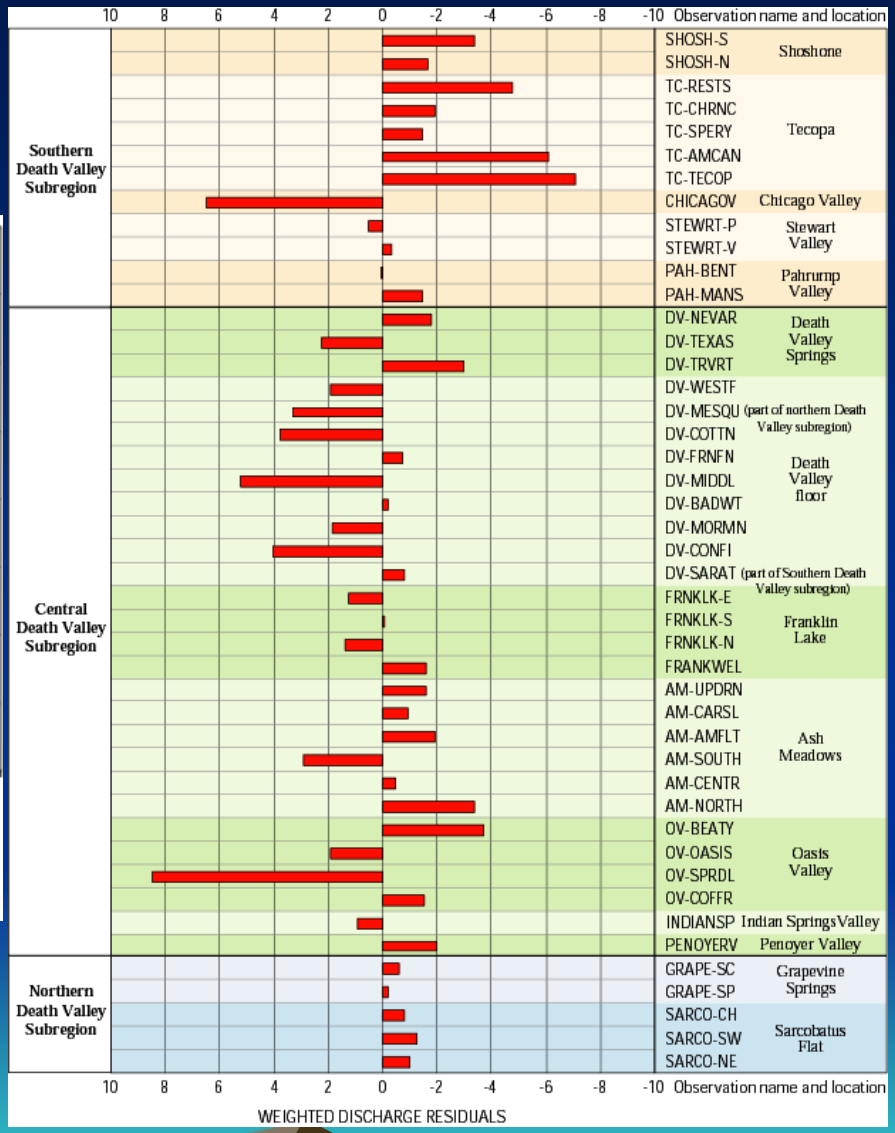
Discharge residuals





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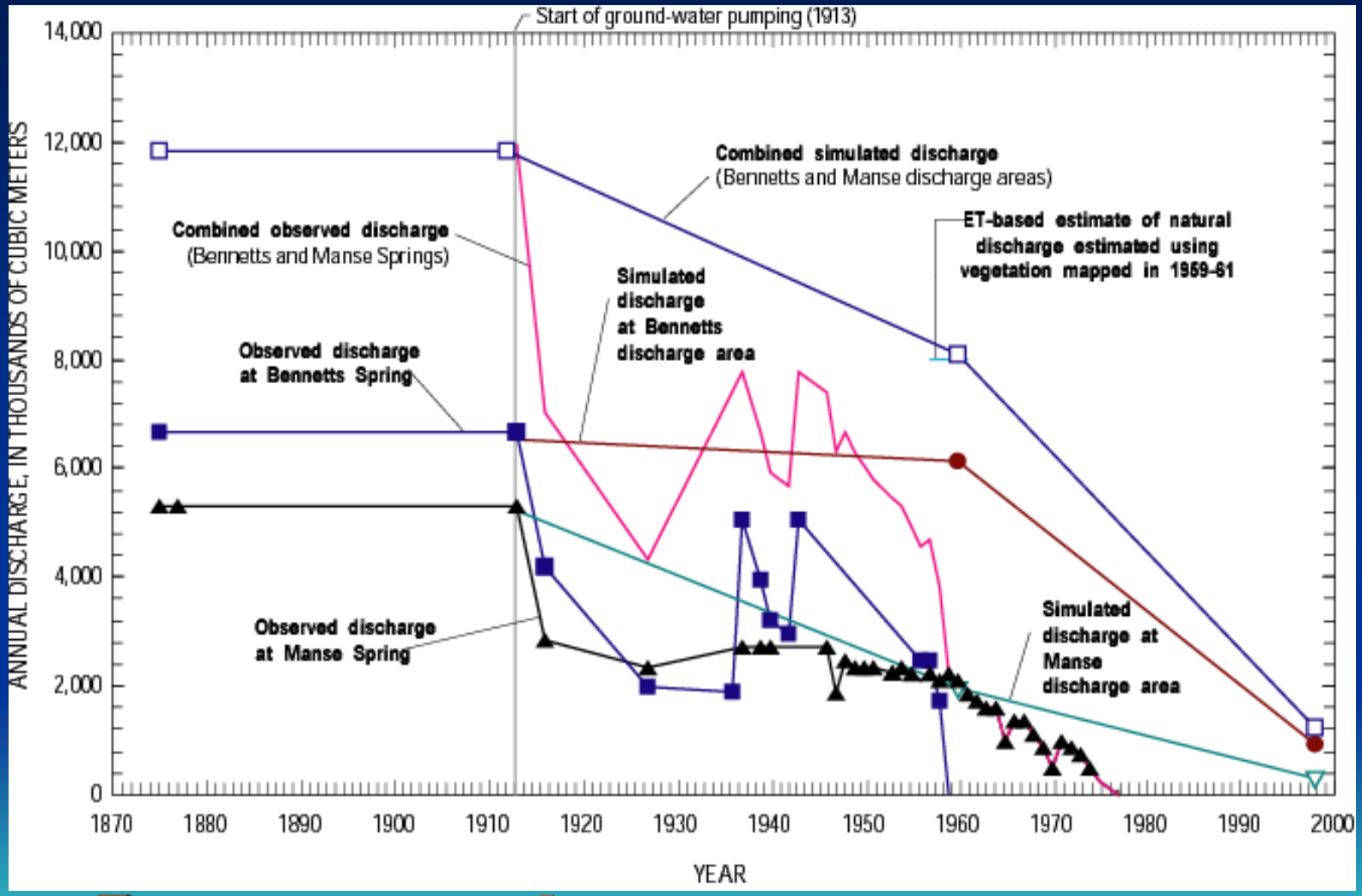
Change in discharge over time - Pahrump



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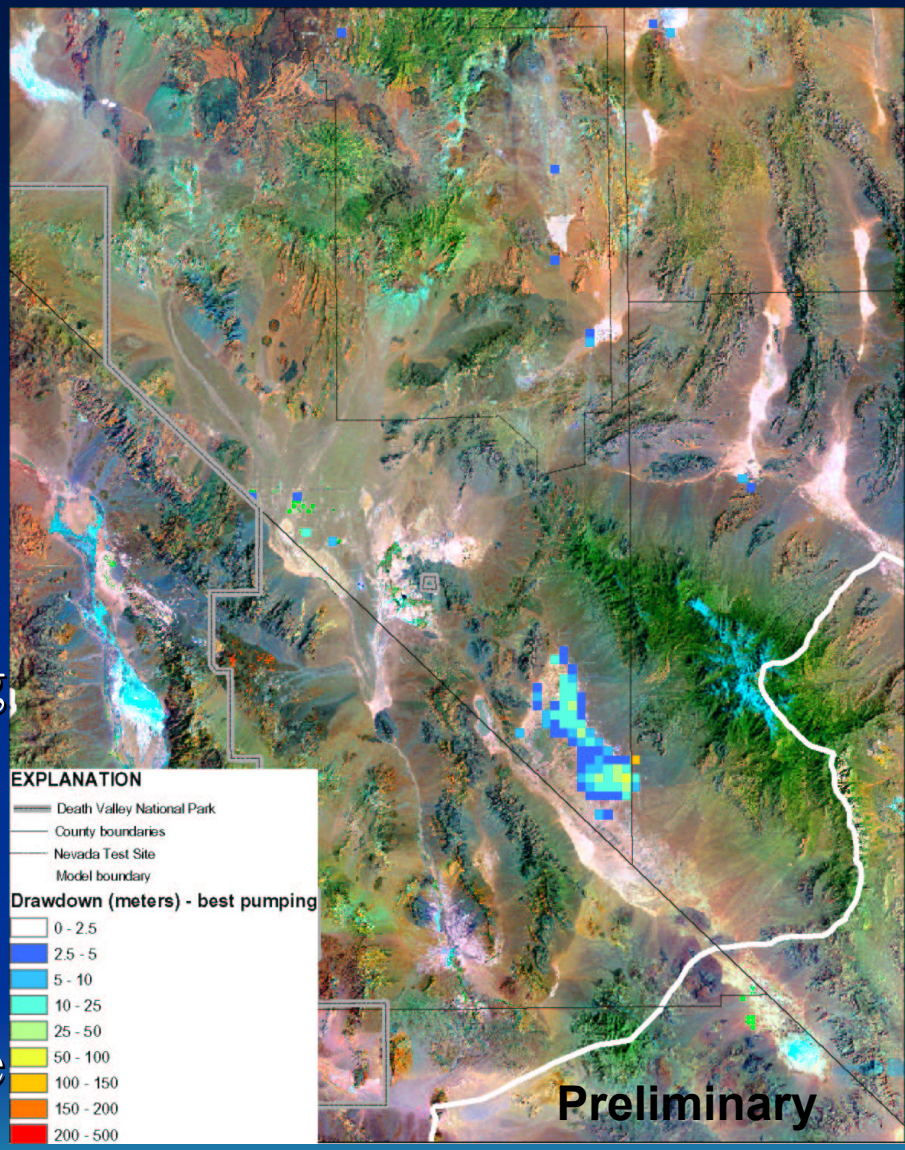
Comments

- REGIONAL MODEL
  - Good for answering regional questions
    - Examples:
      - Boundary conditions for site-scale models
      - Increase/Decrease in spring discharge (riparian community) based on pumping in region
      - Change in water levels based on pumping over time
  - Need more site-specific scale model to address more detailed concerns



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Report outline

- Released on-line: Death Valley Regional Ground-Water Flow System, Nevada and California----Hydrogeologic Framework and Transient Ground-Water Flow Model, Wayne R. Belcher, editor
  - http://pubs.water.usgs.gov/sir2004-5205/
- Part A: Introduction (Belcher)
- Part B : Conceptual model of the regional geology and hydrogeology (by Sweetkind, Faunt, and Belcher)
- Part C: Conceptual model of the regional hydrology (by Faunt, D'Agnese and O'Brien)
- Part D: Hydrogeologic Evaluations (by San Juan)
- Part E: Hydrogeologic Framework Model (by Faunt, Sweetkind, and Belcher)
- Part F: Numerical Model of Ground-Water Flow (by Faunt, Hill, Blainey, O'Brien, and D'Agnese)
- Appendices: Databases and Data Sources (Bedinger and Harrill)

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The Future – FY05 and On

- Simulate flow paths and water budgets
- Pumping scenarios
- Sensitivity Analysis on storage properties
- Use new methods to rank the importance of potential new observations, including long-term monitoring

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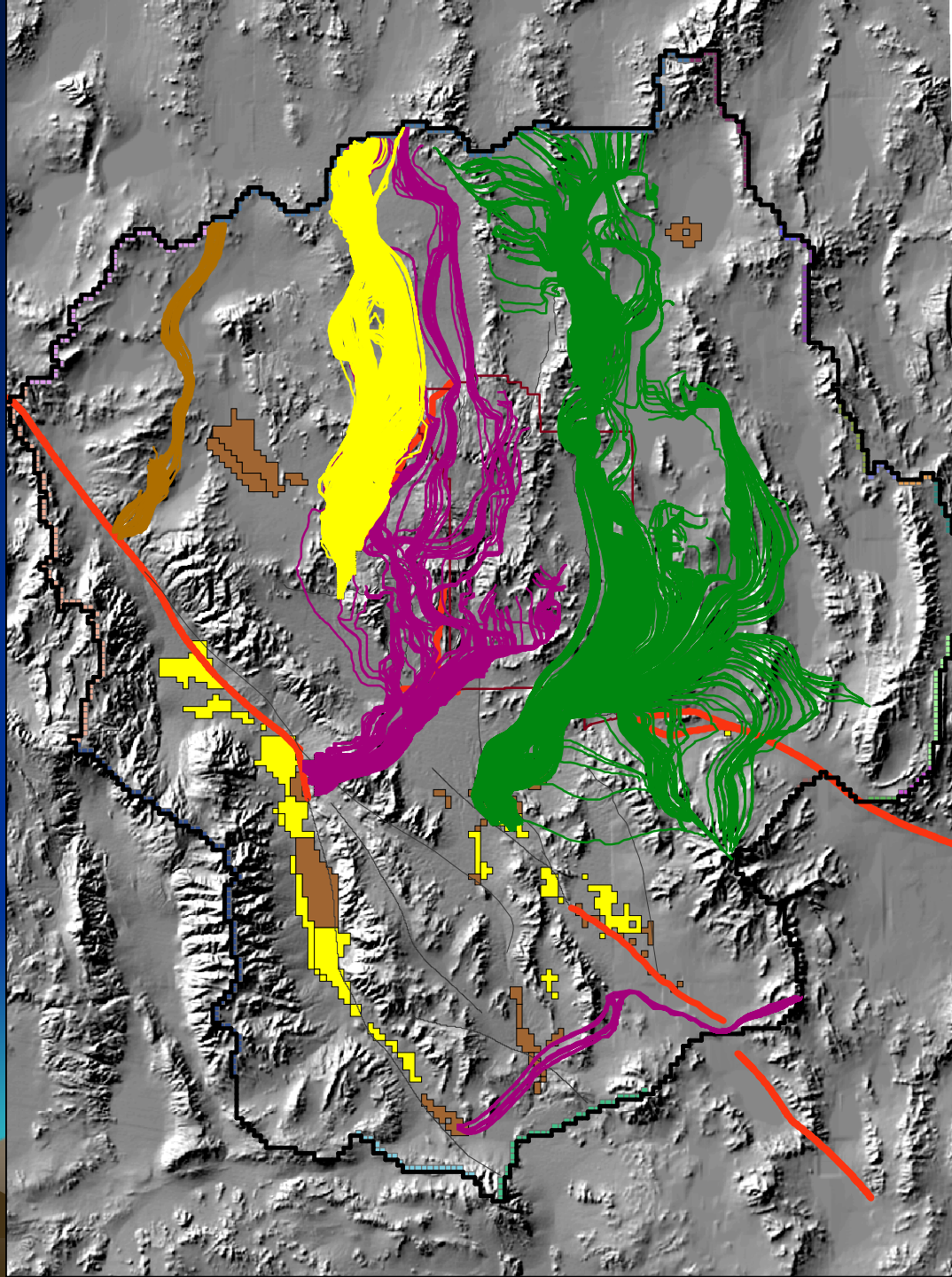
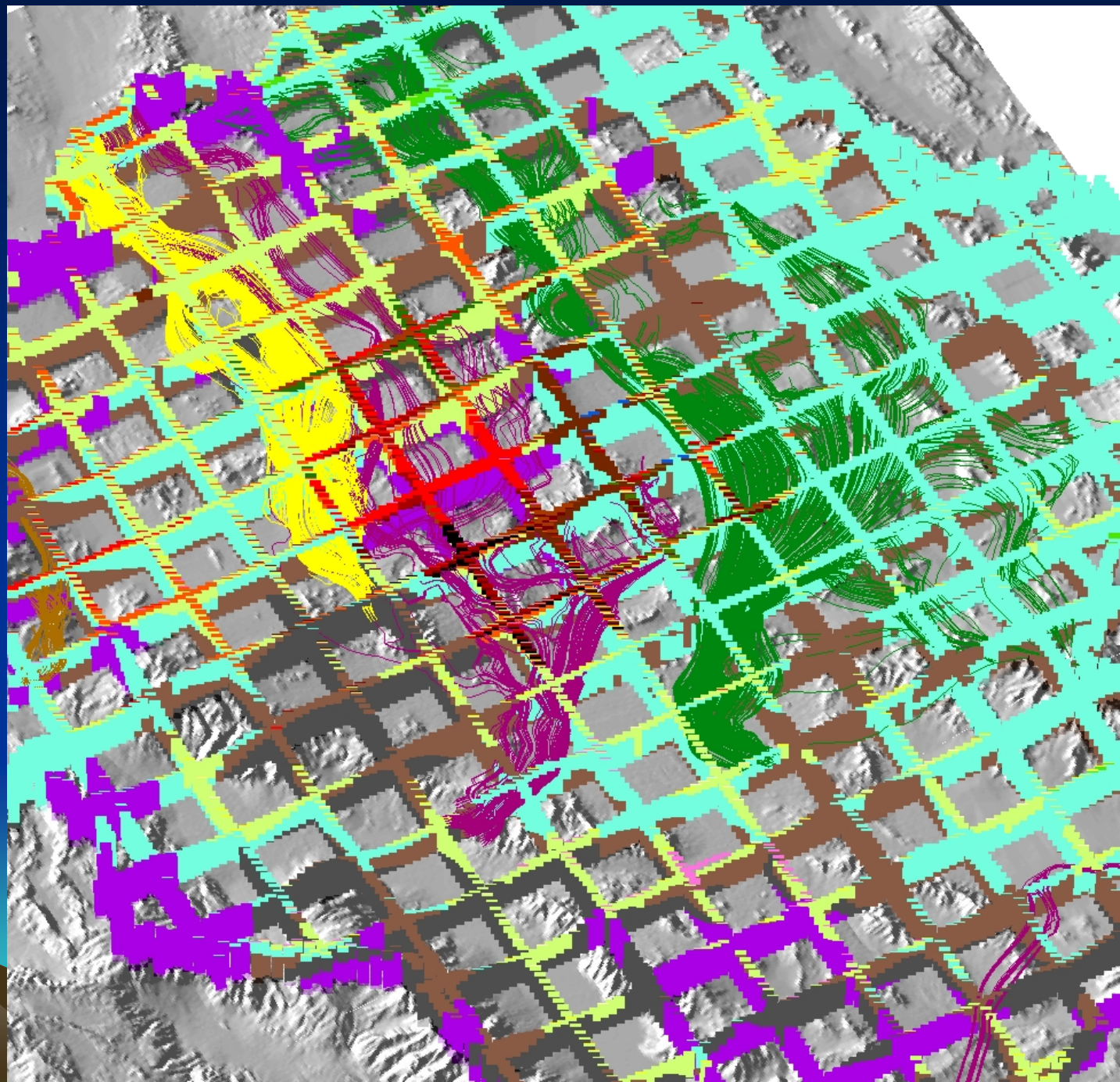
Simulated flow paths

Regional springs



Simulated flow paths in 3D with geology



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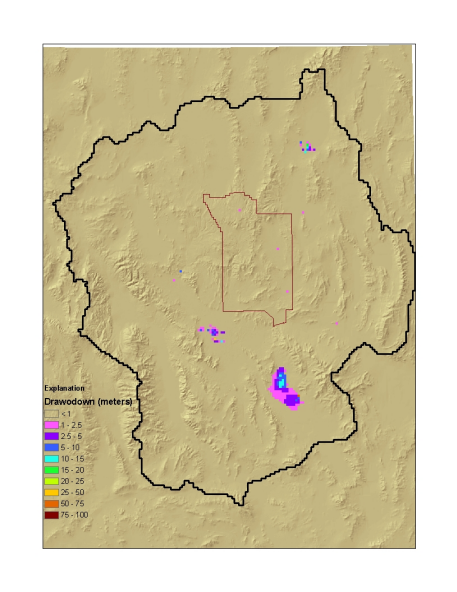
Predictive MODFLOW model simulations

- Additional 50 years with 1998 pumping applied in each year
  - Not calibrated
- Once storage is depleted, drawdown will increase rapidly and boundary conditions will be affected

Notes:
- No change in flow at constant head boundaries
- Little change in flow from springs and ET
- Most of discharge still from storage



Movie of drawdown through time (1913-2048)

Preliminary

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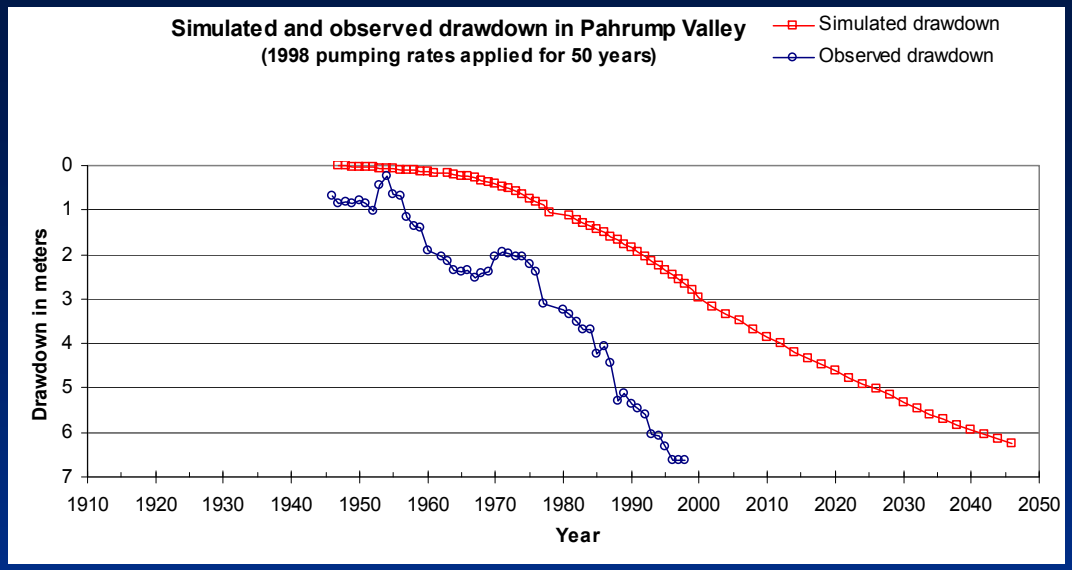

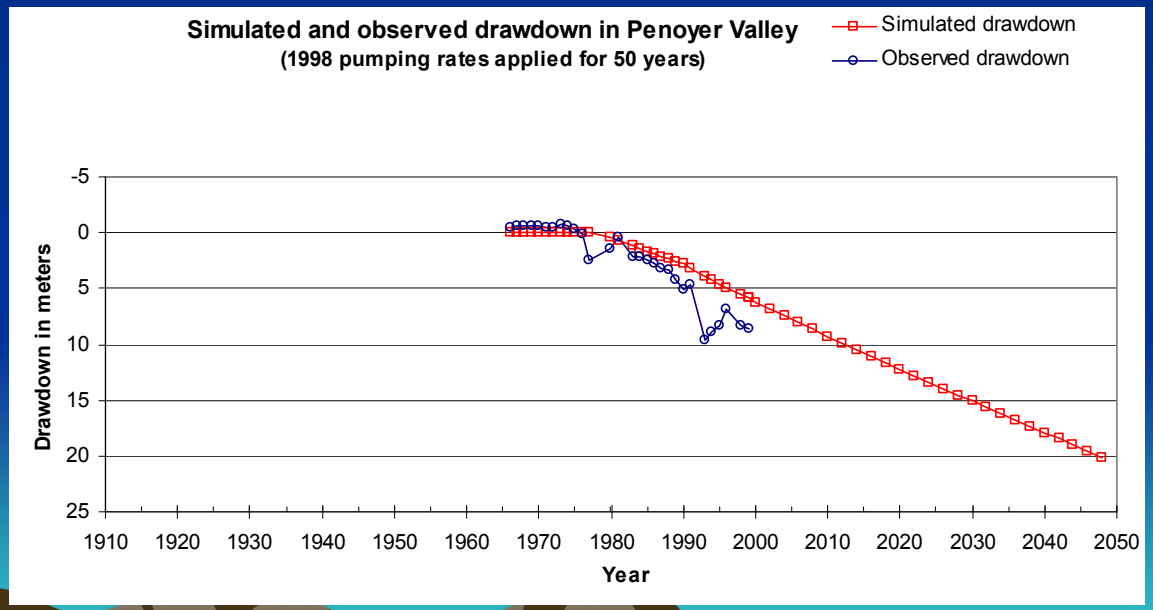

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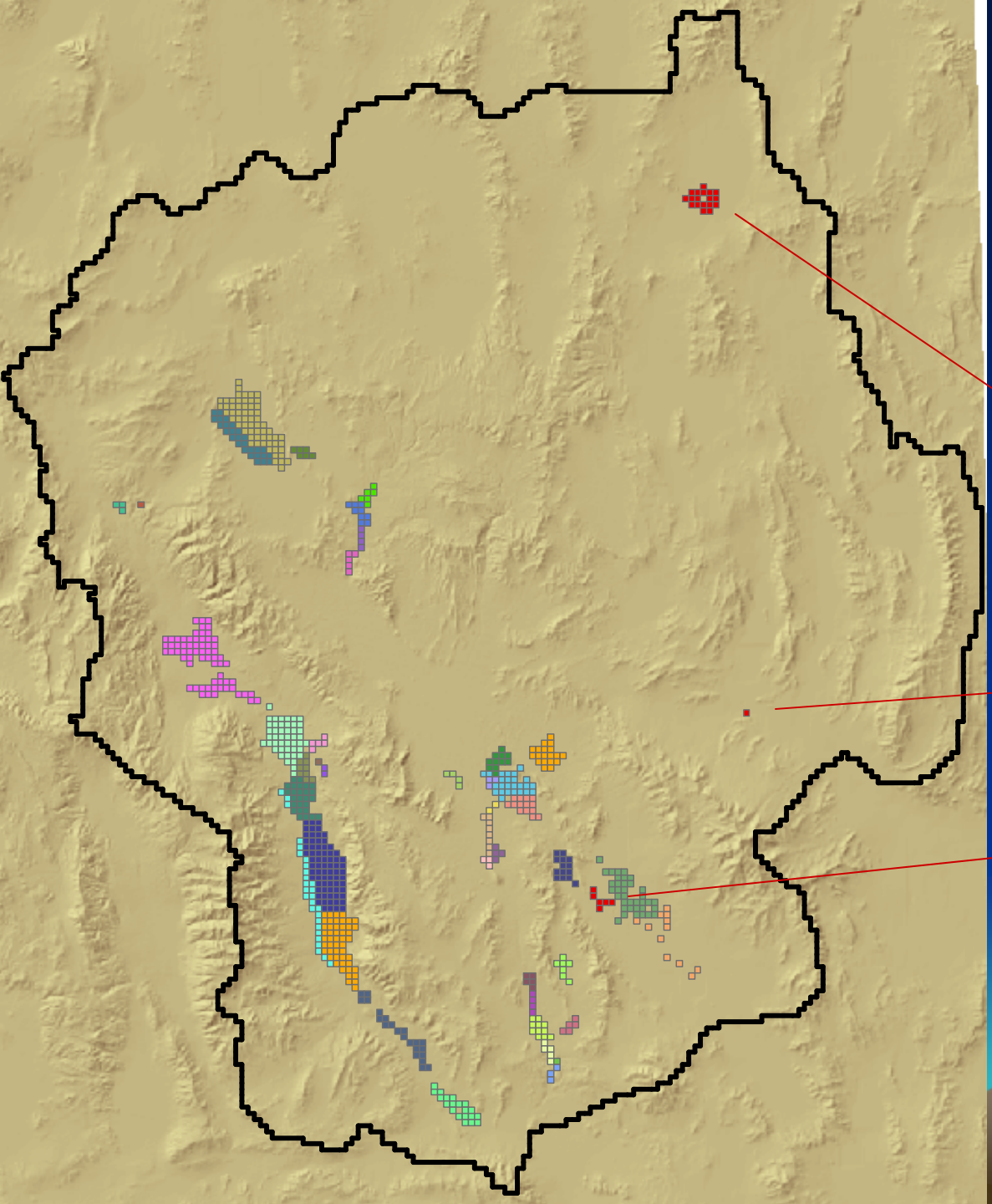
Preliminary



Areas of reduced discharge due to 50 years of pumping at 1998 rates

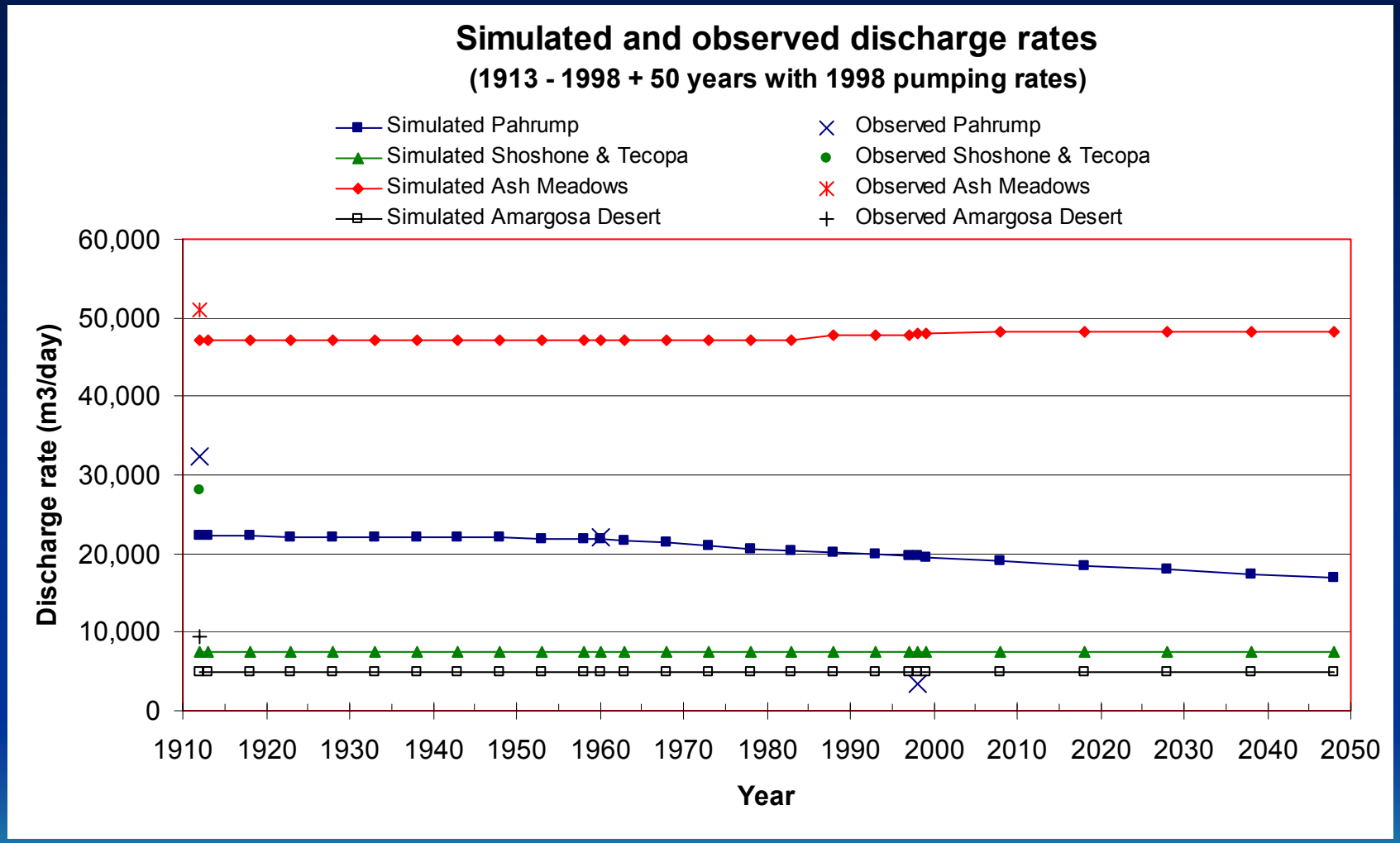
Penoyer Valley
80% of steady state discharge

Indian Springs
93% of steady state discharge

Stewart Valley
93% of steady state discharge

Preliminary

Simulated and observed discharge



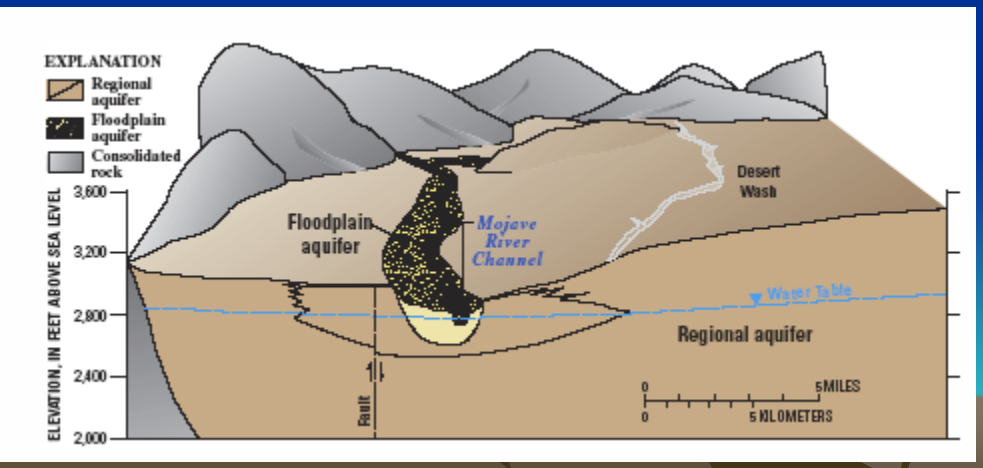
Preliminary

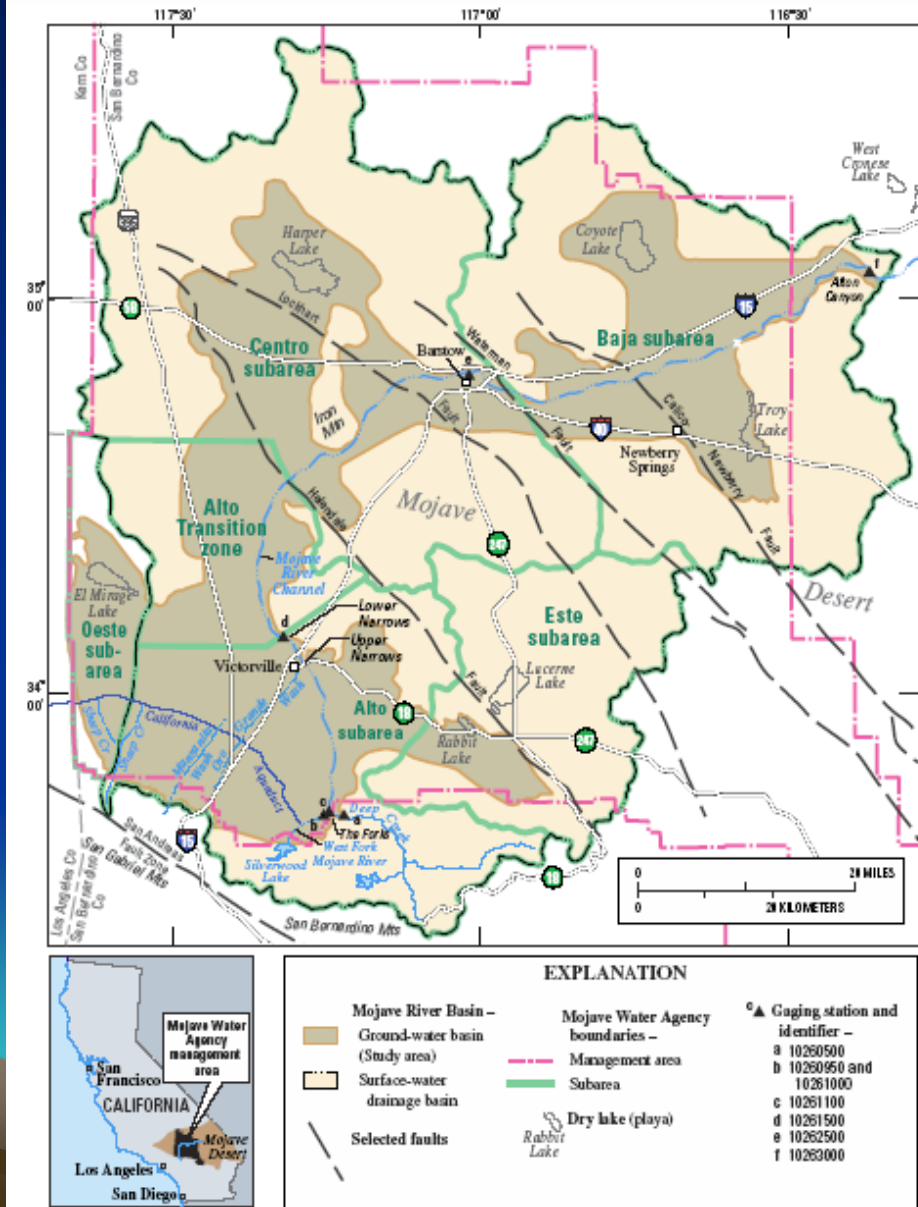
USGS

Water-Management Alternatives in the Mojave River Ground-Water Basin

USGS Open-File Report 02-430
Stamos, Martin, and Predmore

http://water.usgs.gov/pubs/of/ofr02430/ofr02430.book.pdf





USGS

Conclusions

- Regional models and visualization of data and their results can be used to *help* see affects of pumping or other changes (ie. climate) on water levels and discharge (spring flow and evapotranspiration)

USGS