Environmental Management Modeling Activities at Los Alamos National Laboratory (LANL)

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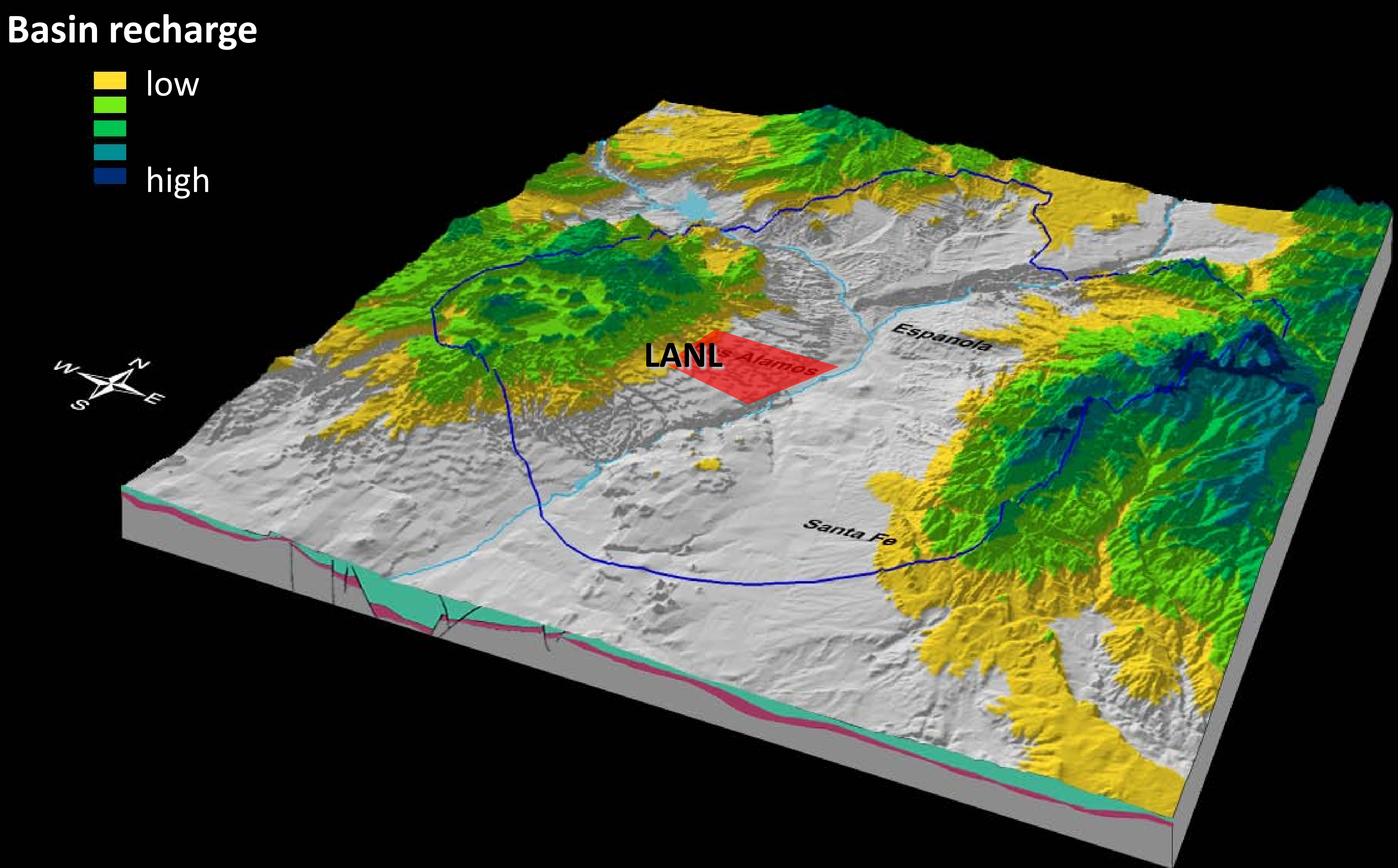
Summary

- Importance of groundwater at Los Alamos
  Regional hydrogeology
- Contaminant sources and Material Disposal Areas
- History of groundwater-related Work at LANL
  - General facility monitoring (1949-1998; 12 wells)
  - Hydrogeologic Work Plan (1998-2005; 25 wells)
    - ✓ Provided framework for characterization of facility-scale hydrogeology (Synthesis report, 2005)
  - Consent Order (since 2005; > 20 wells)
    - ✓ Site specific investigations targeted toward decision making
- Modeling activities related to Environmental Management

LANL & Espanola basin



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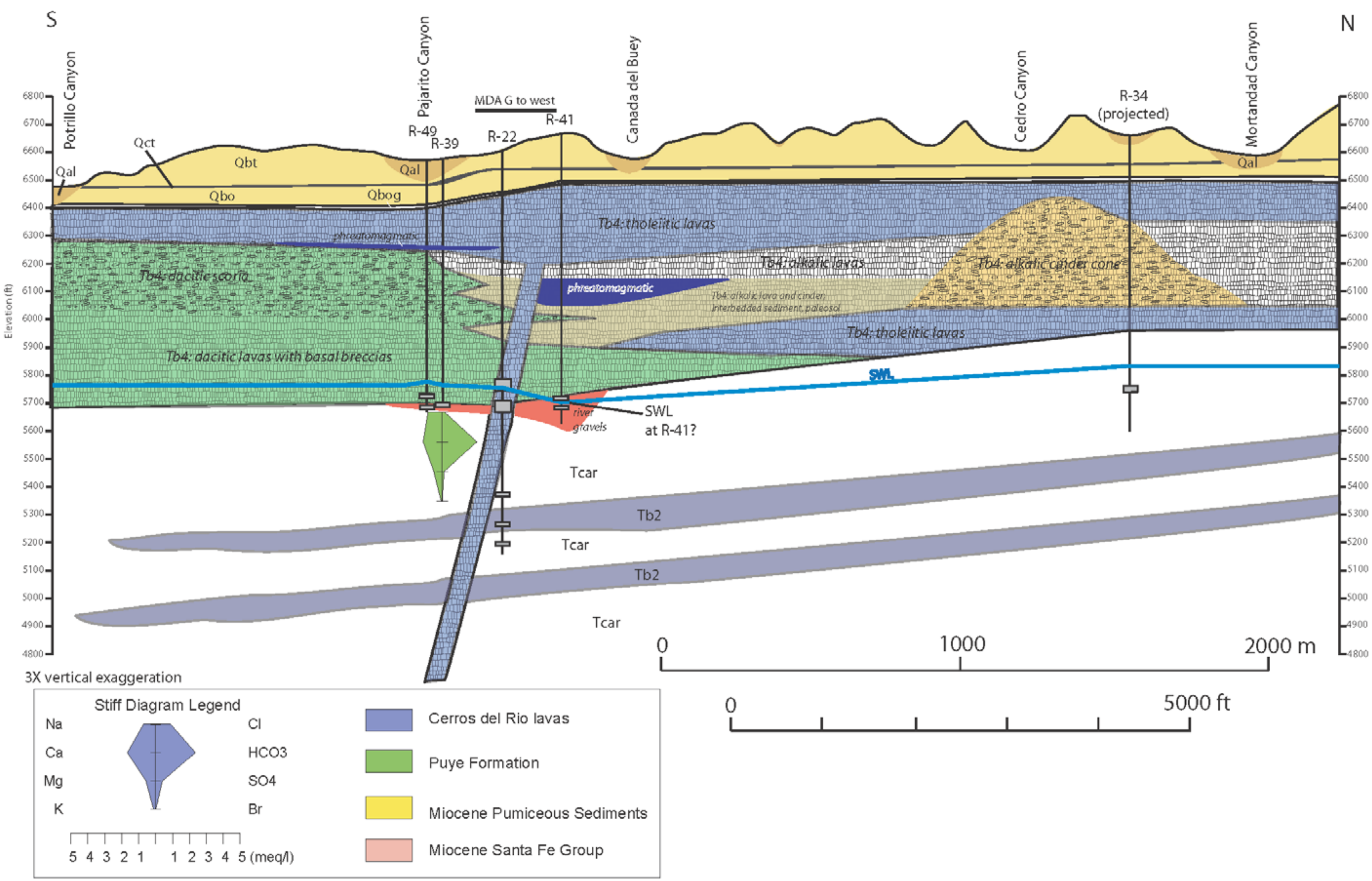
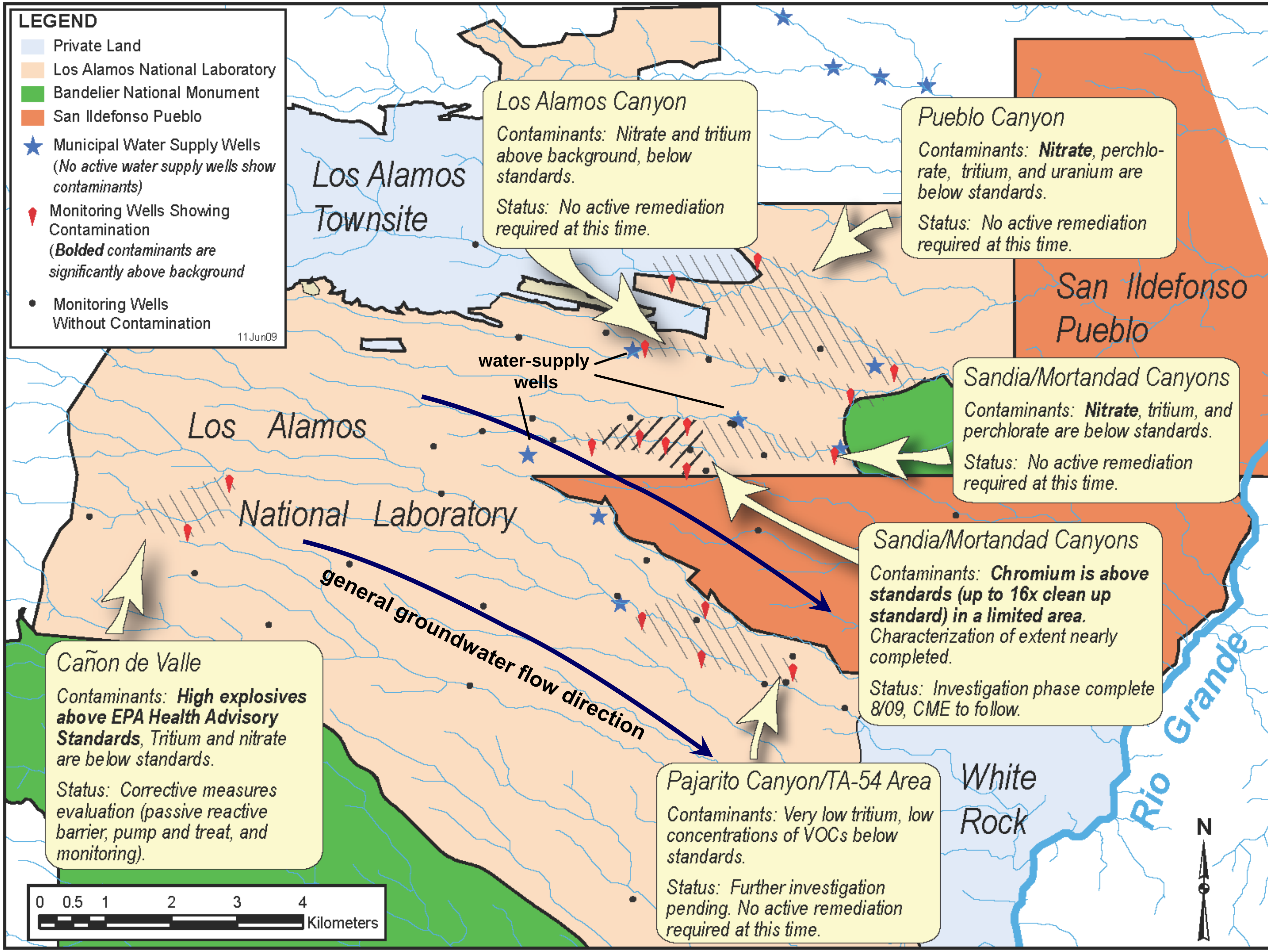
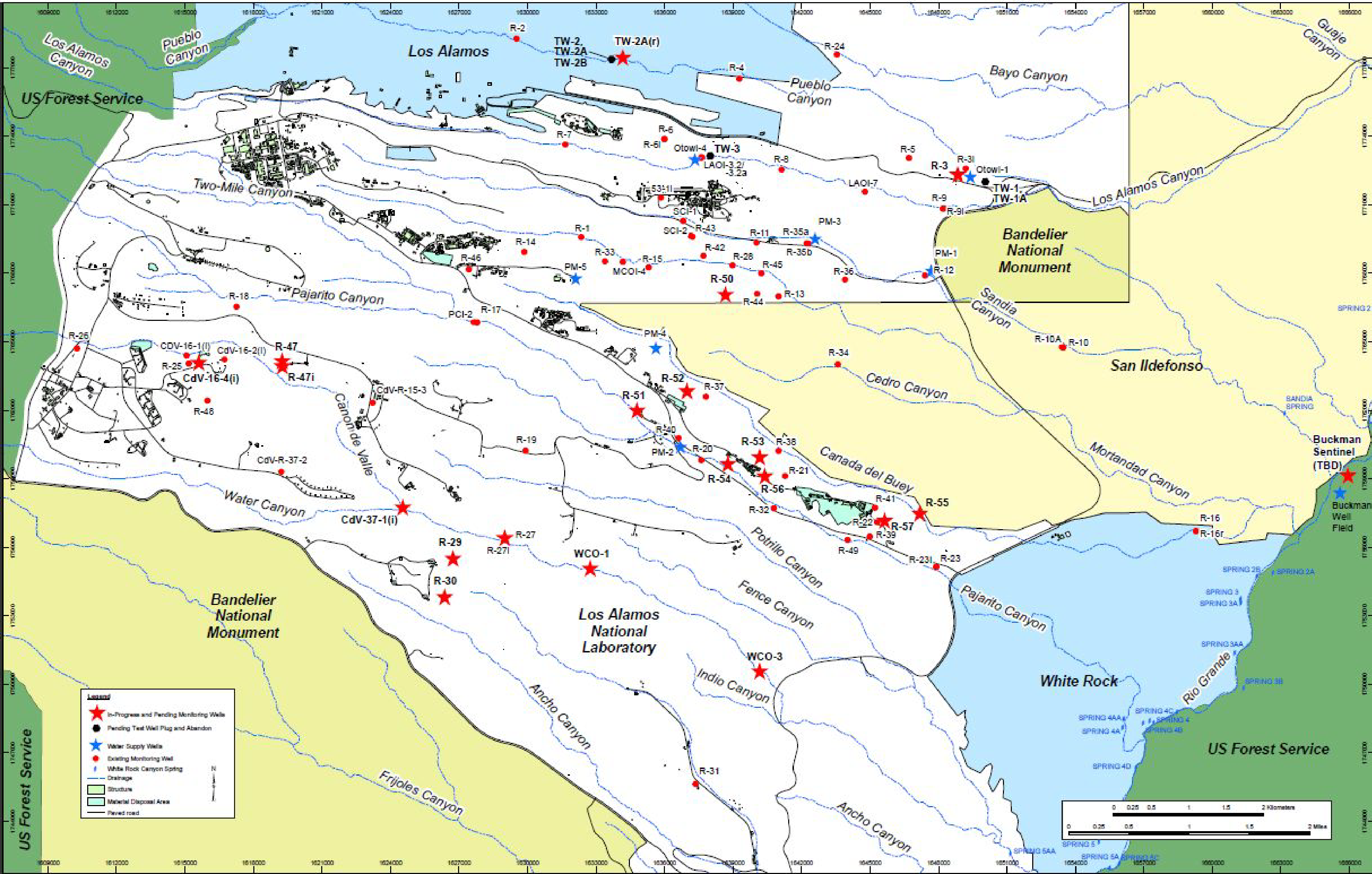



LEGEND
Private Land
Los Alamos National Laboratory
Bandelier National Monument
San Ildefonso Pueblo
Municipal Water Supply Wells
(No active water supply wells show contaminants)
Monitoring Wells Showing Contamination
(Bolded contaminants are significantly above background
Monitoring Wells Without Contamination
11Jun09
Los Alamos Townsite
Los Alamos Canyon
Contaminants: Nitrate and tritium above background, below standards.
Status: No active remediation required at this time.
Pueblo Canyon
Contaminants: Nitrate, perchlorate, tritium, and uranium are below standards.
Status: No active remediation required at this time.
San Ildefonso Pueblo
water-supply wells
Sandia/Mortandad Canyons
Contaminants: Nitrate, tritium, and perchlorate are below standards.
Status: No active remediation required at this time.
Los Alamos National Laboratory
general groundwater flow direction
Sandia/Mortandad Canyons
Contaminants: Chromium is above standards (up to 16x clean up standard) in a limited area. Characterization of extent nearly completed.
Status: Investigation phase complete 8/09, CME to follow.
Cañon de Valle
Contaminants: High explosives above EPA Health Advisory Standards, Tritium and nitrate are below standards.
Status: Corrective measures evaluation (passive reactive barrier, pump and treat, and monitoring).
Pajarito Canyon/TA-54 Area
Contaminants: Very low tritium, low concentrations of VOCs below standards.
Status: Further investigation pending. No active remediation required at this time.
White Rock
Rio Grande
N
0 0.5 1 2 3 4
Kilometers

Regional and Intermediate wells at LANL



Groundwater at LANL

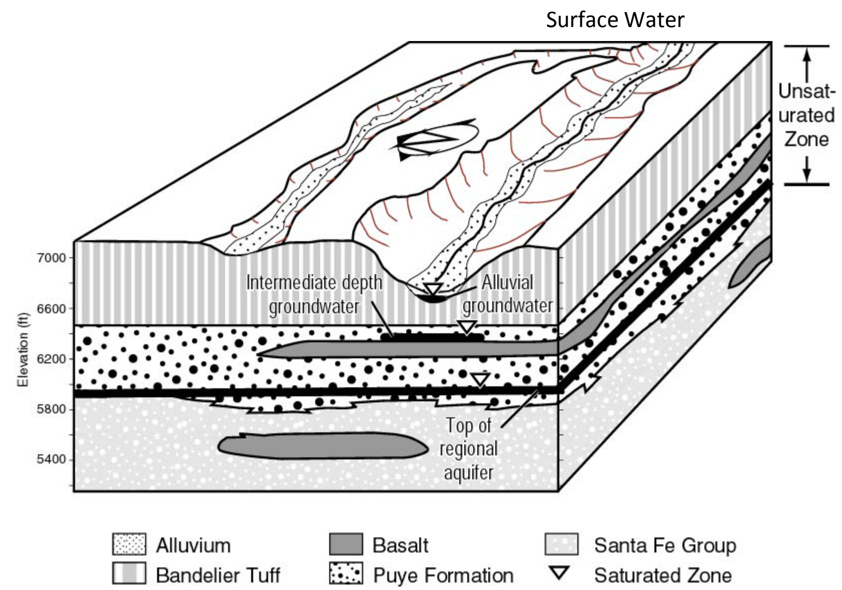
Groundwater is key to environmental management and selection of remedial alternatives

Interconnected hydrogeologic zones:

- **Alluvial groundwater (canyon bottoms)**
- **Perched-intermediate groundwater**
- **Regional groundwater (complex basin-scale aquifer used for water supply of ~200,000 residents)**
- **Discharges to Rio Grande (major downstream community of Albuquerque 600,000 residents)**

<u>Important characteristics</u>:

- Thick vadose zone with perching horizons (flow is not strictly vertical)
- Low infiltration under mesas, higher transient infiltration under canyons
- Highly heterogeneous media including interfingered fractured and porous units
- Water-supply wells located close to contaminant sources



Consent Order

<u>Compliance Order on Consent</u> **between LANL and New Mexico Environment Department (NMED):**

- ❖ **Regulatory framework for Environmental Management and Corrective Actions**
- ❖ **Requires completion by 2015**
- ❖ **Groundwater is key to selection of remedial alternatives (concentrations anywhere in the aquifer should be below MCL's)**

<u>Highlights:</u>

- ➢ **Initially NMED and stakeholders had major issues with application of models for Environmental Management**
- ➢ **Regular technical interactions between LANL, NMED, stakeholders**
- ➢ **Currently there is good acceptance of model utilization and model results**

STATE OF NEW MEXICO
ENVIRONMENT DEPARTMENT

IN THE MATTER OF:

THE UNITED STATES DEPARTMENT	)	COMPLIANCE ORDER
OF ENERGY AND THE REGENTS OF THE	)	ON CONSENT
UNIVERSITY OF CALIFORNIA	)	
	)	
	)	PROCEEDING UNDER
	)	THE NEW MEXICO
LOS ALAMOS NATIONAL LABORATORY	)	HAZARDOUS WASTE
LOS ALAMOS COUNTY, NEW MEXICO,	)	ACT § 74-4-10 AND THE
	)	NEW MEXICO SOLID
RESPONDENTS.	)	WASTE ACT § 74-9-36(D)

MARCH 1, 2005
(Revised June 18, 2008)

Modeling Activities

Various models have been applied for EM:

- **Scale and resolution: basin, LANL-site, canyon, contamination-site**
- **Dimensionality: 1-3D; steady-state/transient**
- **Simulated processes: subsurface multi-phase flow, multi-component transport, geochemical reactions, soluble and vapor-phase contaminants, erosion, biotic intrusion, surface flow and sediment transport, air transport, …**
- **Complexity: system/process**
- **Purpose:**
  - **characterization**
  - **(model-based) decision support**
    - ✓ **driven by performance and risk**
    - ✓ **performed using process models using advanced model-analysis tools**

Modeling Activities

Critical aspects of modeling activities:

- **<u>traceability and bookkeeping</u> (bottleneck): conceptual and numerical model assumptions; data sources; references; expert knowledge; inputs from stakeholders and regulators; version control**
- **<u>automated data import</u> (from MySQL database into the models)**
- **<u>computational efficiency</u> (parallelization, model reduction, efficient techniques for <u>simulation</u> and <u>model analysis</u>)**
- **<u>script-based model coupling and pre-/post-processing</u>**

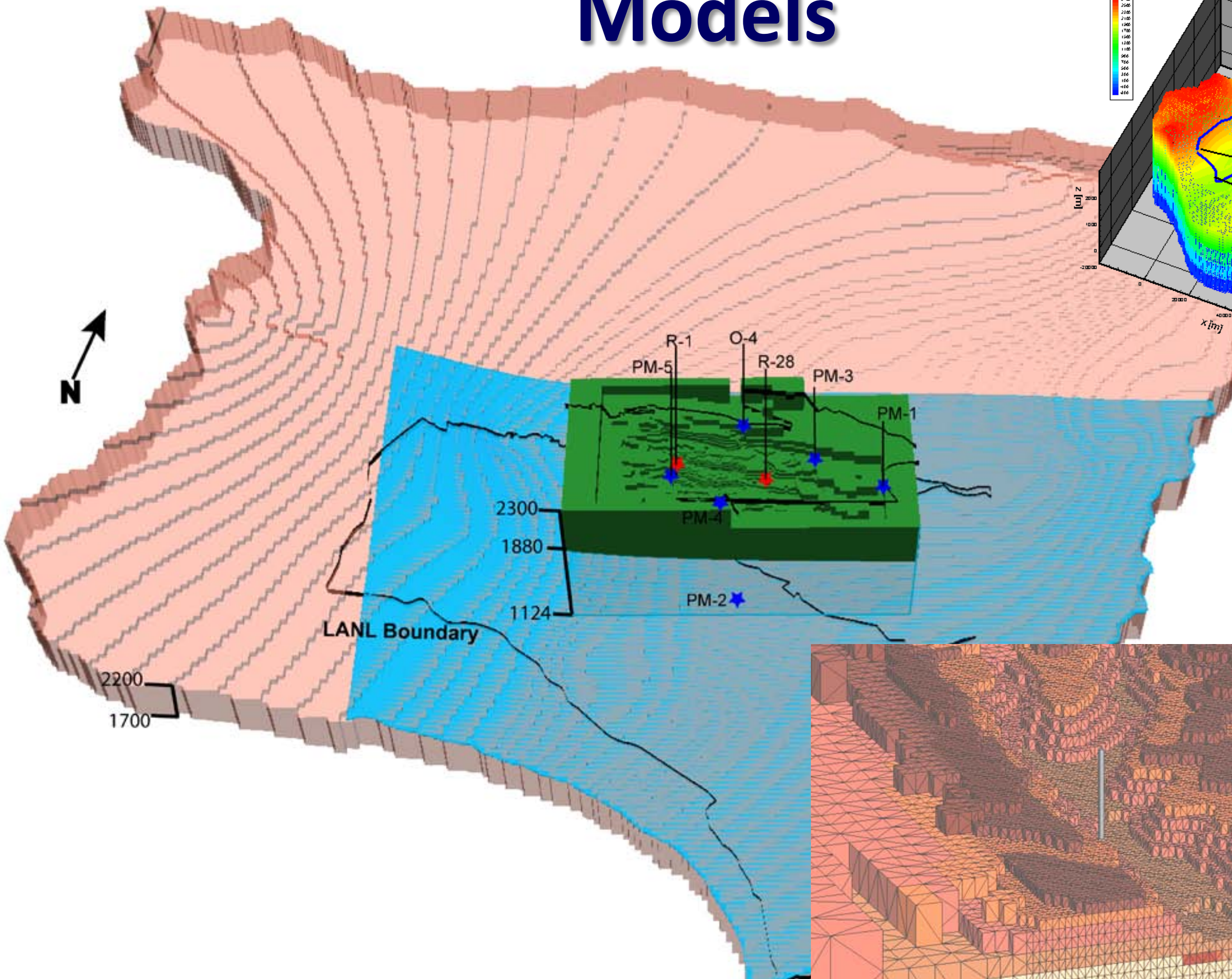
Data

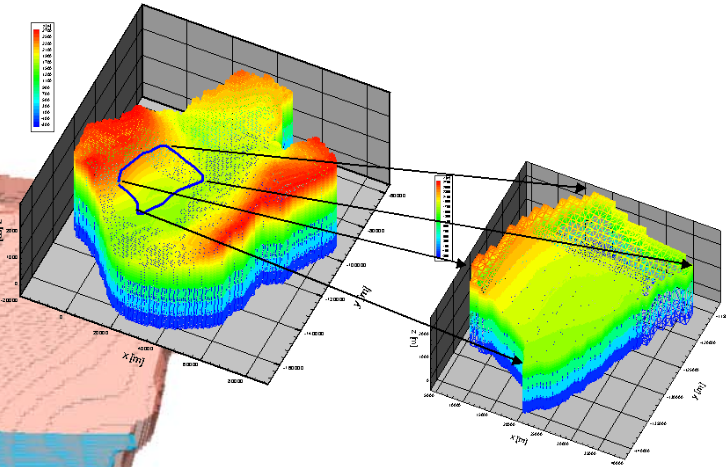
- More than 180 monitoring wells (including >55 regional wells)
- More than 640 monitoring locations (well screens, gages, springs …)
- More than 600 geochemical analytes
- More than 800,000 geochemical data entries
- 7 water-supply wells in close vicinity (LANL, Los Alamos)
- More than 20 water-supply wells close by (Santa Fe, Pueblos, residential)
- More than 3,500,00 water-level observations
- More than 70,000 daily pumping records associated with water-supply wells
- Most of the information is available online and is updated several times each month http://racerdat.com/

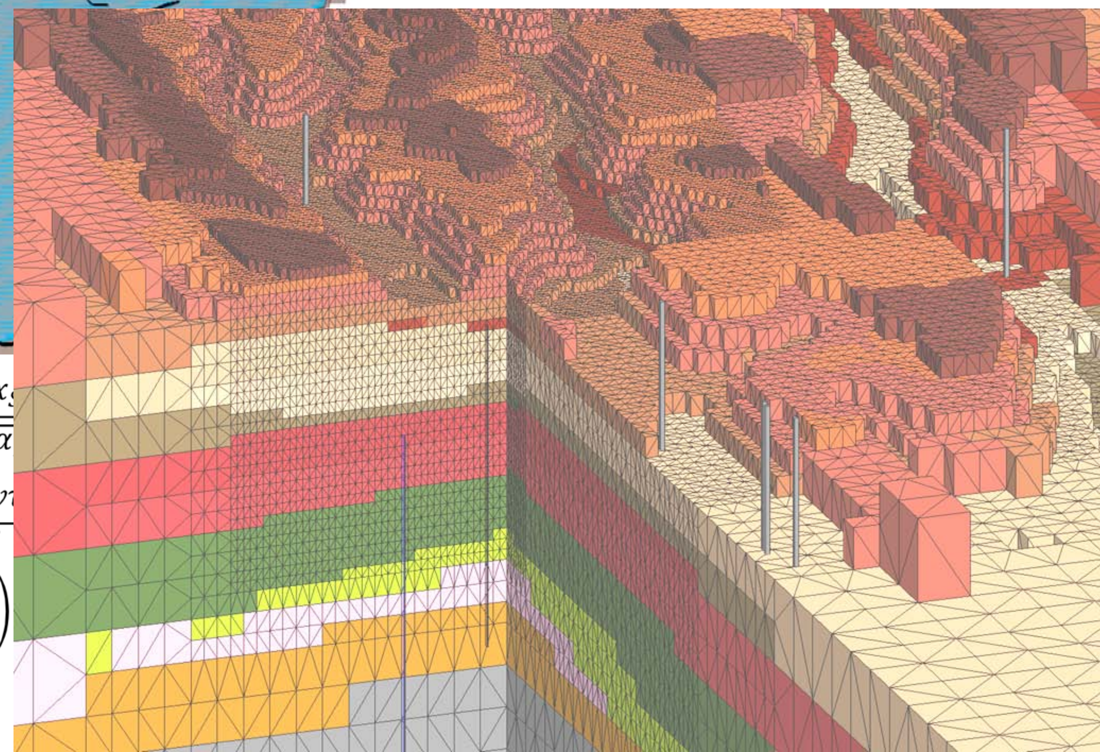
Examples of Modeling Work at LANL

- **<u>Characterization</u>**
  - conceptual model testing, evaluation and ranking
  - estimation of aquifer-parameter heterogeneity
  - nature and extent of contaminant plumes
  - source identification (location of contaminant arrival)
- **<u>Decision Support</u> (model-based decision support driven by performance and risk)**
  - evaluation and optimization of characterization activities
  - evaluation and optimization of monitoring network
  - evaluation and optimization of remedial activities
  - performance/risk assessment, composite analyses

Models







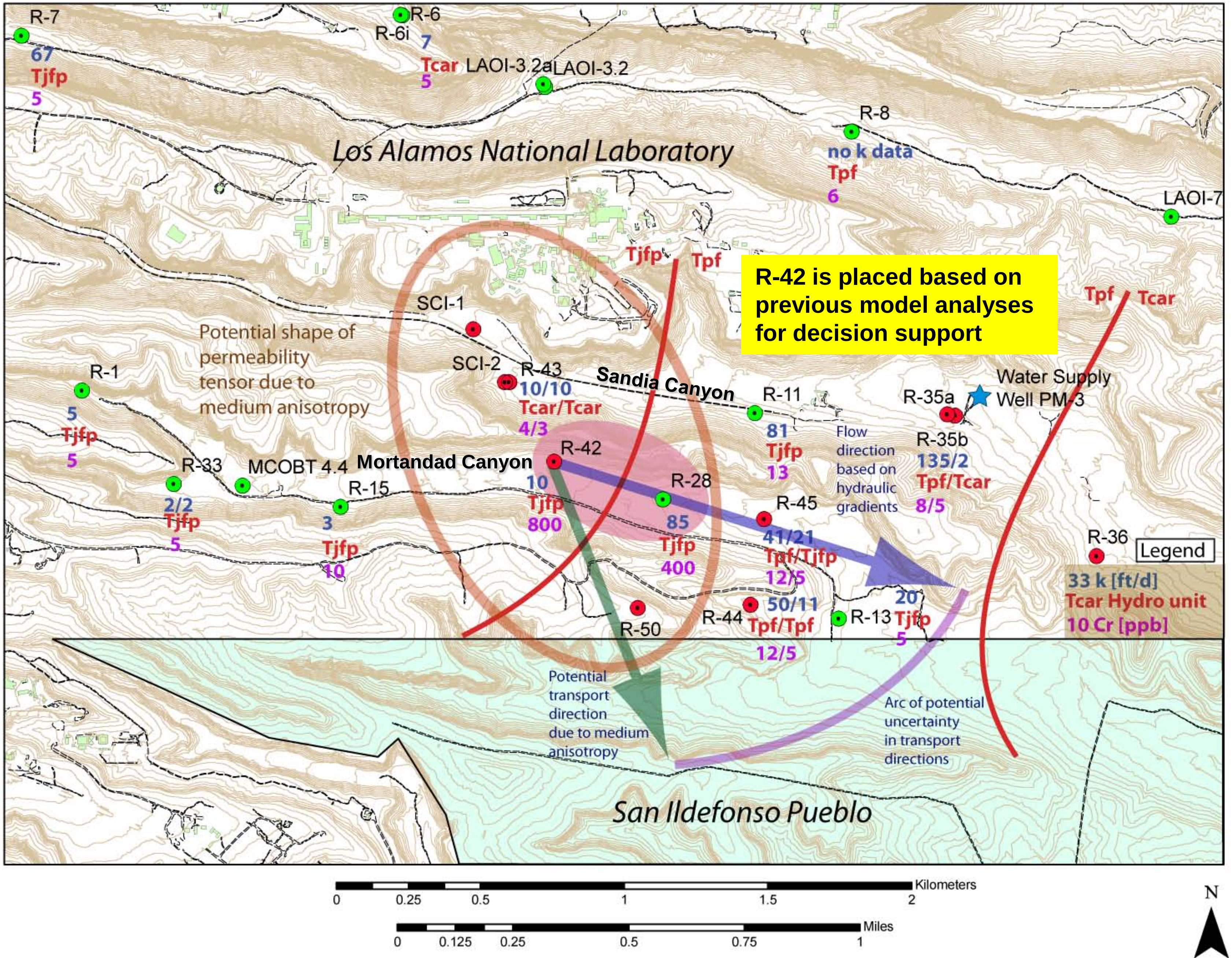
$$c(x,y,z,t) = \frac{1}{8\pi\theta x_S y_S z_S}\int_0^t I(t-\tau)\exp(-\lambda\tau)\left[erfc\left(\frac{x-\frac{1}{2}x_S}{2\sqrt{\alpha}}\right.\right.$$

$$\times\left[erfc\left(\frac{y-\frac{1}{2}y_S-v\tau}{2\sqrt{\alpha_{TH}v\tau}}\right)-erfc\left(\frac{y+\frac{1}{2}y_S-v}{2\sqrt{\alpha_{TH}v\tau}}\right.\right.$$

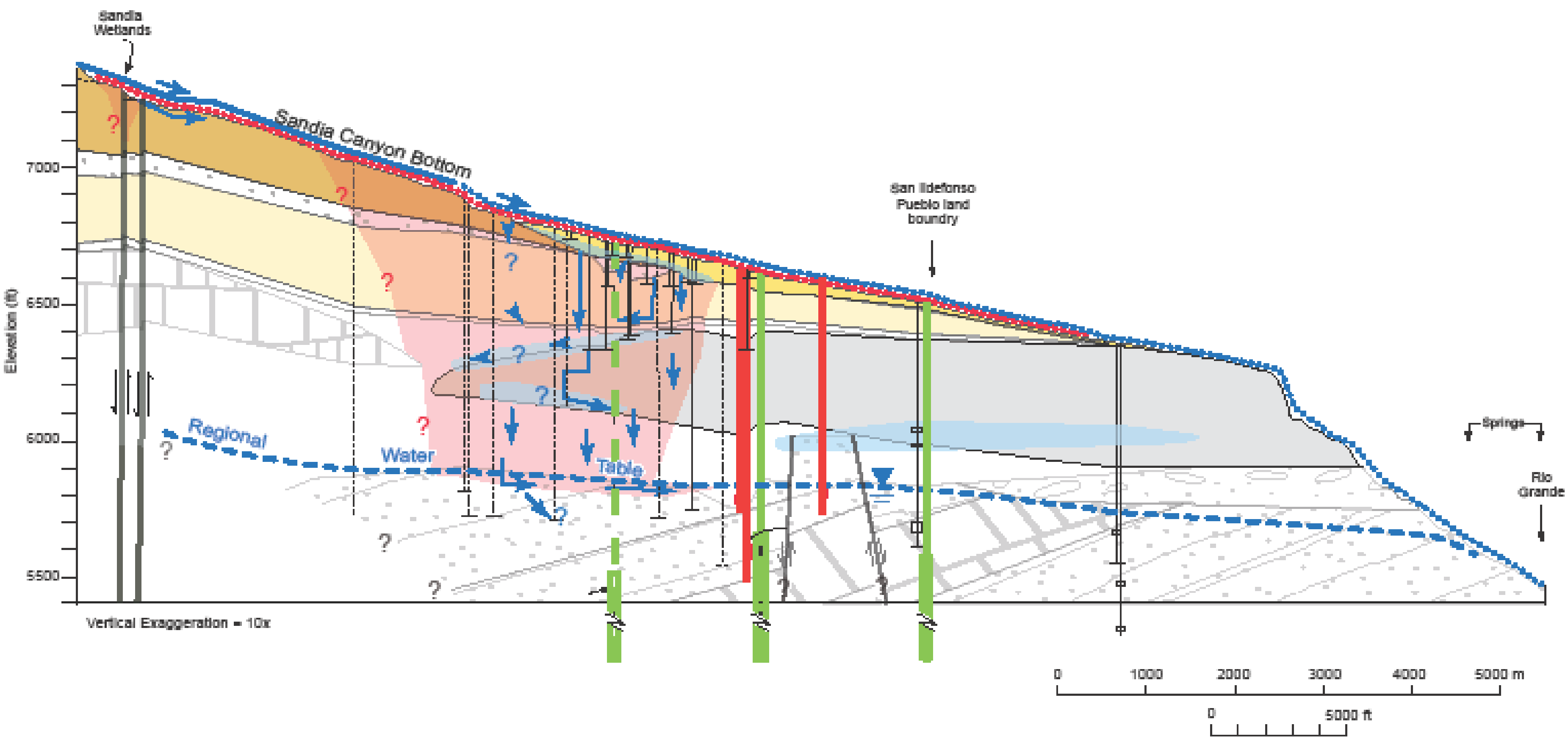
$$\times\left[erfc\left(\frac{z-(z_0+z_S)}{2\sqrt{\alpha_{TV}v\tau}}\right)-erfc\left(\frac{z-z_0}{2\sqrt{\alpha_{TV}v\tau}}\right)\right.$$

$$\left.-\,erfc\left(\frac{z+z_0}{2\sqrt{\alpha_{TV}v\tau}}\right)\right]d\tau\alpha_L$$

Chromium (Sandia Canyon) Project



Conceptual cross-section of Chromium migration beneath Sandia Canyon

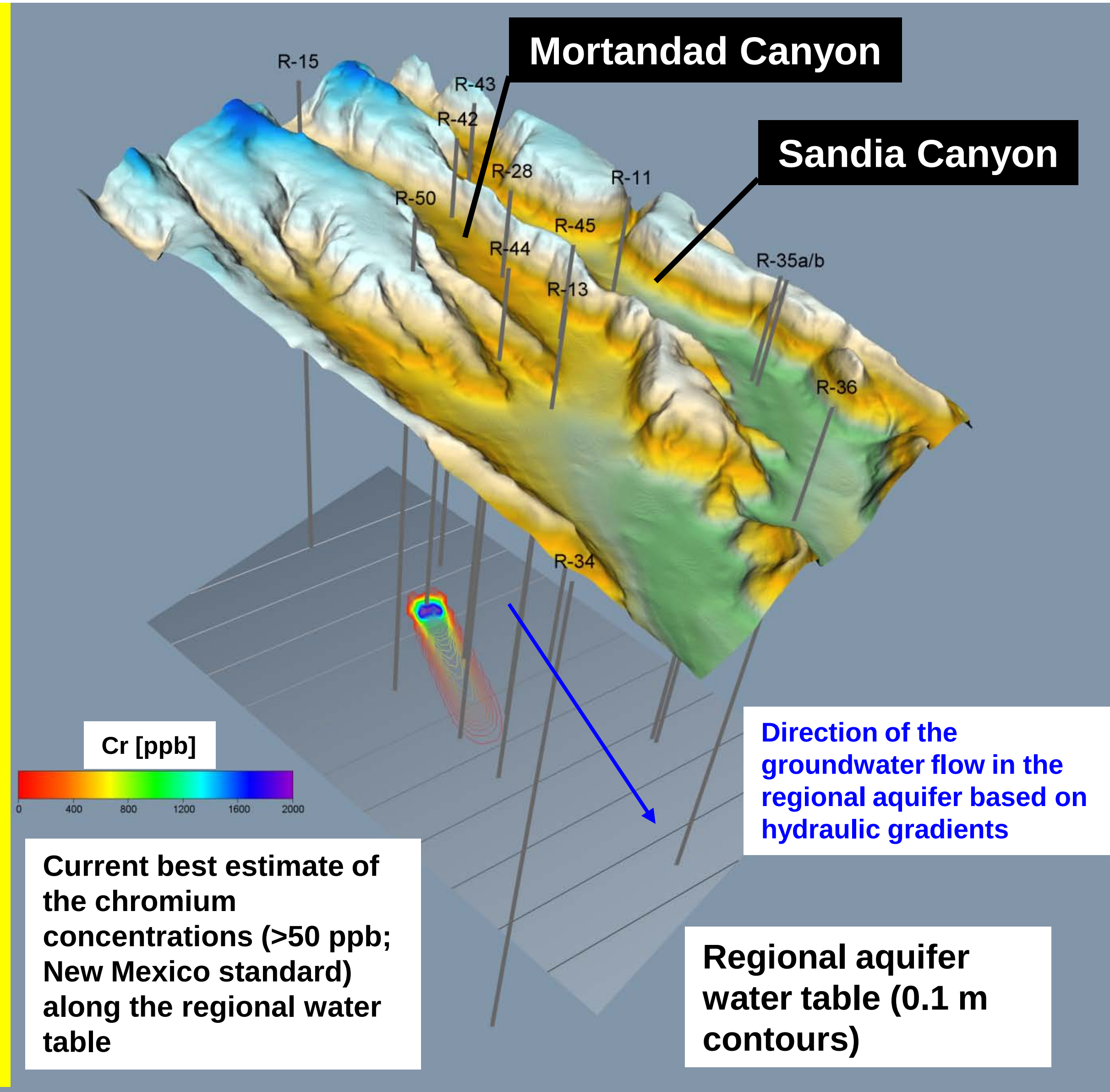


Numerical modeling of flow and transport in the regional aquifer near Sandia Canyon

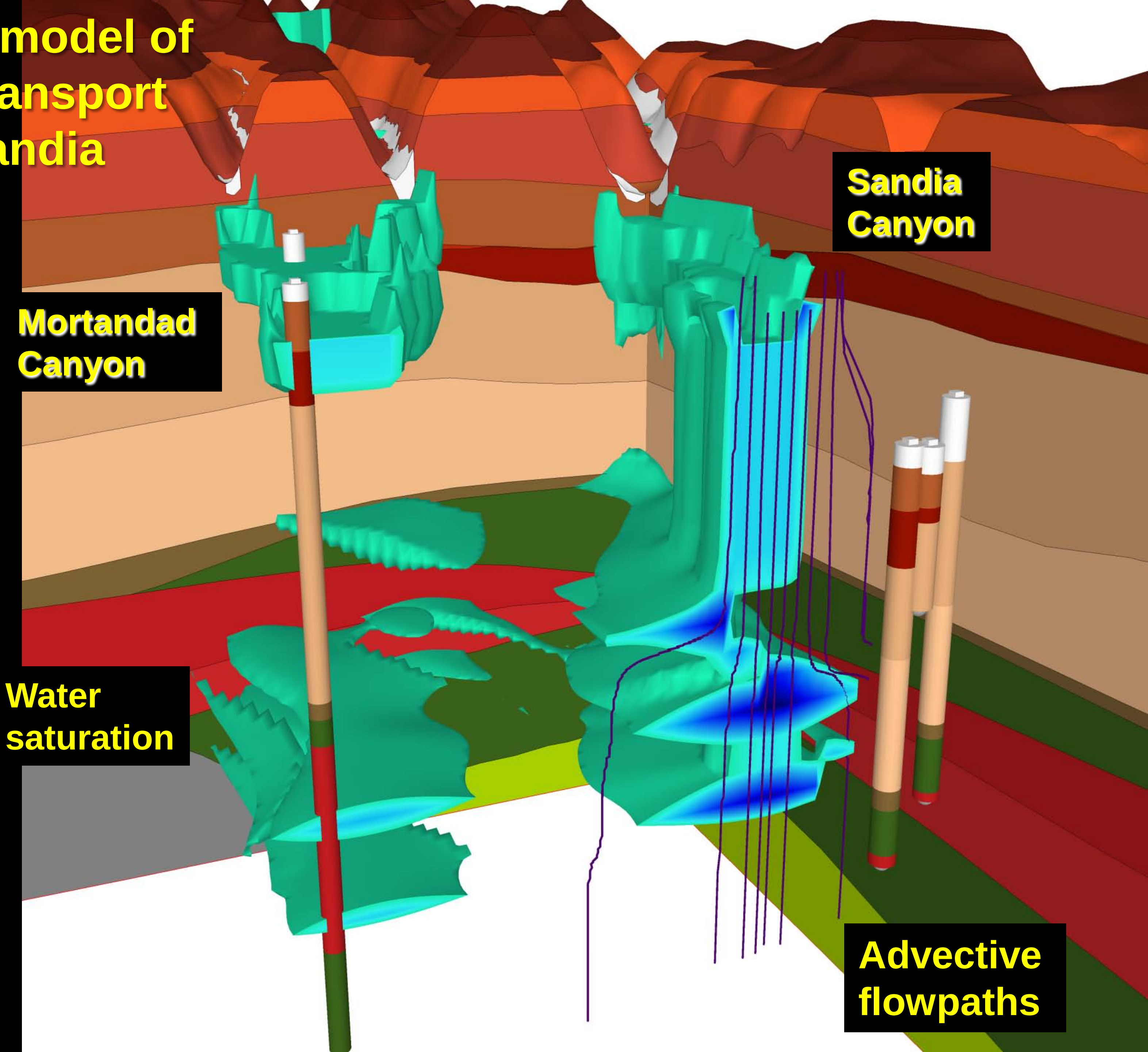
The numerical model is capturing current conceptual understanding and calibrated against existing data (taking into account uncertainties)

Regardless of existing uncertainties, the model provide information related to:

- **spatial distribution of contaminant mass,**
- **contaminant flux to the regional aquifer,**
- **monitoring-network design, and**
- **environmental risk**

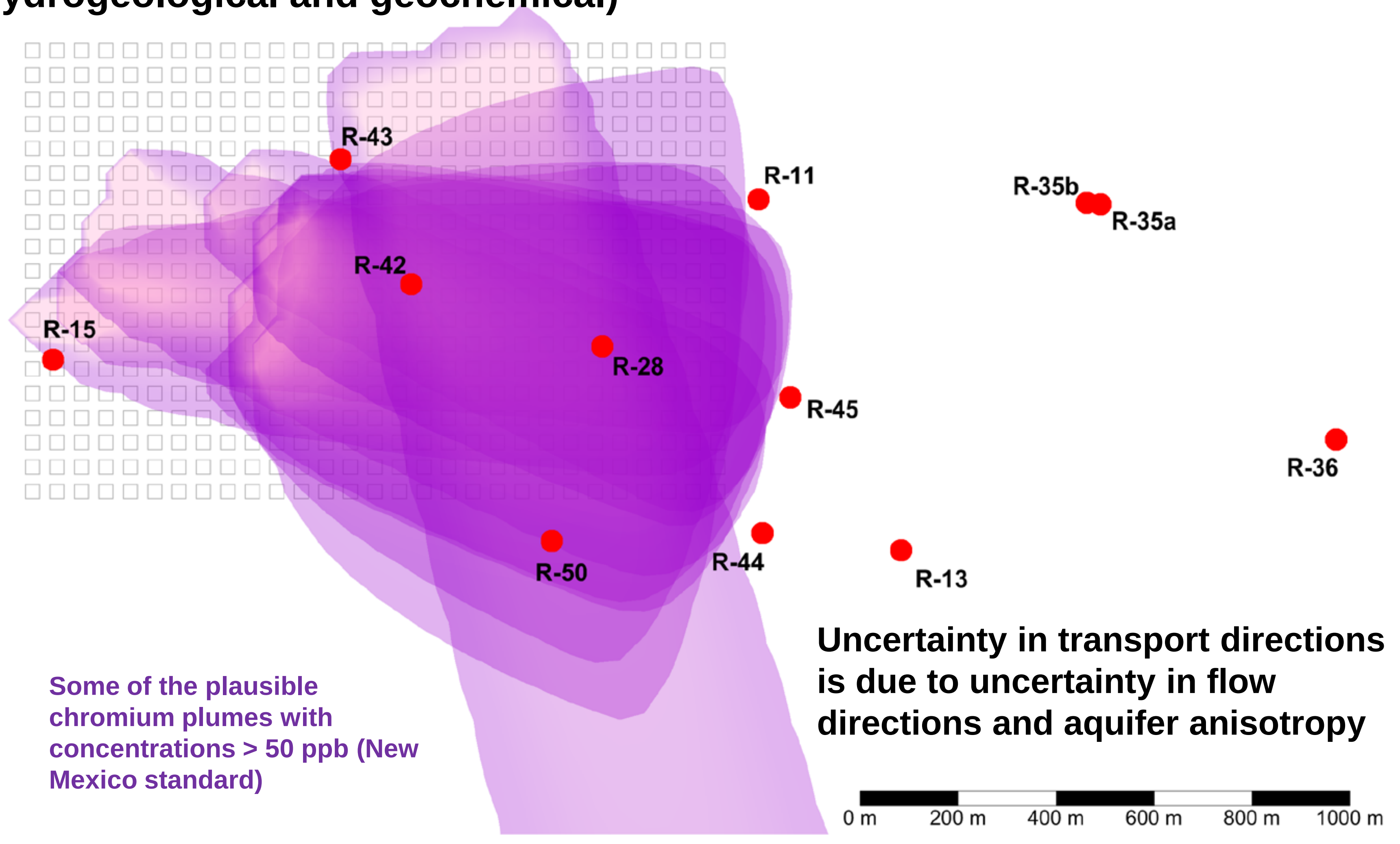


Numerical model of flow and transport beneath Sandia Canyon



Model predictions of the chromium plume in the regional aquifer near Sandia Canyon

- Due to uncertainties, a series of alternative models (plumes) are plausible
- Model predictions are constrained by all the available regional-aquifer data (hydrogeological and geochemical)



Some of the plausible chromium plumes with concentrations > 50 ppb (New Mexico standard)

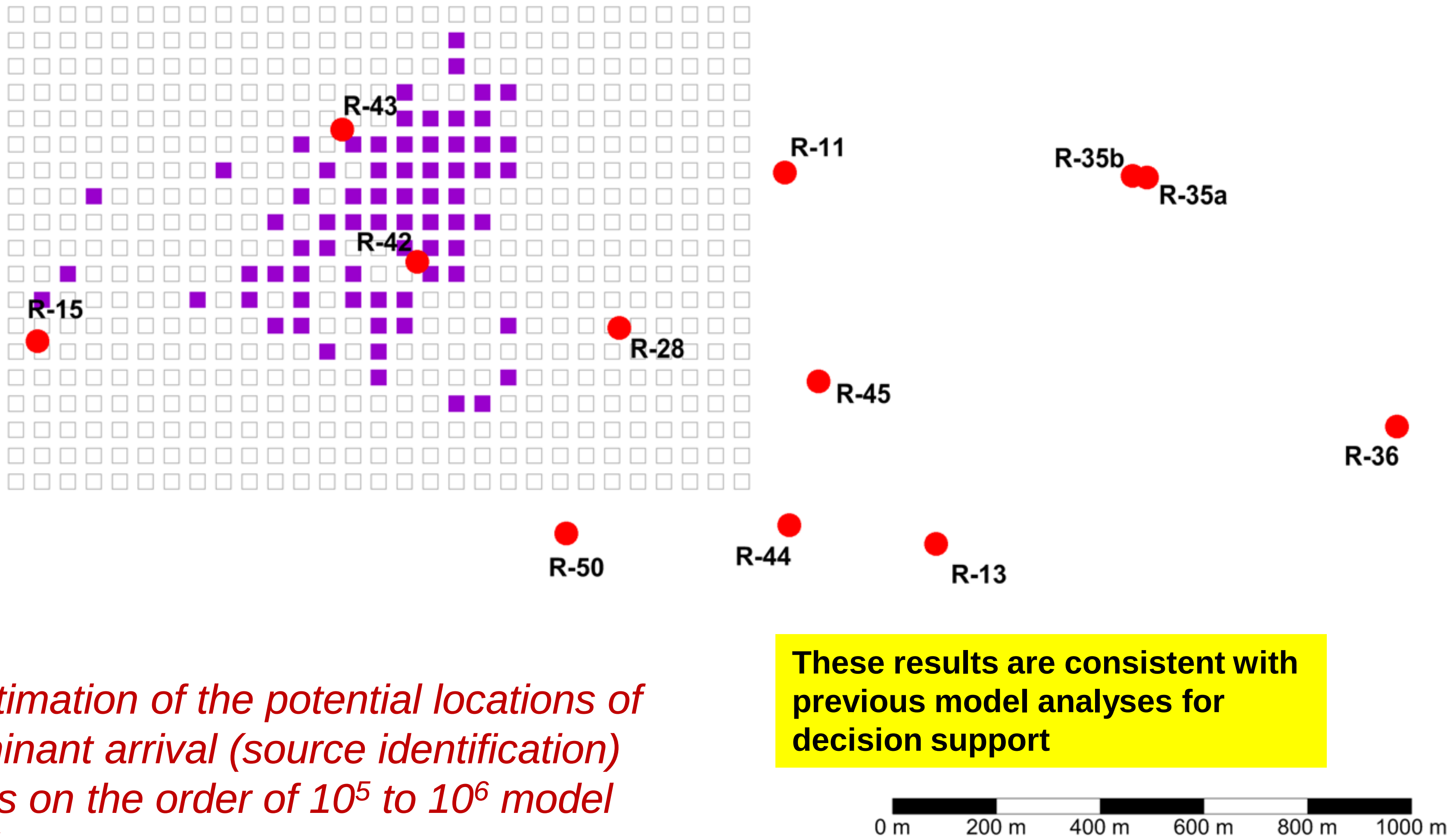
Uncertainty in transport directions is due to uncertainty in flow directions and aquifer anisotropy

Plausible contaminant-arrival locations

The source-identification problem is ill-posed:

- **substantial prior uncertainties,**
- **large number of unknown parameter,**
- **limited amount of observation data,**
- **model complexity and non-linearity**

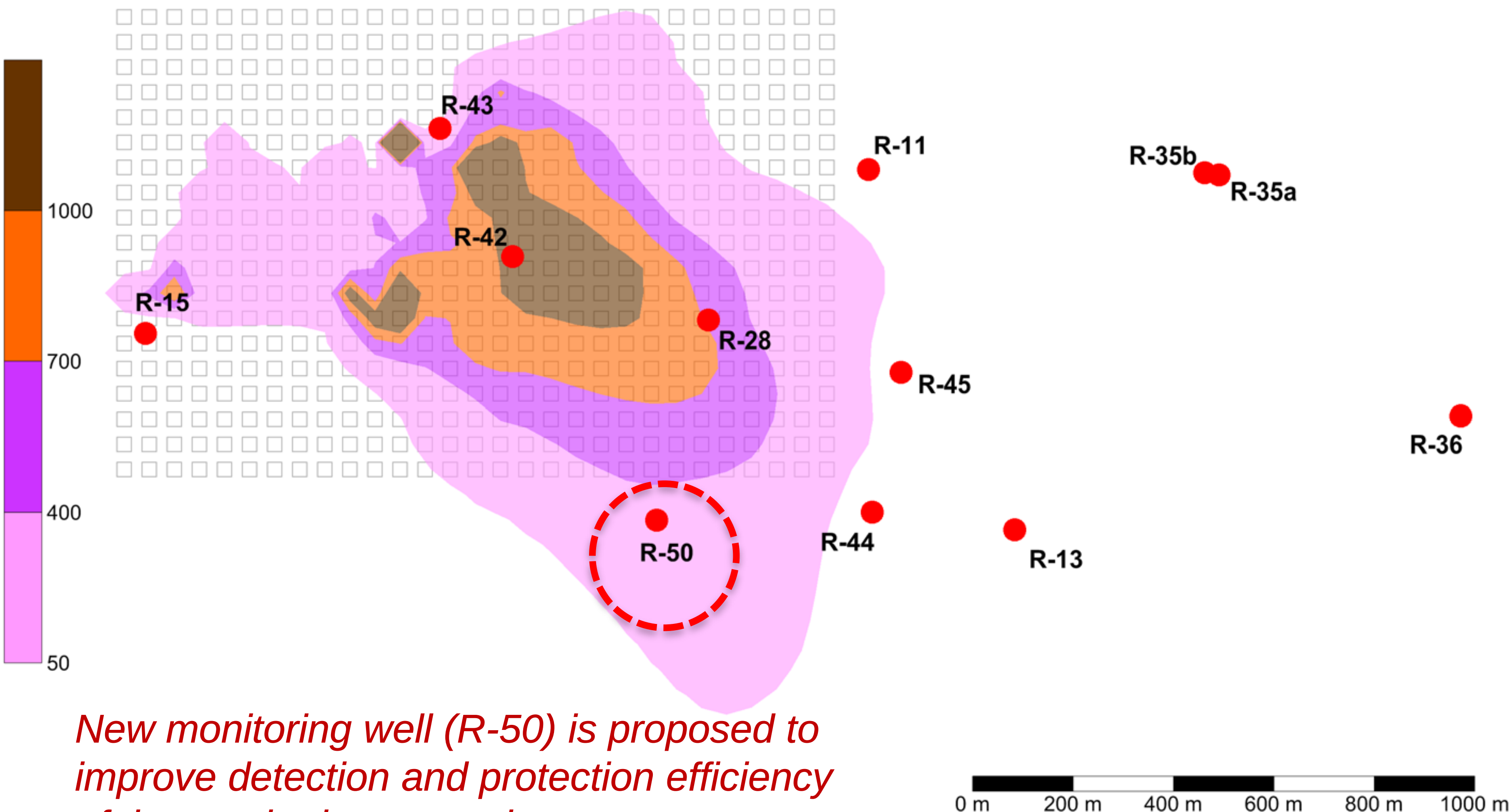
allow for multiple plausible solutions of the inverse problem



The estimation of the potential locations of contaminant arrival (source identification) requires on the order of 10^5 to 10^6 model executions.

These results are consistent with previous model analyses for decision support

Average contaminant concentrations taking into account uncertainties in contaminant flow and transport

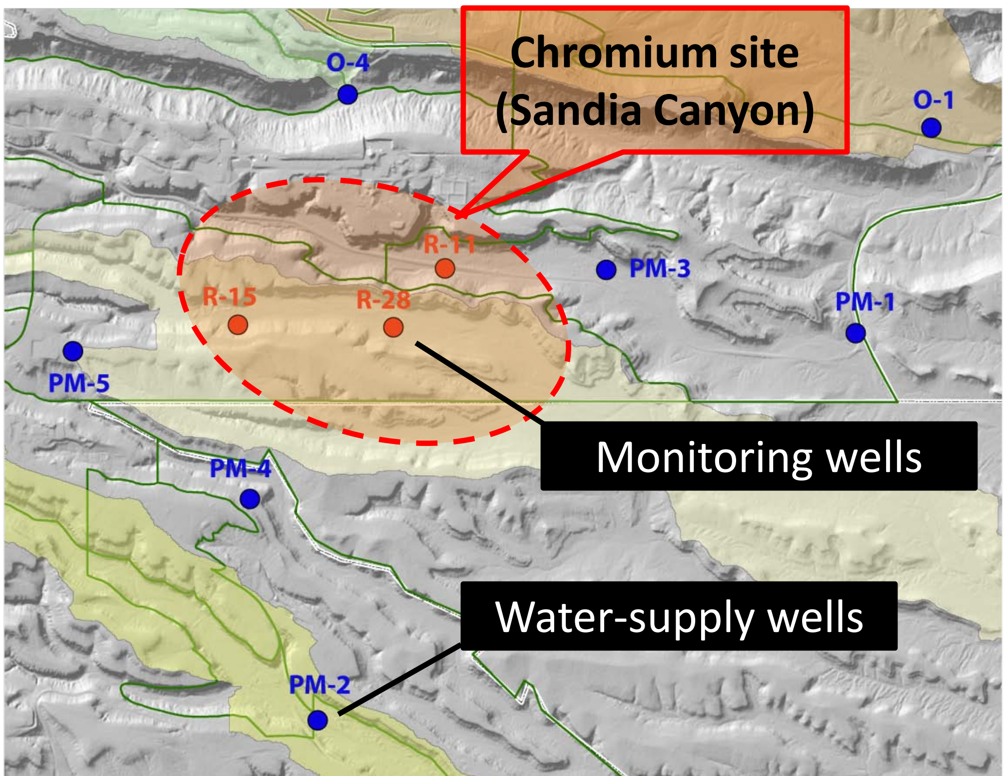


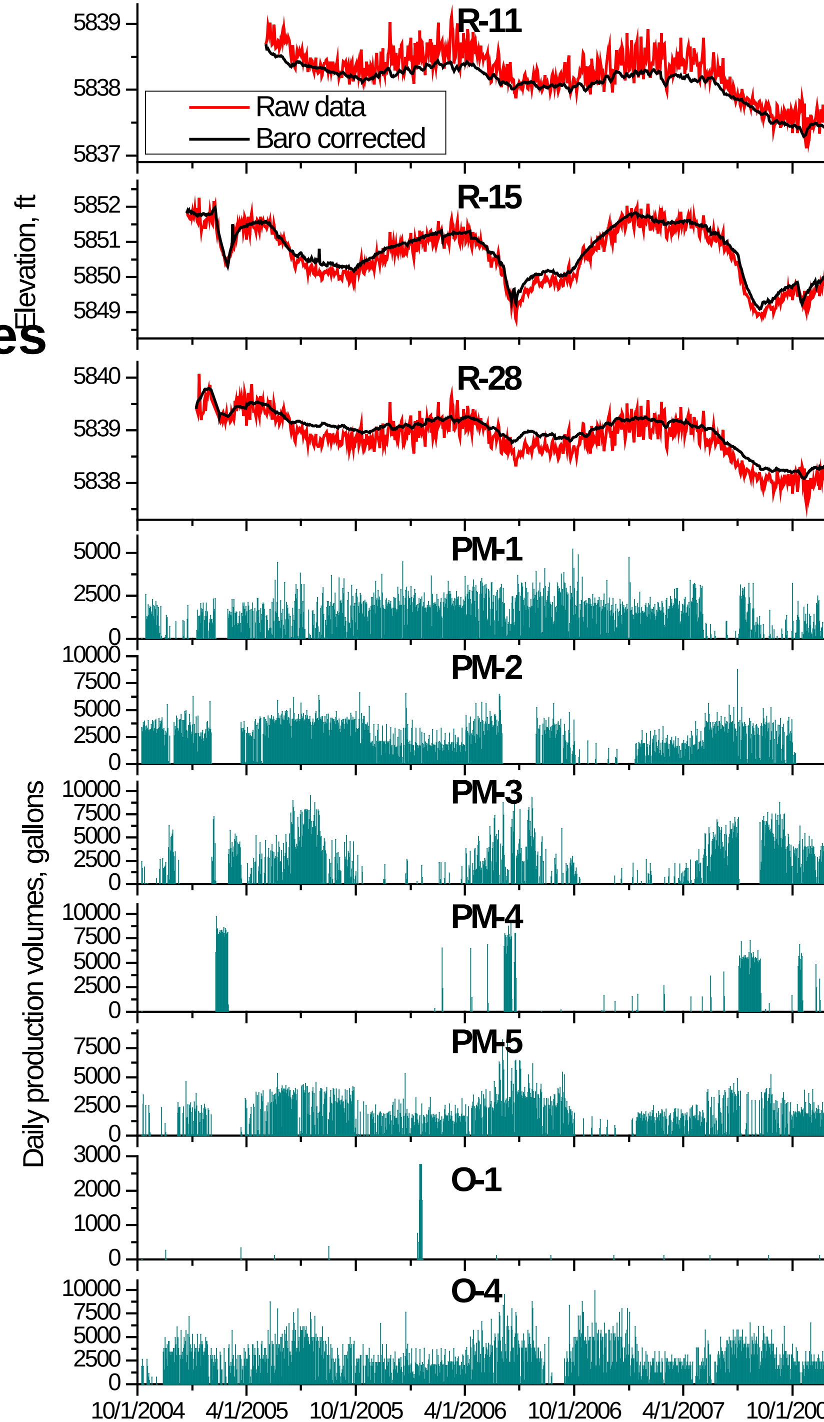
New monitoring well (R-50) is proposed to improve detection and protection efficiency of the monitoring network.

Water Levels vs. Pumping Records

- Identification of water-supply wells causing observed water-level fluctuations
- Estimation of effective aquifer properties and their spatial distribution

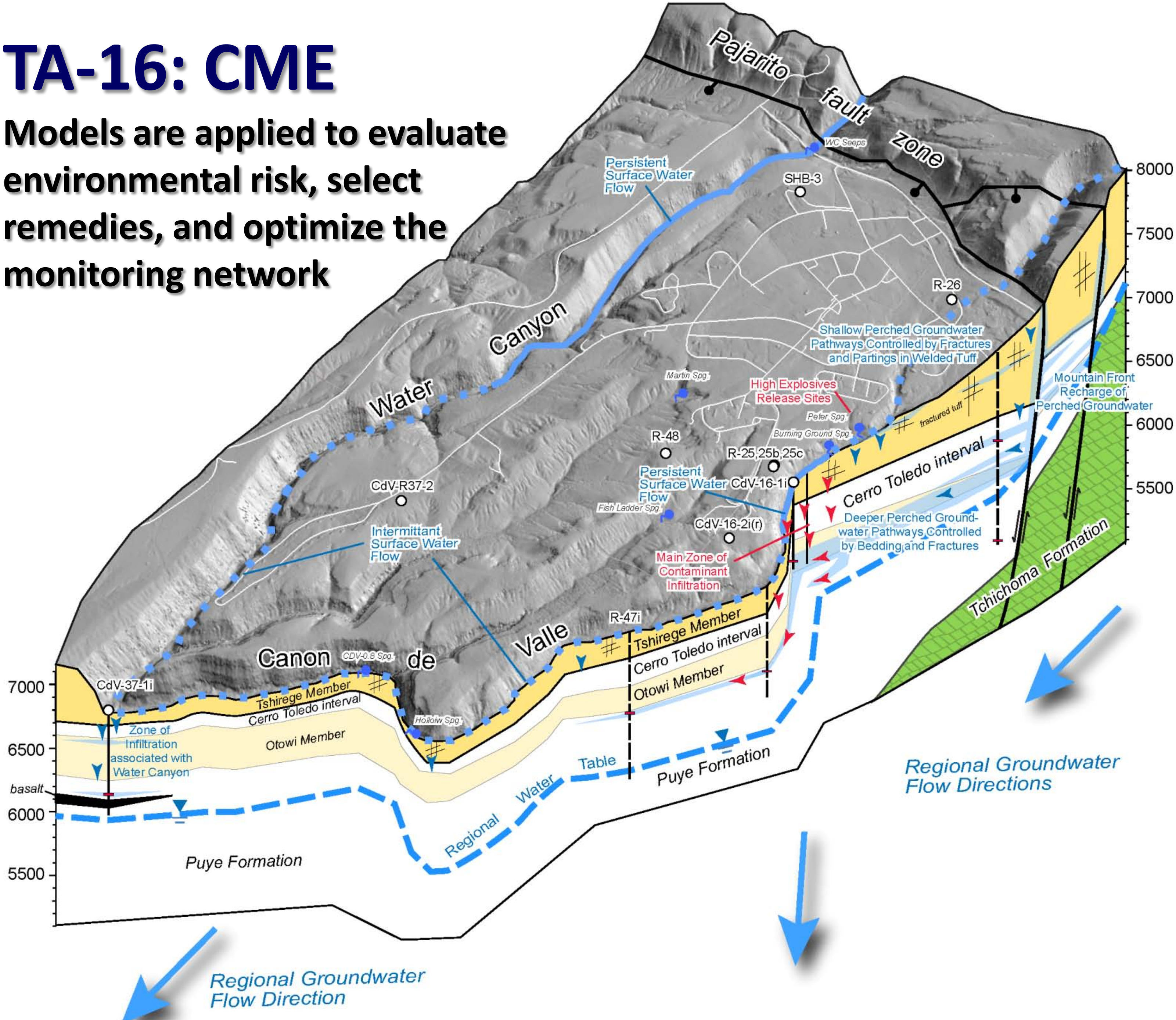
These results are important for contaminant fate and transport in the regional aquifer





TA-16: CME

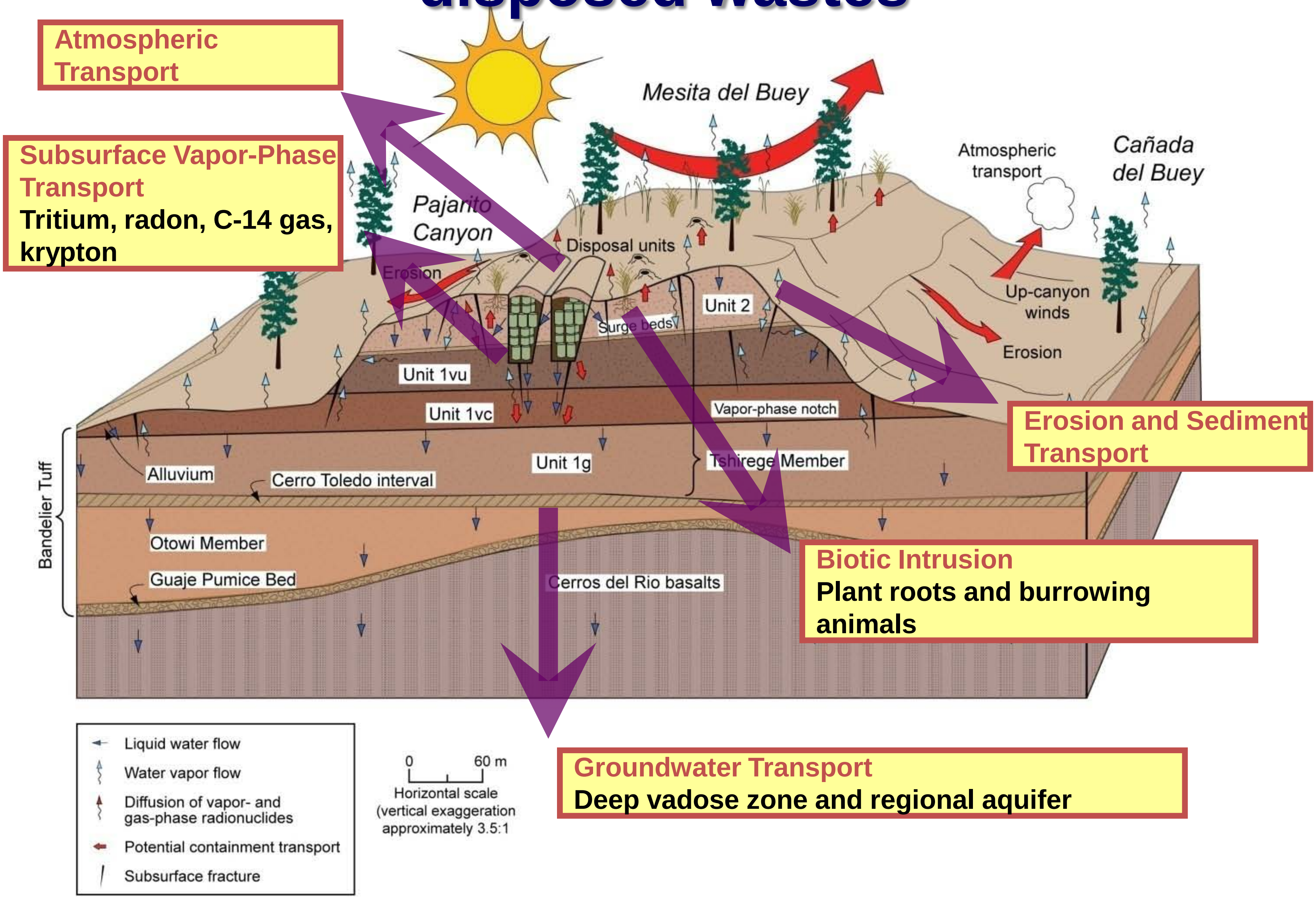
Models are applied to evaluate environmental risk, select remedies, and optimize the monitoring network



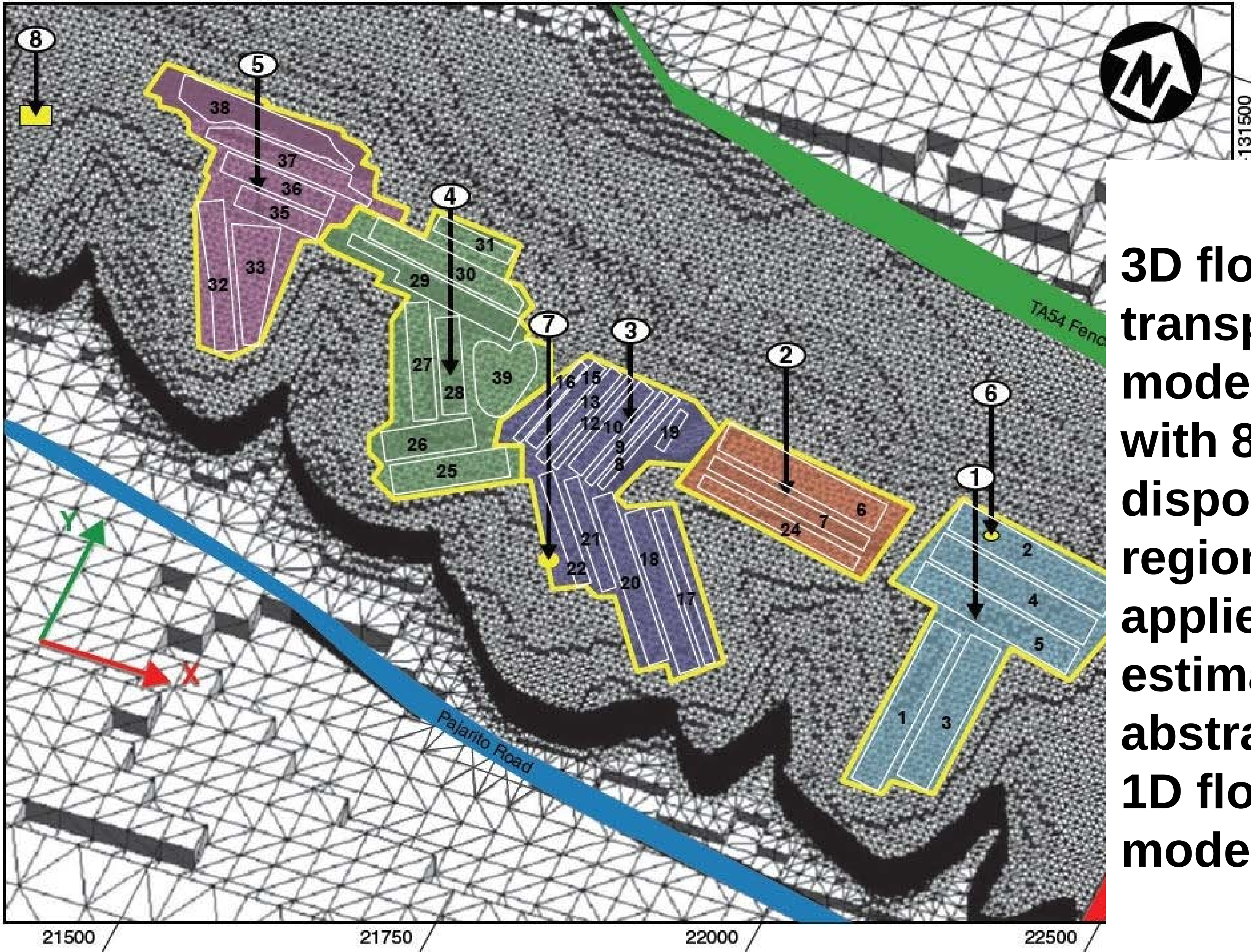
TA-54 MDA G: Performance Assessment and Composite Analysis

- Operating site since 1957
- Radioactive waste
- 100 Acres, 35 pits, 200+ shafts

TA-54 MDA G: Natural transport processes for disposed wastes



TA-54 MDA G: Modeling approach for Performance Assessment and Composite Analysis



3D flow and transport model with 8 disposal regions is applied to estimate abstracted 1D flow path models

TA-54 MDA G: Modeling approach for Performance Assessment and Composite Analysis

Diffusive Transport (GoldSim): Model predicts fluxes of vapor- and gas-phase radionuclides at ground surface

Infiltration (HYDRUS): Model predicts spatial distribution of infiltration rates

Erosion and Sediment Transport (SIBERIA): 3D model estimates cover thickness vs time

System Model (GoldSim)

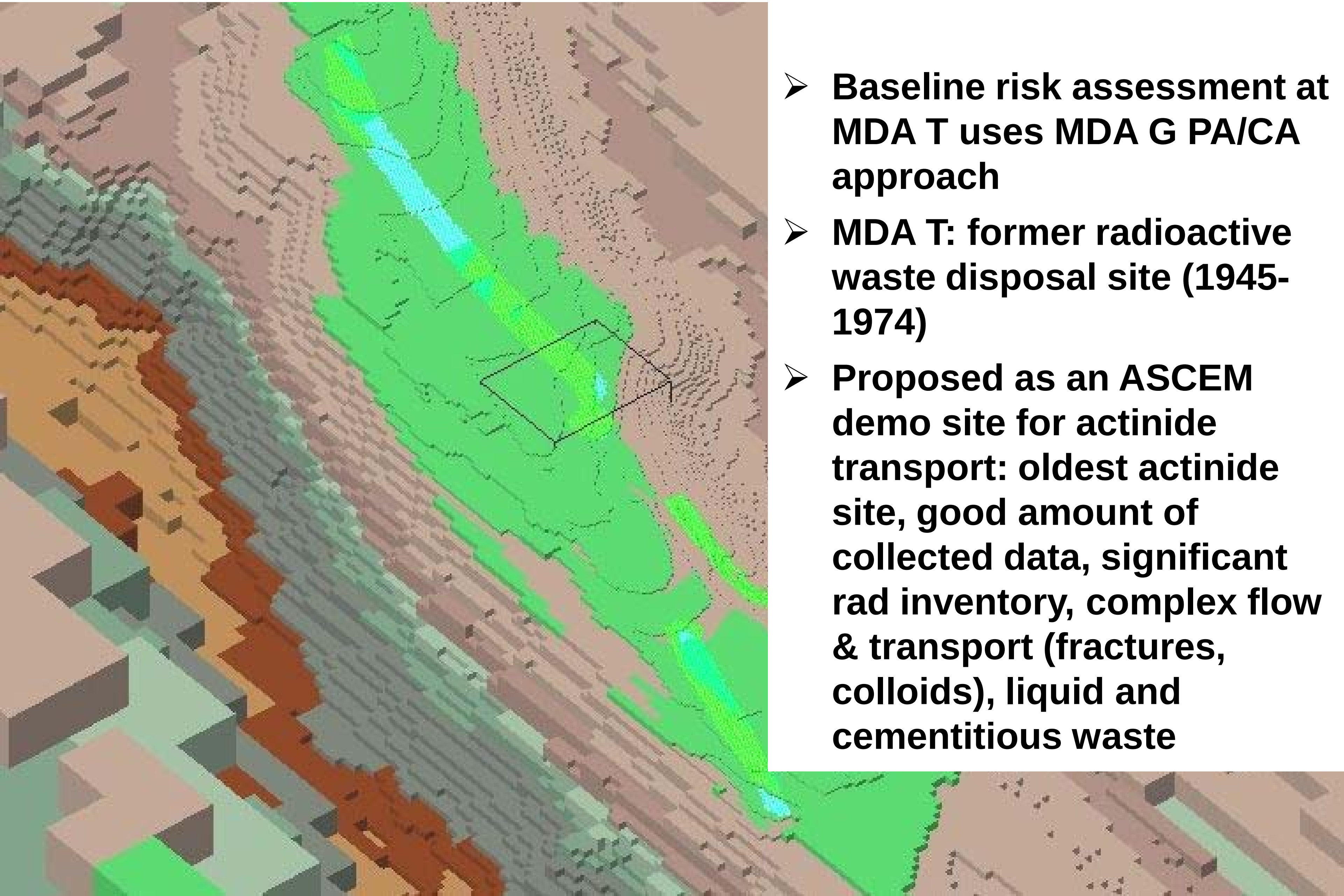
- Integrates results from process models
- Estimates potential radiation doses received by humans

Atmospheric Dispersion (CALPUFF) : Complex terrain model estimates contaminant deposition rates

Biotic Intrusion (GoldSim): Model predicts rates of contaminant deposition on facility surface following root and burrow penetration into waste

Groundwater Flow and Transport (FEHM): 3D model used to develop 1D process-model abstraction for use in the system model

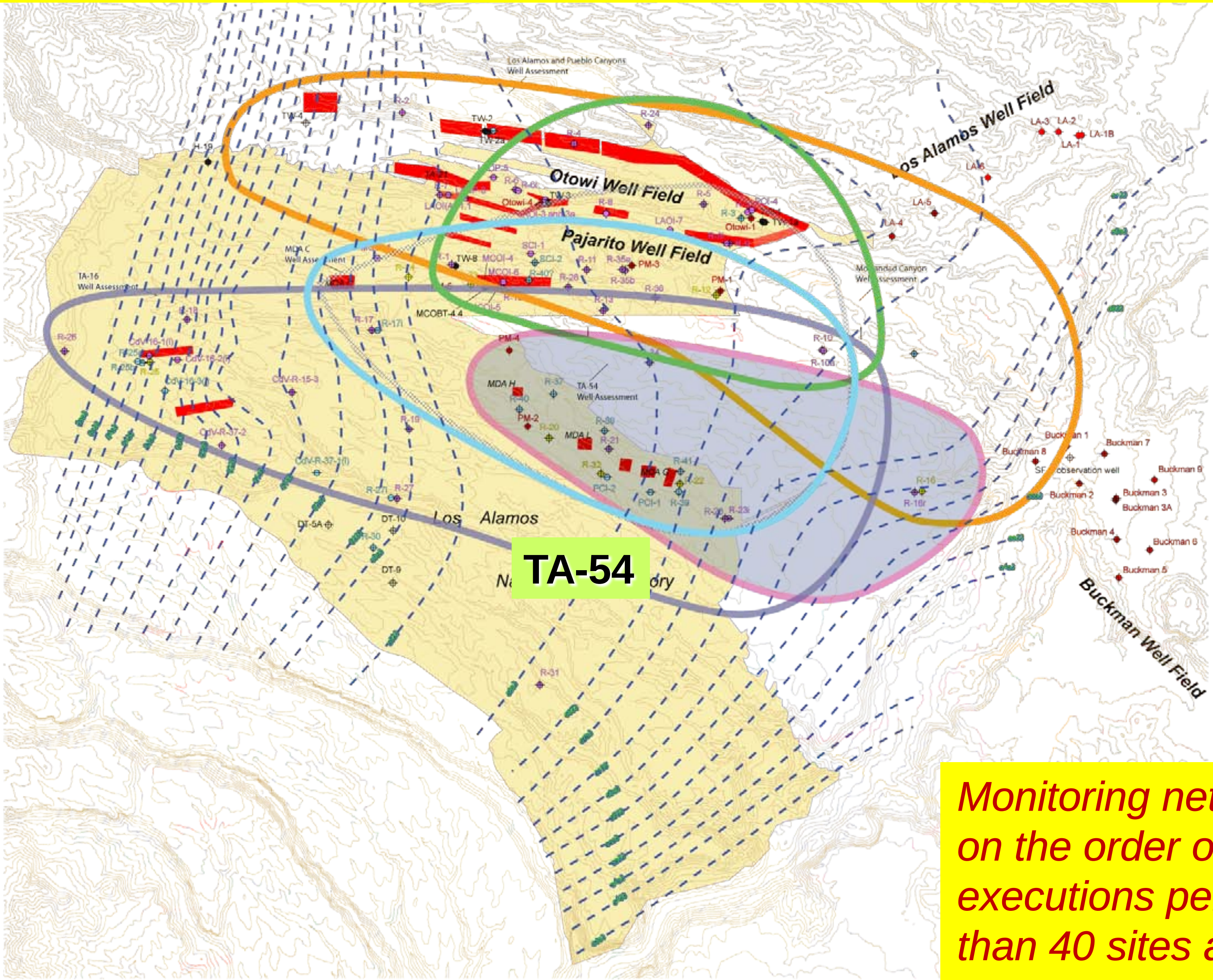
TA-21 MDA T: Baseline risk assessment



- Baseline risk assessment at MDA T uses MDA G PA/CA approach
- MDA T: former radioactive waste disposal site (1945-1974)
- Proposed as an ASCEM demo site for actinide transport: oldest actinide site, good amount of collected data, significant rad inventory, complex flow & transport (fractures, colloids), liquid and cementitious waste

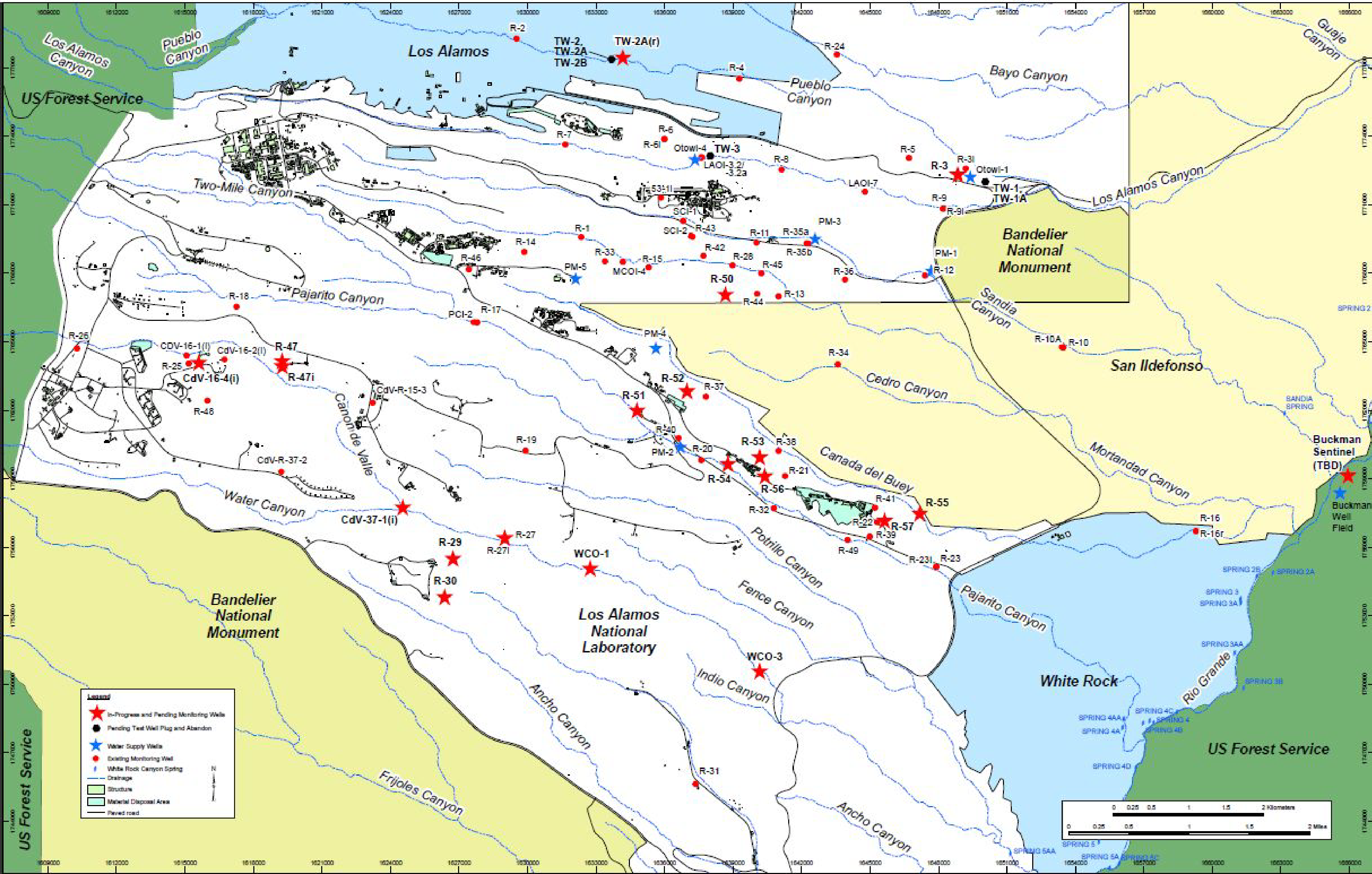
Monitoring Network Evaluations

Monitoring Network Evaluations are based on Monte-Carlo quantification of uncertainties. The goal is to achieve 95% detection and protection efficiency of potential plumes in regional aquifer.



Monitoring network analyses require on the order of 10^3 to 10^4 model executions per site. Currently more than 40 sites are analyzed.

Some of the wells proposed by network evaluations



Conclusions

- **LANL is a complex site for environmental management**
  - series of contaminant sources and disposal areas with long operational records, data collection history, and site studies
  - thick vadose zone with perching horizons
  - infiltration rates exhibit strong spatial and temporal variability
  - highly heterogeneous geologic medium with interfingered fractured and porous units
  - water-supply wells located in close vicinity to contaminant sources
  - active regulators and stakeholders
- **Groundwater is key to environmental management and selection of remedial alternatives**
- **Models with different complexity (process/system) are applied for environmental management and decision making**

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