General

GW
Handouts 3/23-24/06

Conceptual Model of Some Effects of Drilling Fluid To Stabilize Borehole During Monitoring Well Construction

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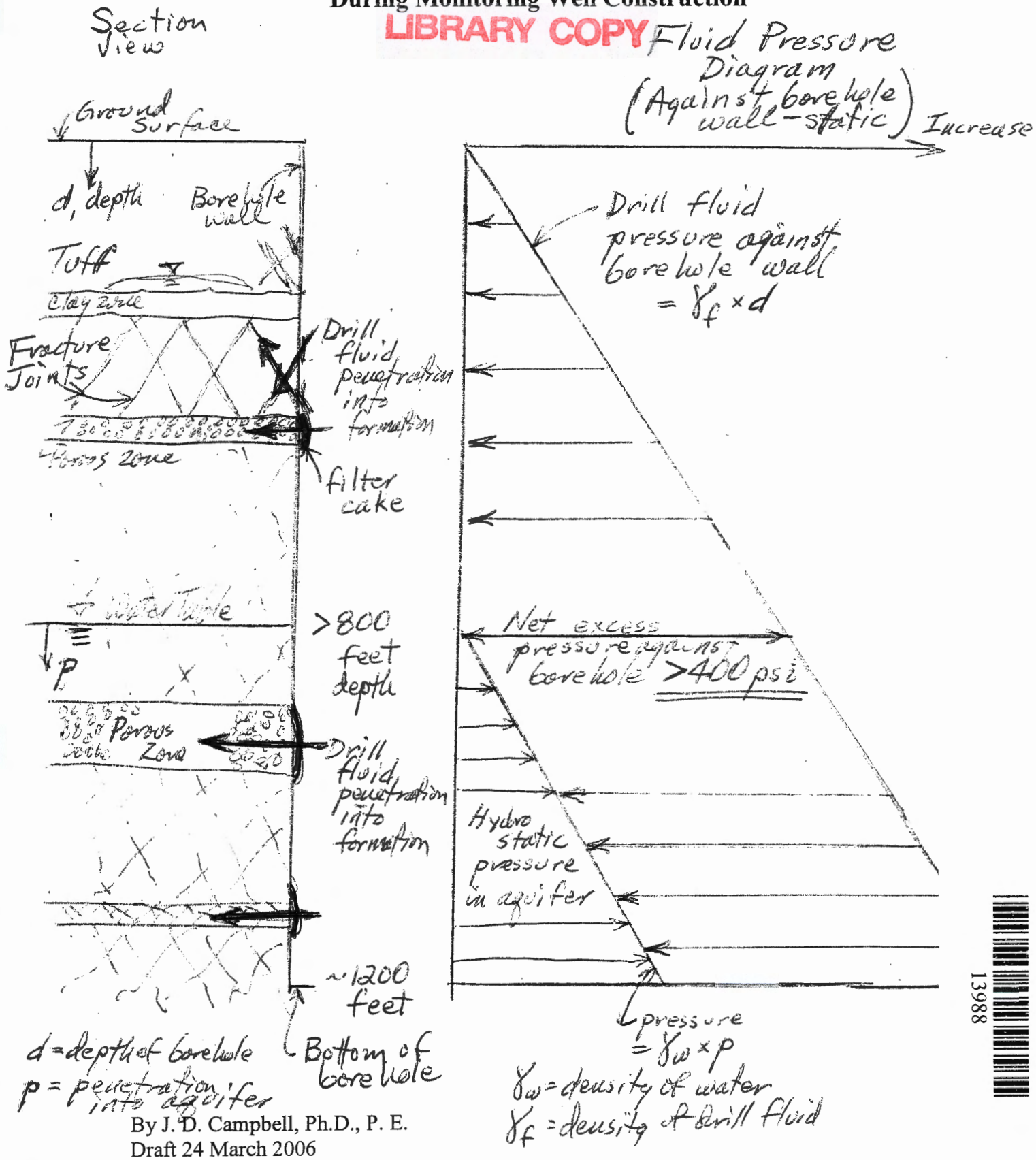


By J. D. Campbell, Ph.D., P. E.
Draft 24 March 2006

13988

Perspectives on NAS Committee Study by:
J. D. Campbell, Ph.D., P. E.
Chair, NNMCAB

The Northern New Mexico Citizen's Advisory Board (NNMCAB) continues to review environmental conditions and studies conducted at LANL and to provide Recommendations to DOE based on our analyses together with citizen input.

Over the past several years, studies conducted under the Hydrogeologic Workplan at LANL and summarized in the Synthesis Report have provided a large amount of valuable data to characterize the geology and hydrogeology at LANL. These data provide a basis on which LANL will move forward with New Mexico Environment Department (NMED) to implement the Consent Order under RCRA and with DOE under its self-regulating responsibilities. With the desire to utilize characterization wells as monitoring wells to detect trace constituents in the groundwater, questions have developed about the impacts of drill fluids used in construction of the wells on groundwater samples obtained from the wells. Immediate resolution of the groundwater data quality issues is required for implementation of actions being taken now by LANL and NMED under the Consent Order and DOE under its responsibilities.

During the NNMCAB's review of this information in the summer of 2004, additional input was received from Bob Gilkeson regarding complex but very important questions regarding the ability of existing well screens at LANL to produce groundwater samples representative of aquifer chemistry. A data quality objective (DQO) for monitoring wells to be used in the current environmental studies requires the ability to detect trace levels of constituents of concern for contaminant migration studies and to evaluate potential impacts to groundwater by the operations and past disposal practices at LANL.

Following interactive discussions with LANL regarding these complex questions, the NNMCAB in January 2005 requested a review of these issues by the EPA National Risk Management Research Laboratory in Ada, OK. Many productive discussions were held to evaluate these issues and EPA issued a draft report in October 2005 and a final report in February 2006. Based on this EPA review, uncertainties remain about the ability of many or most of the existing well screens to produce groundwater samples representative of the aquifer chemistry prior to drilling the well. Even with the active participation of many individuals and agencies to resolve these questions, the reliability and utility of large amounts of groundwater quality data from these wells remains in question.

The NAS Committee would best assist LANL, DOE, NMED and the citizens of New Mexico by utilizing the expertise within the Committee to provide appropriate and representative DQO's for the detection and evaluation of impacts to the soil, rock units, and groundwater in the vadose zone and regional aquifer beneath LANL and the methodology to achieve these DQO's. Representative and reliable data are needed immediately to support the predictive modeling of potential migration of contaminants

now and for the next 10's, 100's or 1,000's of years. Reliable data and analyses are needed to support the selection of remedial actions and to monitor their effectiveness into the future.

The NNMCAB and others have recommended to DOE that a "task force" be established to provide technical review and recommendations to LANL to assist in resolution of these data quality issues being studied by this Committee. This Committee could provide valuable input immediately to LANL to assist in resolution of groundwater data quality issues by allowing open dialog and sharing of the Committee members' experience and expertise with task force participants and/or technical representatives of LANL, DOE, and NMED. This open dialog and input is needed prior to the development of a formal report from the Committee on this and other issues.

The NNMCAB will continue to study and review LANL's approach to environmental cleanup. We look forward to the Committee's recommendations on approaches and methodologies to evaluate present and pending impacts to human health and to the environment so that reliable risk-informed remedial actions may be selected by NMED under the Consent Order and DOE under its self-regulating responsibilities. Further, we look forward to the Committee's recommendations on how the reliability of LANL's predictive models and the effectiveness of the remedial actions may be monitored and evaluated so that New Mexicans can be confident of a safe environment and useable groundwater for future generations.

Control of Groundwater Contamination Sources

David B. Rogers, Presenter

LANL ENV-Environmental Remediation and Surveillance Program, and Nuclear Waste & Infrastructure Services Division

March 24, 2006

How has LANL controlled groundwater contamination sources?

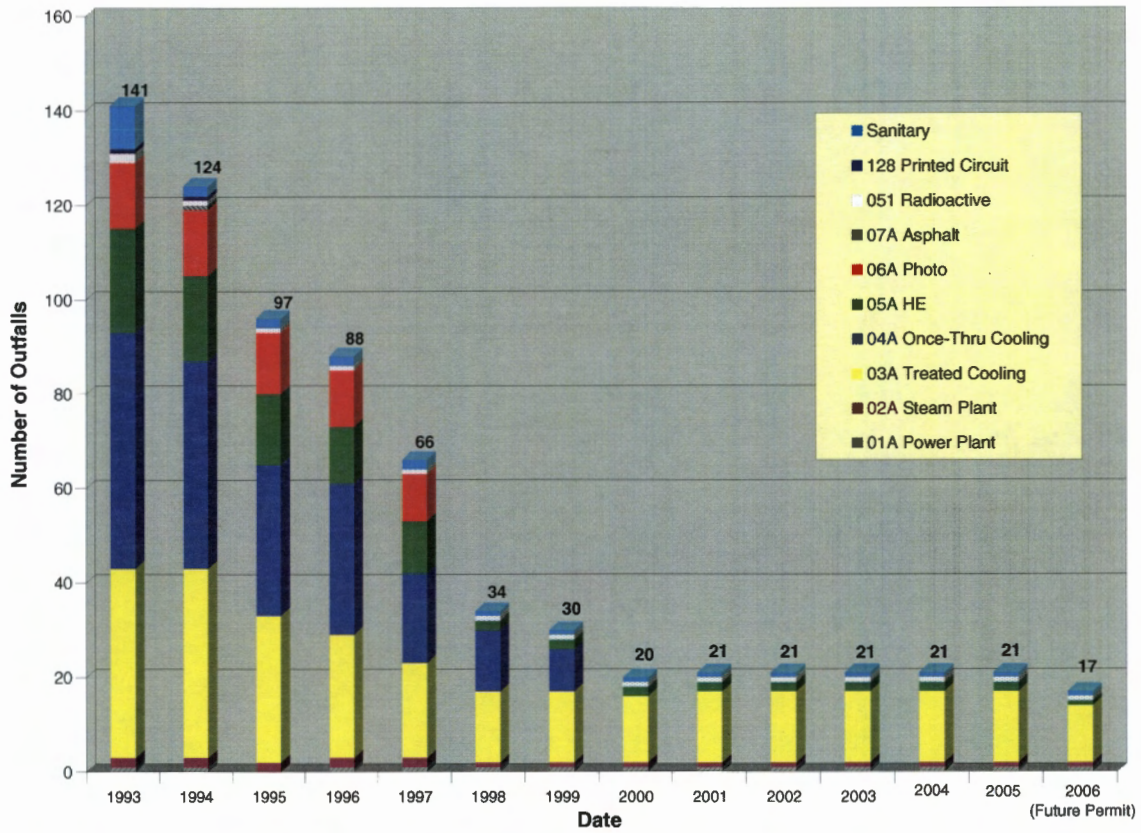
- Outfalls are the main source of groundwater contamination.
- Major LANL contaminant impacts on groundwater are due to past large-volume liquid effluent releases.
- Wastes buried on mesa tops have little groundwater contamination impact:
  - Little water movement through waste.

LANL NPDES permit

- NPDES- National Pollutant Discharge Elimination System:
  - monitoring covers a limited range of constituents.
- Federal Water Pollution Control Act Amendments of 1972 required permits for any pollutant discharged from a point source into waters located in the United States.
- EPA Region 6 administers LANL's NPDES permit.
- LANL received its first NPDES permit in 1978.

How has LANL reduced NPDES outfalls?

- Outfalls decreased from 141 to 21 since 1994

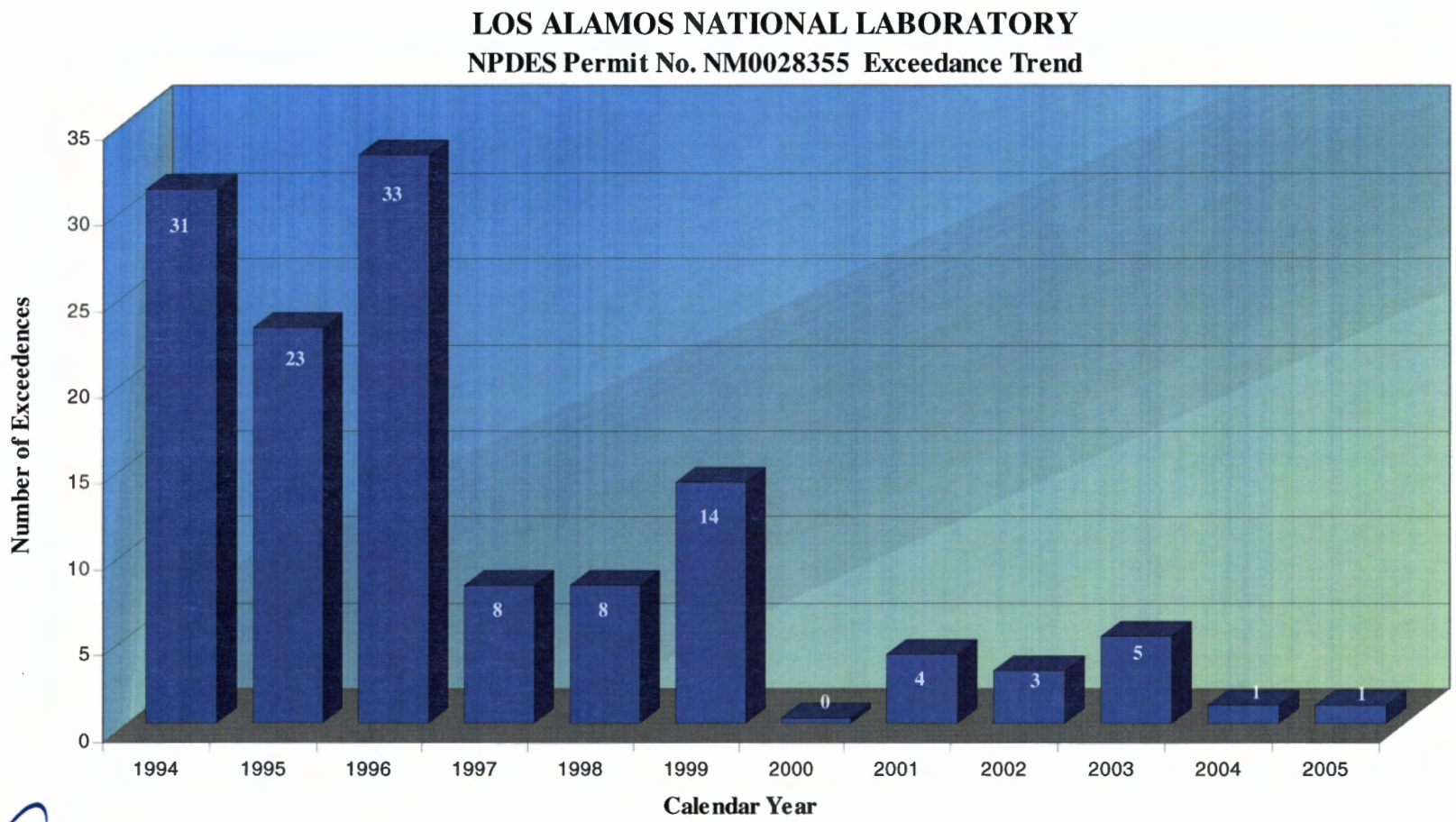


How has LANL reduced NPDES outfalls?

Flow decreased 80% due to outfall reduction and process improvements:

- For 1993 to 1997 total average flow was 1300 M gal/yr.
- Flow decreased to 230 M gal/yr for 1998 to 2005.
- Numbers are estimates based on permit application:
  - most flows are not measured.

How has LANL improved effluent quality- NPDES exceedances have decreased.

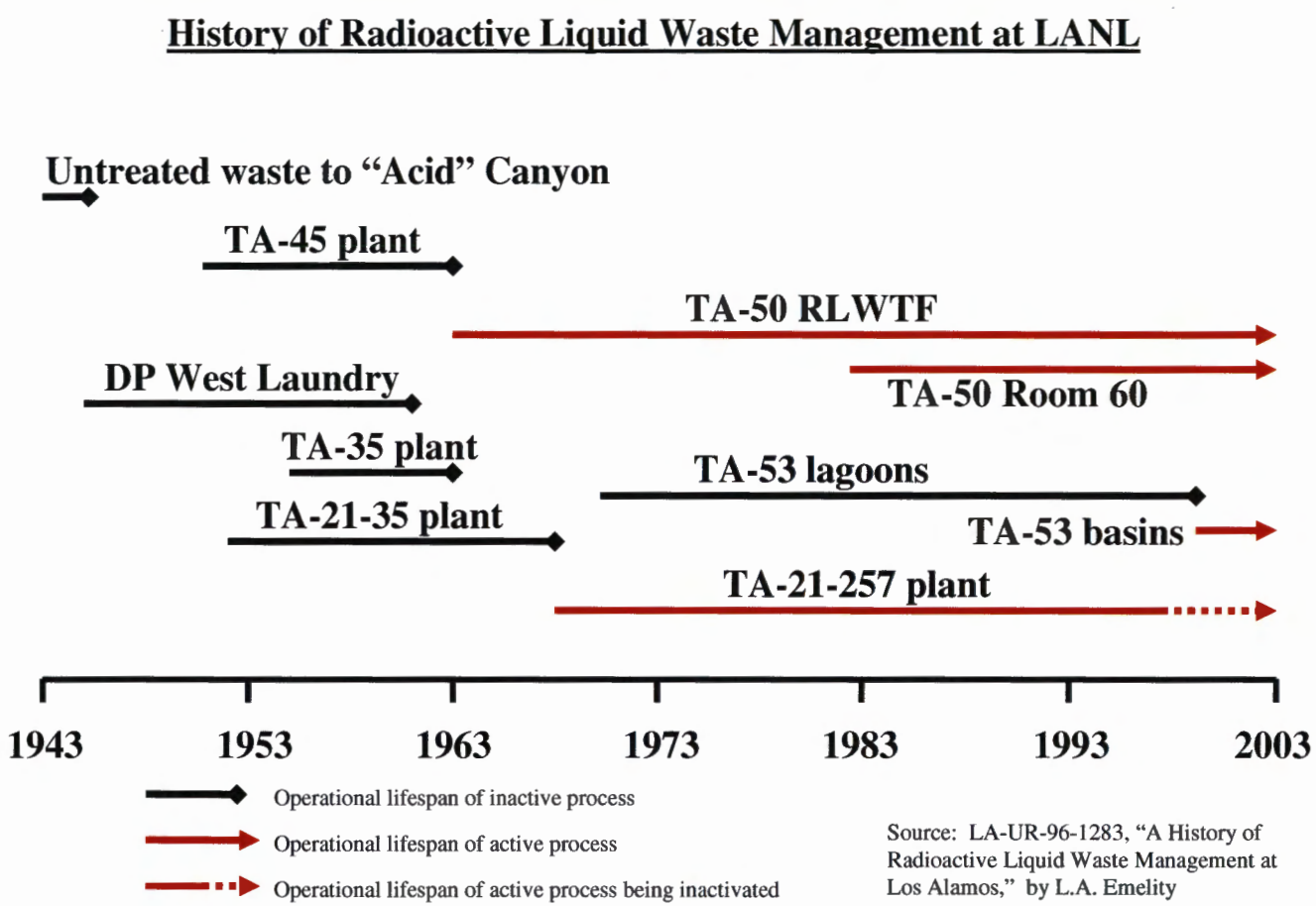


How has LANL improved NPDES performance?

NPDES exceedances have decreased over time:

- Due to outfall reduction,
- Due to process improvements:
  - driven by more stringent permit requirements,
  - improvements to meet new requirements for each permit led to decrease in exceedances.

How has LANL reduced radioactive effluent outfalls?



Source: LA-UR-96-1283, "A History of Radioactive Liquid Waste Management at Los Alamos," by L.A. Emelity

How has LANL reduced radioactive effluent outfalls?

Current radioactive liquid waste treatment facilities:

- TA-50 RLWTF:
  - only current radioactive effluent outfall,
  - treats radioactive liquid wastes from more than 1000 generating points,
  - waste collected via four miles of double-walled pipes,
  - discharged to Mortandad Canyon,
  - one state and two federal agencies monitor quality.

TA-50 Radioactive Liquid Waste Treatment Facility

How has LANL reduced radioactive effluent outfalls?

Current radioactive treatment facilities (continued):

- TA-21 RLWTF
  - pretreatment of waste from tritium research until 2004,
  - treated water was trucked to TA-50 RLWTF,
  - facility in process of shut down.
- TA-53 RLWTF
  - treats waste from accelerator research at the Los Alamos Neutron Science Center,
  - uses water storage, to allow radioisotope decay, and solar evaporation.

TA-50 Radioactive Liquid Waste Treatment Facility

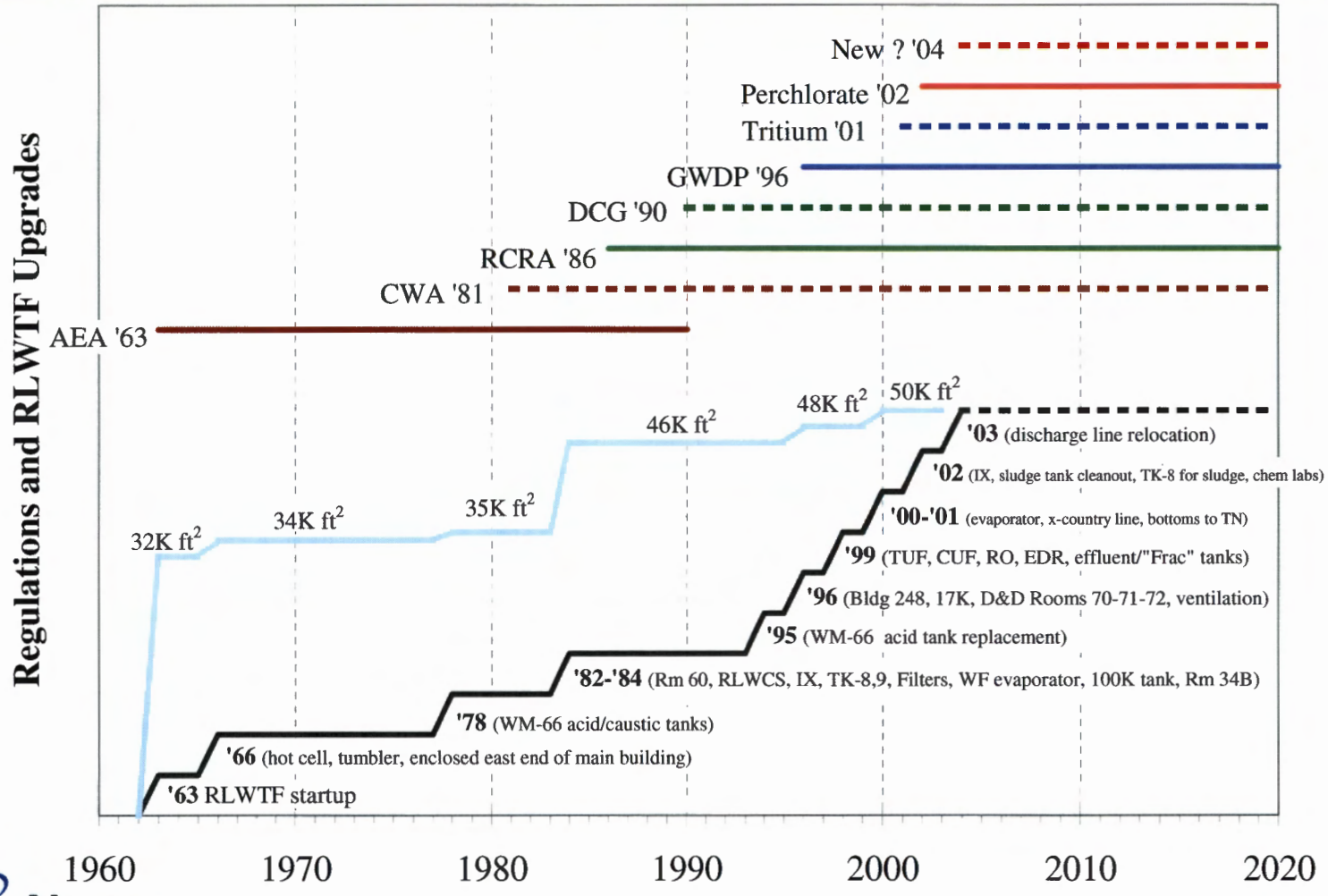
- Initial coagulation-flocculation-sedimentation
  - Ferric sulfate, lime, NaOH, polymer additions;
  - 95% removal of gross alpha;
  - Sludge dewatered by a rotary vacuum filter.
- Additional steps include ultrafiltration, ion exchange, and reverse osmosis.

How has LANL improved radioactive effluent quality?

Treatment process upgrades for TA-50 RLWTF:

- Facility was constructed in 1963, has undergone significant modification;
- Cost of repairs and upgrades has exceeded $15 million since 1997;
- Improvements include repair of tanks and equipment and the installation of new processes to address more stringent discharge standards.

How has LANL improved effluent quality- TA-50 RLWTF improvement drivers



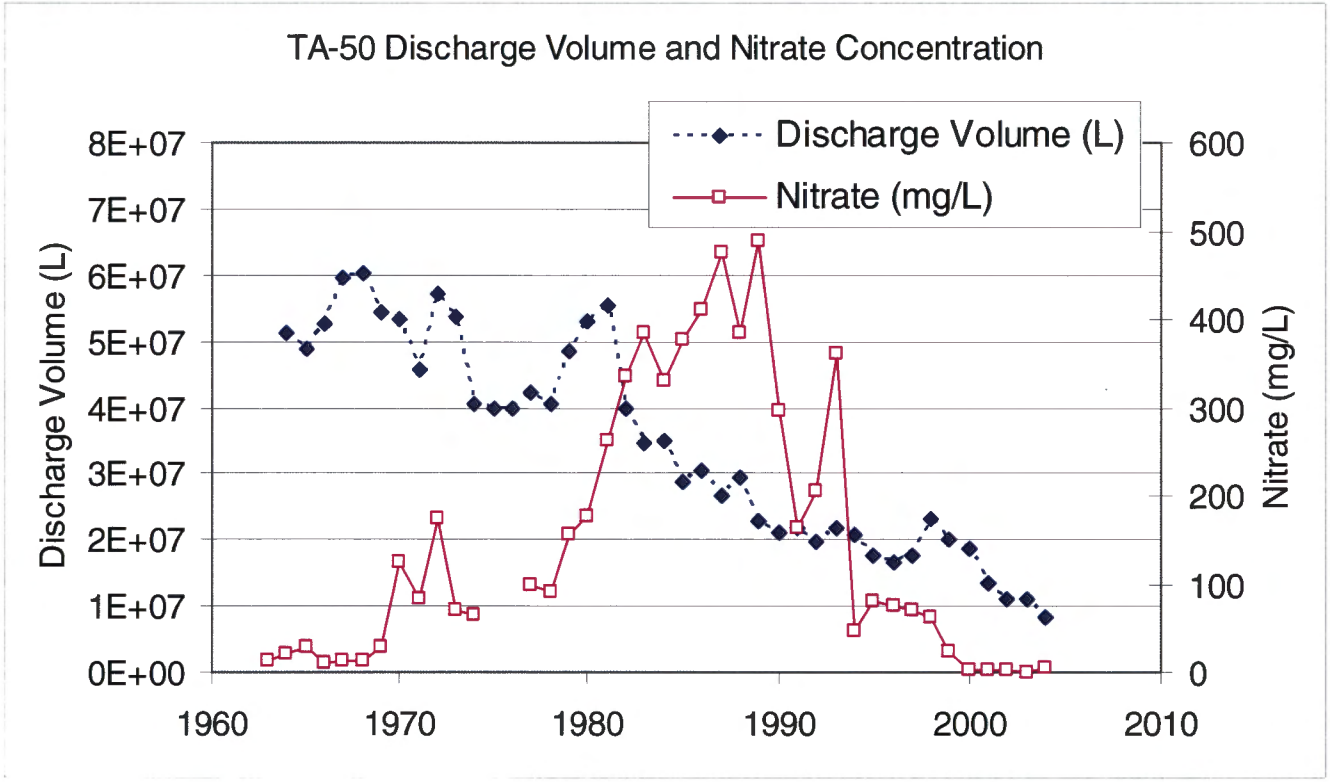
How has LANL improved effluent quality- TA-50 RLWTF improvements

TA-50 RLWTF Effluent Quality Improvements

Constituents Affected	Date	Improvement type
Radionuclides (except tritium)	1999	reverse osmosis and ultrafiltration
Nitrate	1999	waste acceptance criteria and reverse osmosis
Tritium	2000	segregation and evaporation
Perchlorate	2002	ion exchange

How has LANL reduced radioactive effluent flow?

Total TA-50 RLWTF discharge volume has decreased since 1970 due to waste minimization and mission changes.



Effluent quality monitoring at TA-50

- Radioactive effluent monitoring required by DOE Order 5400.5, "Radiation Protection of the Public and the Environment"
  - Weekly composite samples taken inside plant, and
  - Annual monitoring of surface water, sediment, and groundwater in canyon below outfall.
- Weekly NPDES samples taken inside plant,
- Weekly NMED voluntary samples taken inside plant.

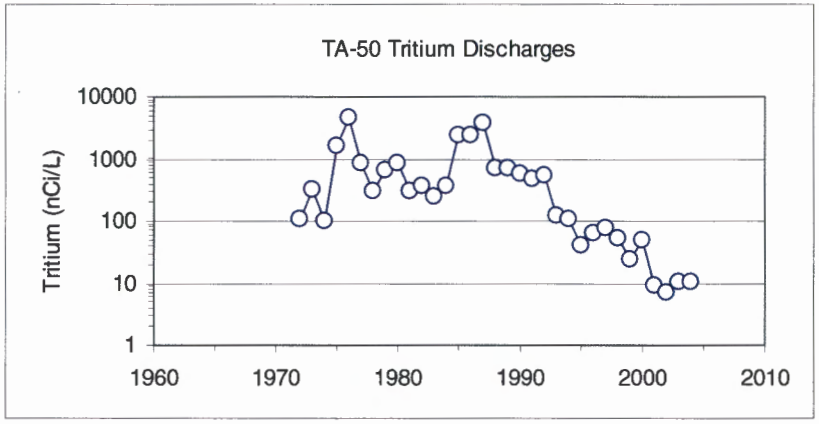
Effluent quality monitoring at TA-50

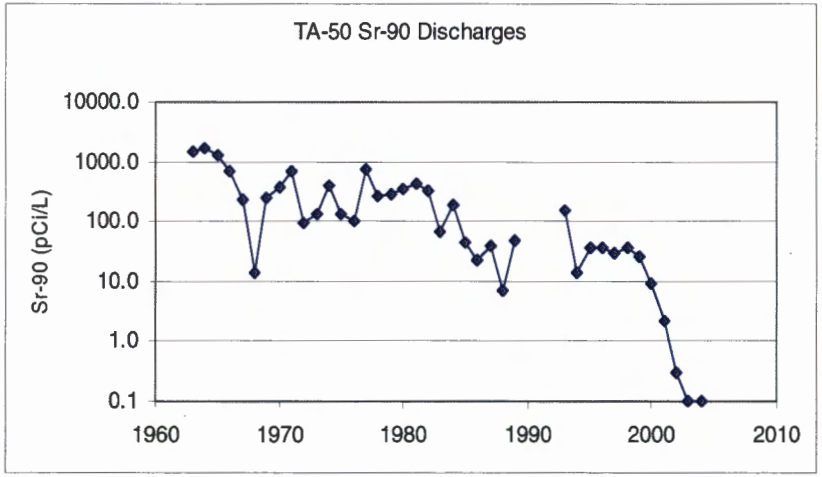
As of calendar year 2005, TA-50 RLWTF effluent:

- met all DOE standards set forth in Order 5400.5 for radiological discharges for six consecutive years,
- was in compliance with all twenty-one (21) NPDES water quality parameters, also for the sixth consecutive year, and
- voluntarily met NMED ground water standards for fluoride, nitrate, and TDS for all but two weeks of the last six years.

Radioactive effluent quality monitoring at TA-50

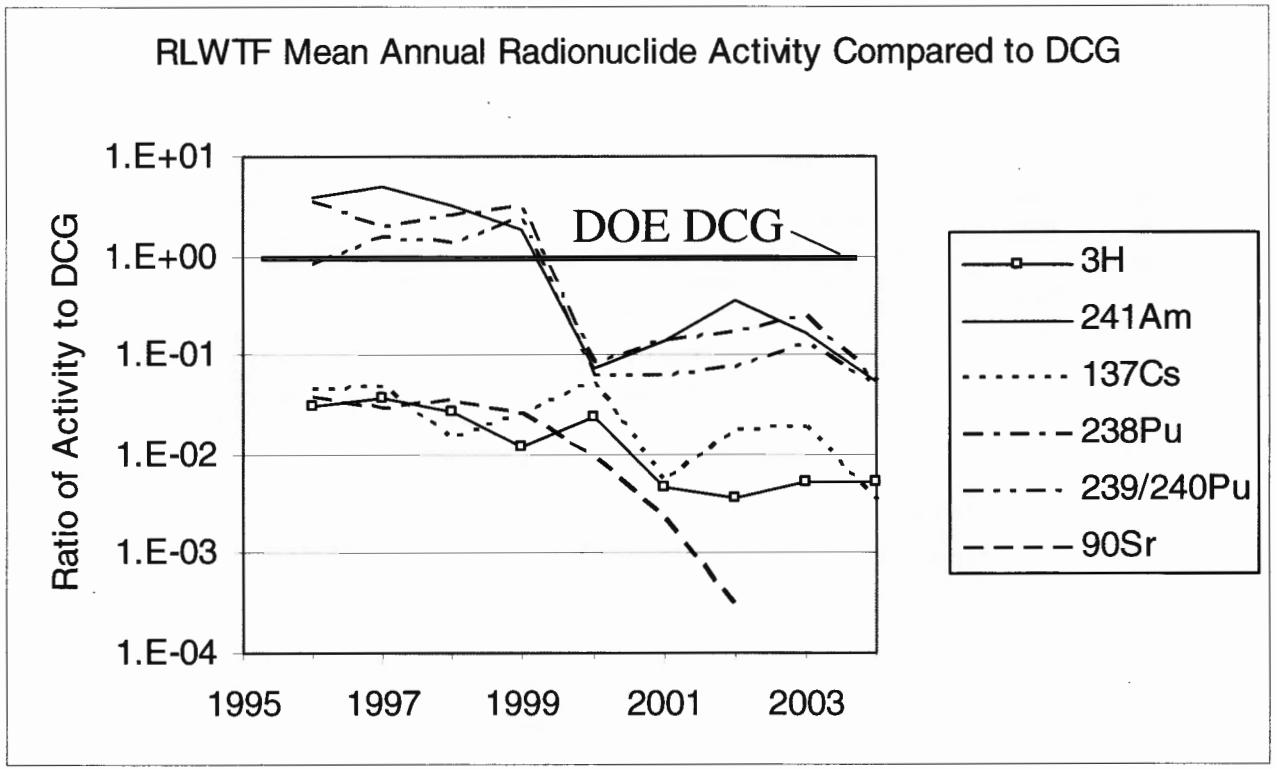
- LANL has discharged radioactive effluent from RLWTF since 1963.
- Annual discharge amounts and concentrations have decreased over time.
- Average annual activity; note log scale.





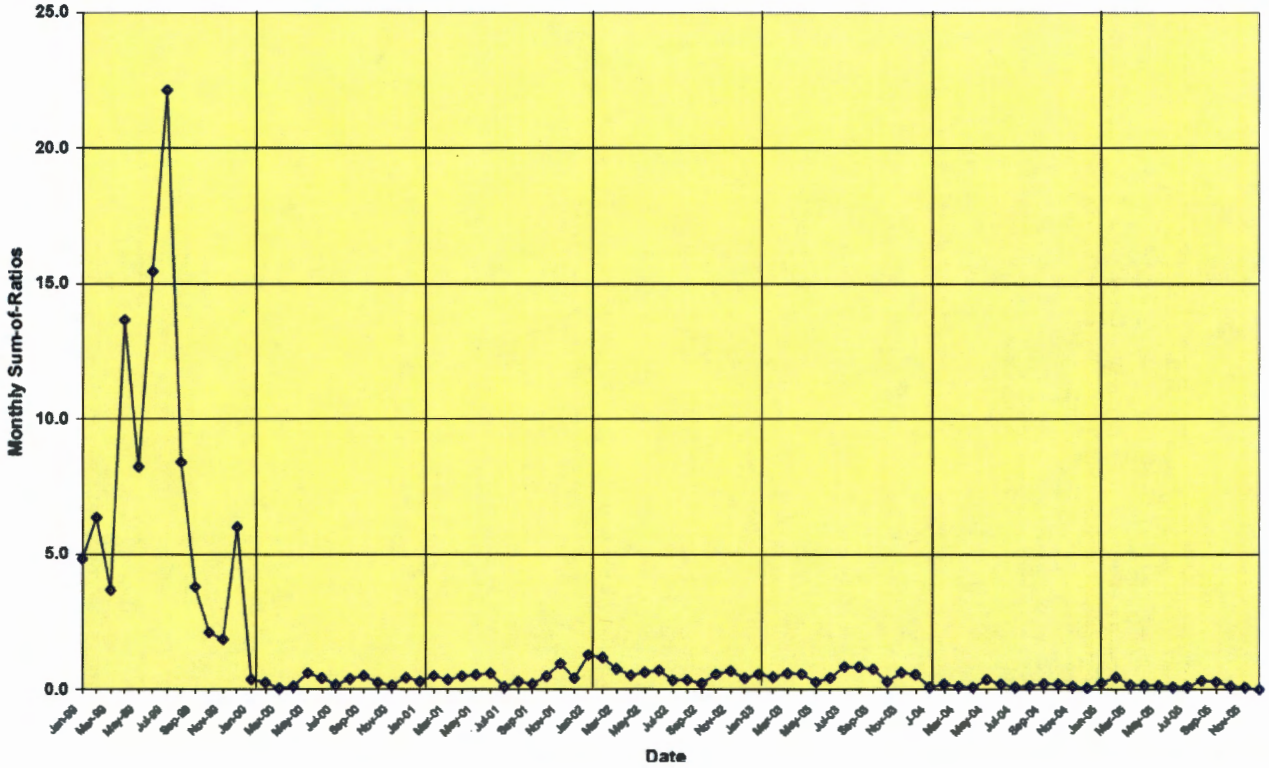
Radioactive effluent quality monitoring at TA-50

- Annual average 100 mrem public dose Derived Concentration Guide performance by nuclide.



Radioactive effluent quality monitoring at TA-50

- Order 5400.5 standard is sum-of-ratios to DCGs must be 1.0 or lower.
- With two exceptions, monthly sum-of-ratios has been below 1.0 since January 2000.



How will LANL improve effluent quality?

Future improvements may include:

- New RLWTF in design phase.
- RLWTF replacement zero liquid discharge still in play.

How has LANL reduced groundwater contamination from outfalls- conclusion

- Reduced number of outfalls from 141 to 17 since 1994,
- Reduced number of radioactive effluent outfalls,
- Reduced flow from outfalls by over 80% since 1994
  - From 1993 to 1997 total average flow was 1300 M gal/yr.
  - Flow decreased to 230 M gal/yr for 1998 to 2005.
- Improved effluent quality through process improvements.

NNSA Requests

- Sources of groundwater contaminants:
  - Have key groundwater contaminant sources, particularly radioactive liquid discharges, been adequately reduced and treated?
  - Is monitoring of discharges appropriate?

Welcome

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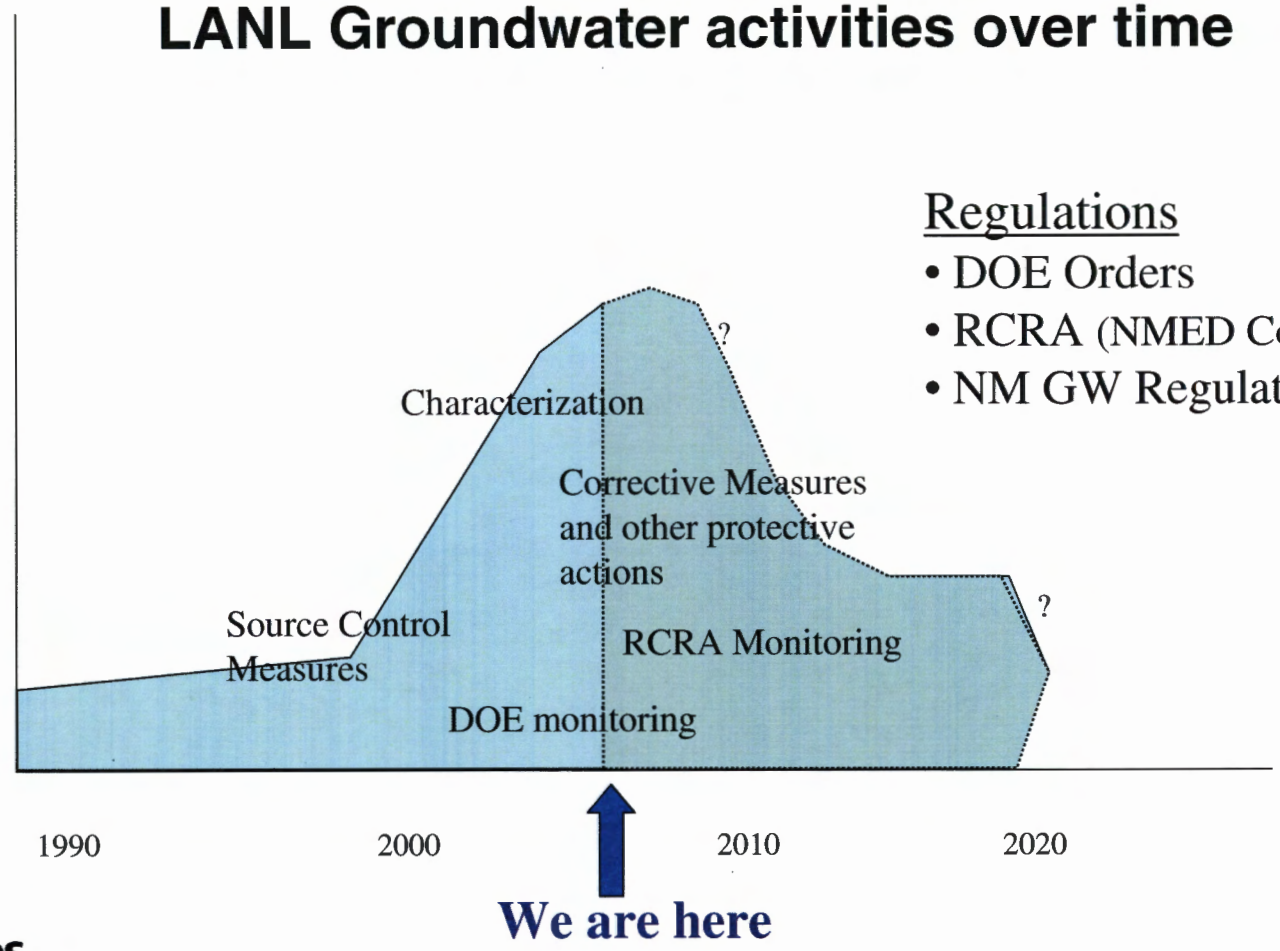
Groundwater Compliance
Framework and Timeline

LANL Groundwater activities over time



Regulations
- DOE Orders
- RCRA (NMED Consent Order)
- NM GW Regulations

NNSA Requests

- Sources of groundwater contaminants
  - Have key groundwater contaminant sources, particularly radioactive liquid discharges, been adequately reduced and treated? Is monitoring of discharges appropriate?
- Groundwater Monitoring
  - Does the current monitoring approach effectively identify contaminants that may migrate at unacceptable levels to public receptor locations?
    - Where are we monitoring too little or too much?
    - Certain characterization wells are not yet reliable. What are best practices for measuring reliability, and for rehabilitation where necessary?

NNSA Requests

- Evaluation and decision-making for radionuclides at environmental restoration sites.
  - Are the current criteria appropriate for evaluating risks and deciding on protective actions for radionuclides in groundwater?

Evaluation and Decision-Making for Radionuclides at Environmental Restoration Sites

Presented for the National Academy of Sciences
Nuclear and Radiation Studies Board
Danny Katzman
March 24, 2006

LA-UR-06-2146

Problem Statement

Is the current process for evaluating radionuclide exposure protective?

Case examples:

- Los Alamos and Pueblo Canyon Investigation Report
- Acid Canyon Voluntary Corrective Measures Report

Key Decision Elements

Land Use Scenarios

- Spatially variable, based on
  - Terrain
  - Proximity to residences
  - Administrative controls
  - Current land use
- Watershed Scale - Mosaic
- Site-specific scenarios

Decision Elements (cont.)

Standard Exposure Scenarios

- Recreational
  - Extended backyard (child)
  - Trail User (adult)
- Industrial
- Residential
- Construction Worker

Site characterization data is used to estimate dose under each applicable scenario

Exposure Scenarios (cont.)

- Exposure assumptions for each scenario are standardized and consistent with non-rad assumptions
- Published set of exposure assumptions
  - Based on 15 mrem/yr target dose limit

Details of Exposure Scenarios

- Pathways
  - water ingestion
  - soil ingestion
  - inhalation
  - external radiation
  - plant ingestion
- Exposure parameters
  - exposure area
  - duration/frequency of exposure
  - ingestion/inhalation rates
  - site-specific exposure parameters could apply
- Different combinations of media are used dependent on scenario
  - e.g., trail user – surface water and shallow sediment
  - Residential – includes groundwater pathway

Target Dose Limits

- 100 mrem/yr DOE target dose to public (4 mrem/yr from water)
- 15 mrem/yr target used at LANL (4 mrem/yr from water)
- ALARA (as low as reasonably achievable)

Decisions

- No further action ("complete")
- Remediation ("complete" or "complete with controls")
  - cleanup to meet 15 mrem/yr target under present-day scenario
- Long-term monitoring ("complete w/controls")
  - checks "performance" of conceptual model

Potential issues associated with decision-making

- Future land-use
  - Changing land-use scenarios associated with loss of institutional control
- Contaminant migration
  - Future "downstream" impacts
  - Cleanup vs long-term monitoring

Site-Wide Geology
of Los Alamos National Laboratory

Presenter: David Vaniman

March 23, 2006

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The World's Greatest Science Protecting America

LA-UR-06-2146

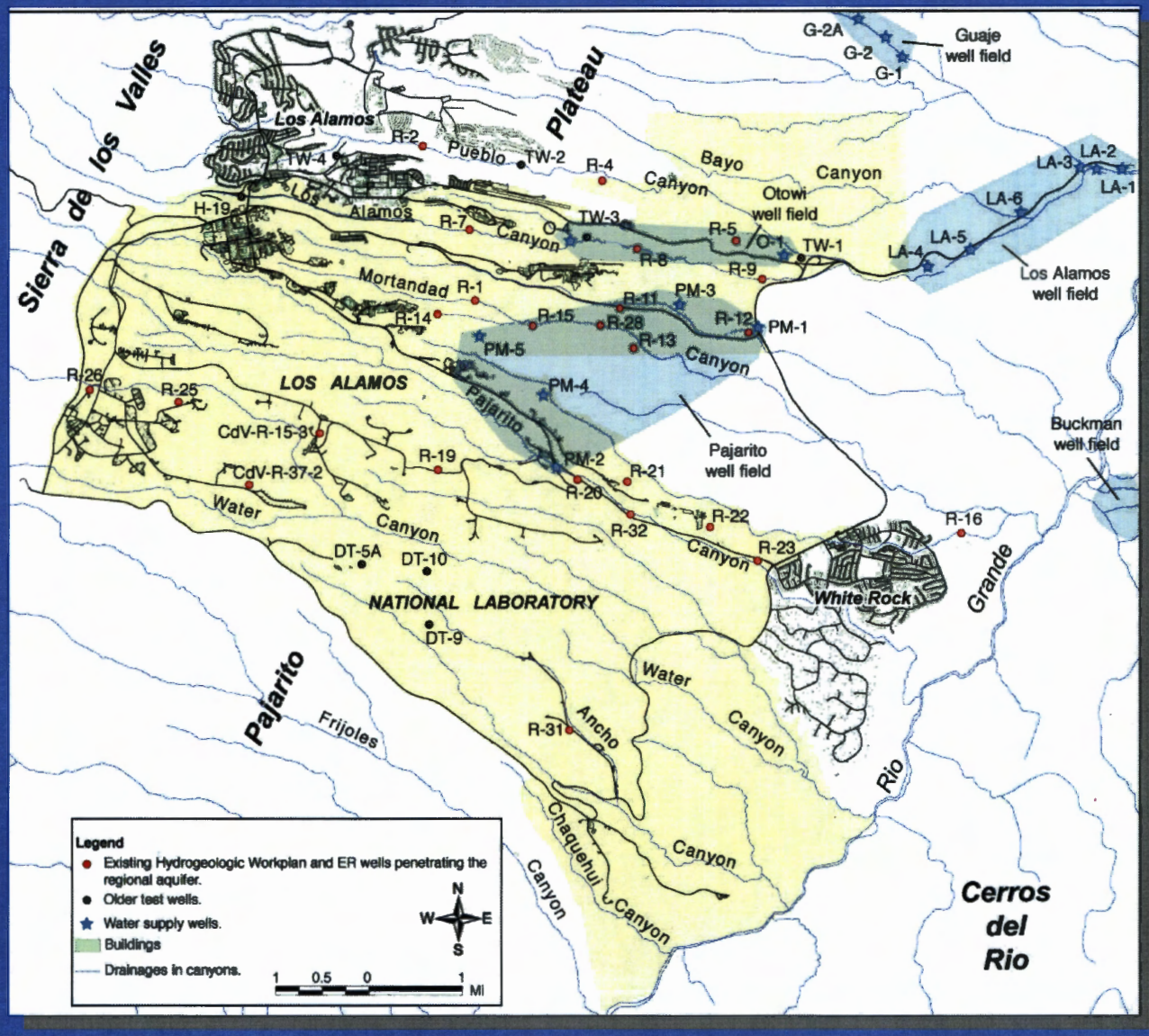
NNSA

acknowledgments

- David Broxton
- Gregory Cole
- Giday WoldeGabriel

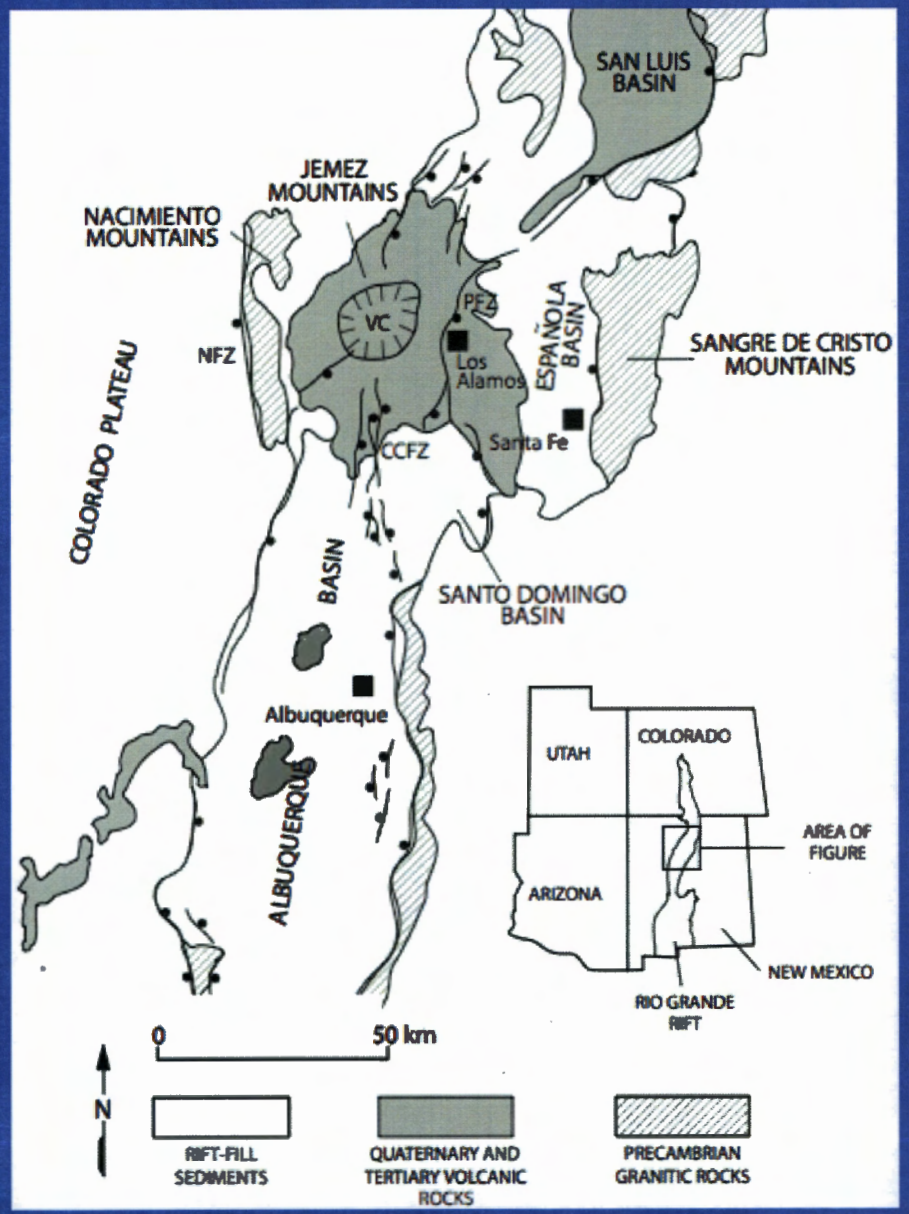
Regional Setting

Location Map



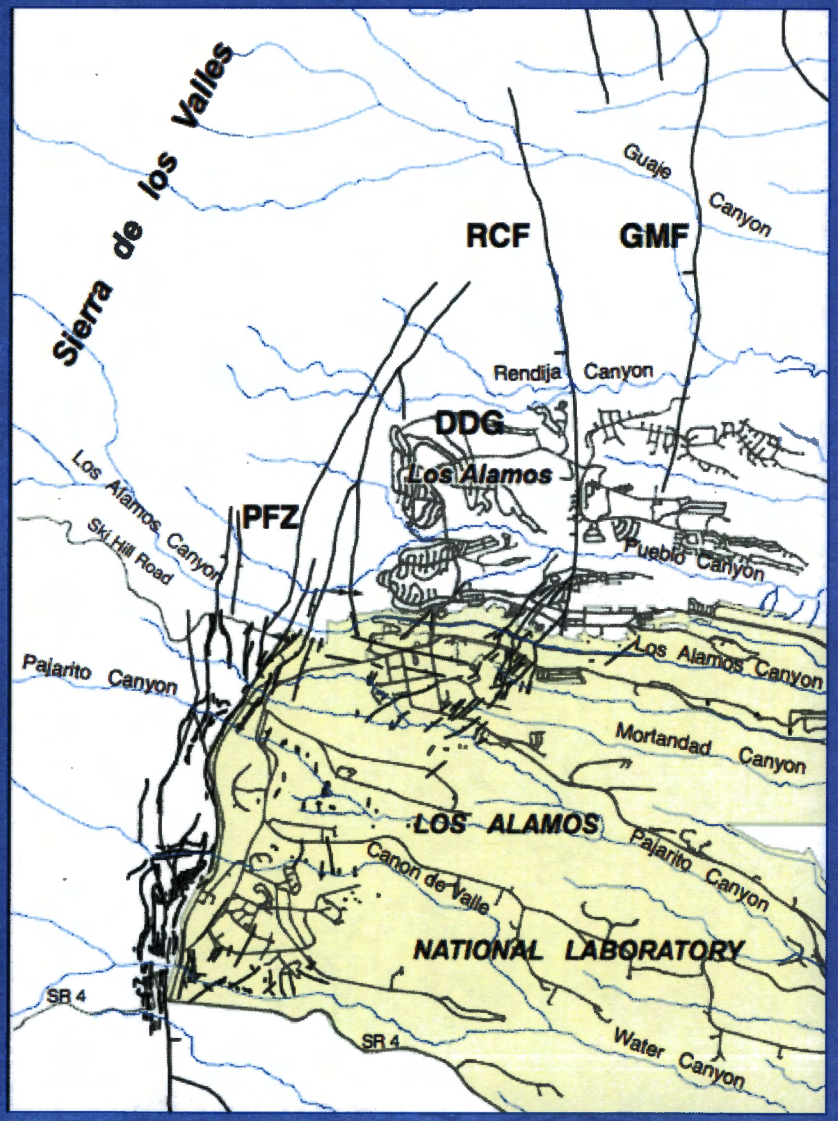
Structural Setting

Tectonic Framework



- Southern Rockies
- Rio Grande Rift
- Colorado Plateau
- Jemez Volcanic Field

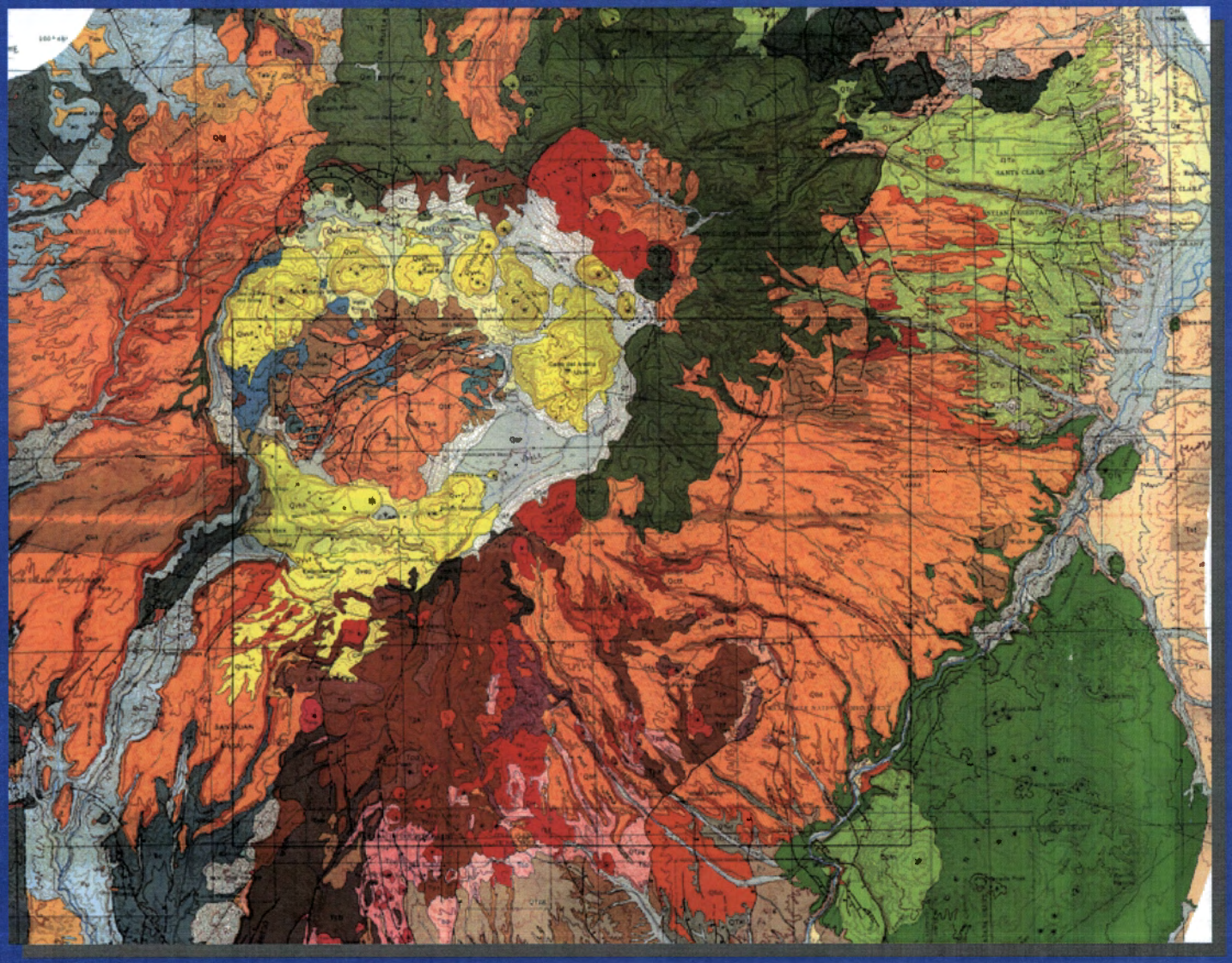
Faults on the Pajarito Plateau

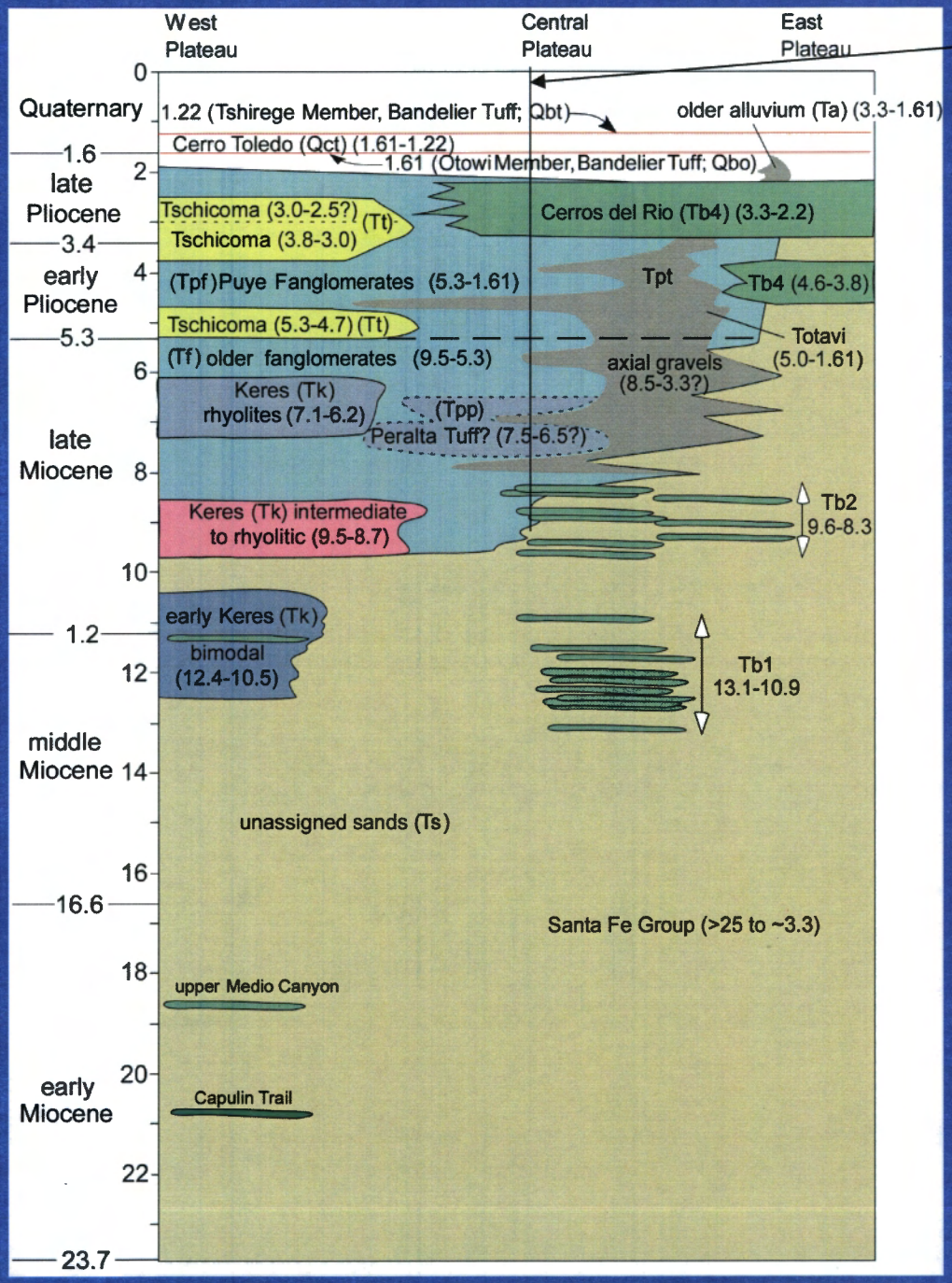


- Pajarito Fault Zone (PFZ)
- Guaje Mountain fault (GMF)
- Rendija Canyon fault (RCF)
- Diamond Drive graben (DDG)

Geologic Units and Stratigraphy

Surface Geology



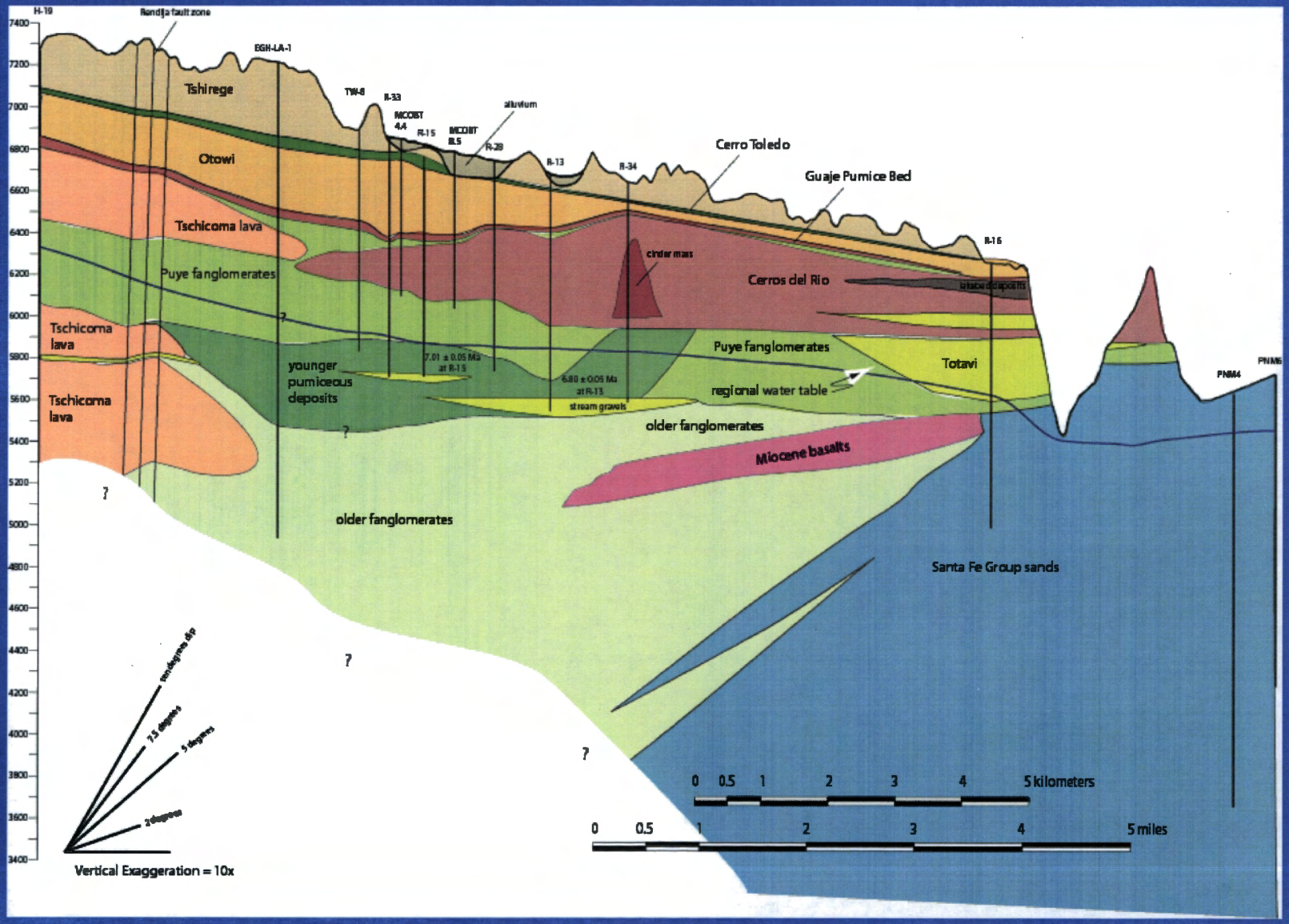


"generic borehole"

Schematic Stratigraphy

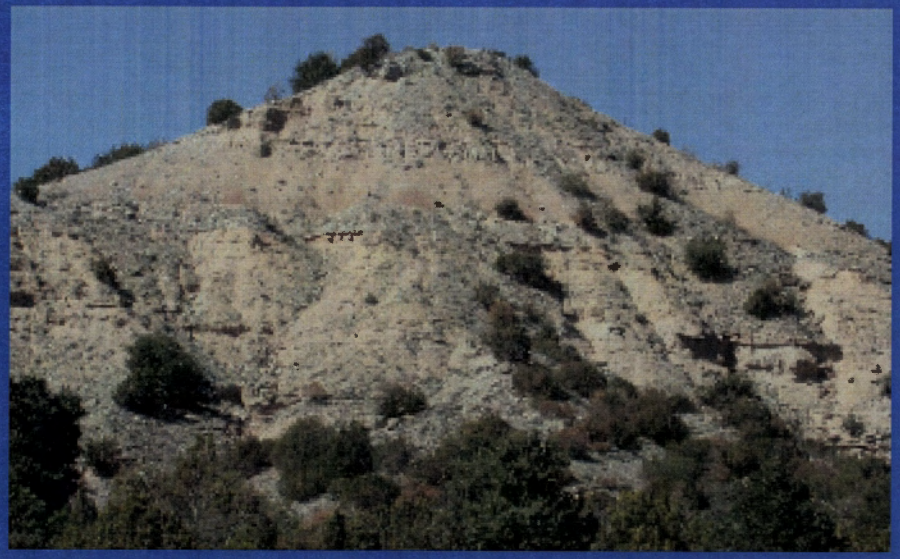
vertical axis is in time (Ma)

Geologic Cross Section



Santa Fe Group

- Silty sands with lenses of gravel
- Significant aquifer unit



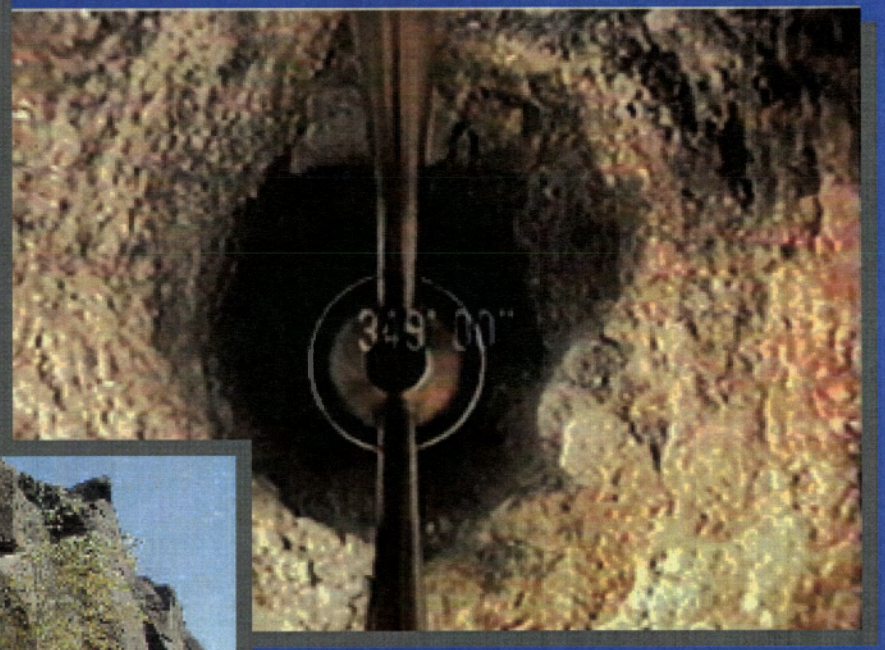
Totavi Lentil

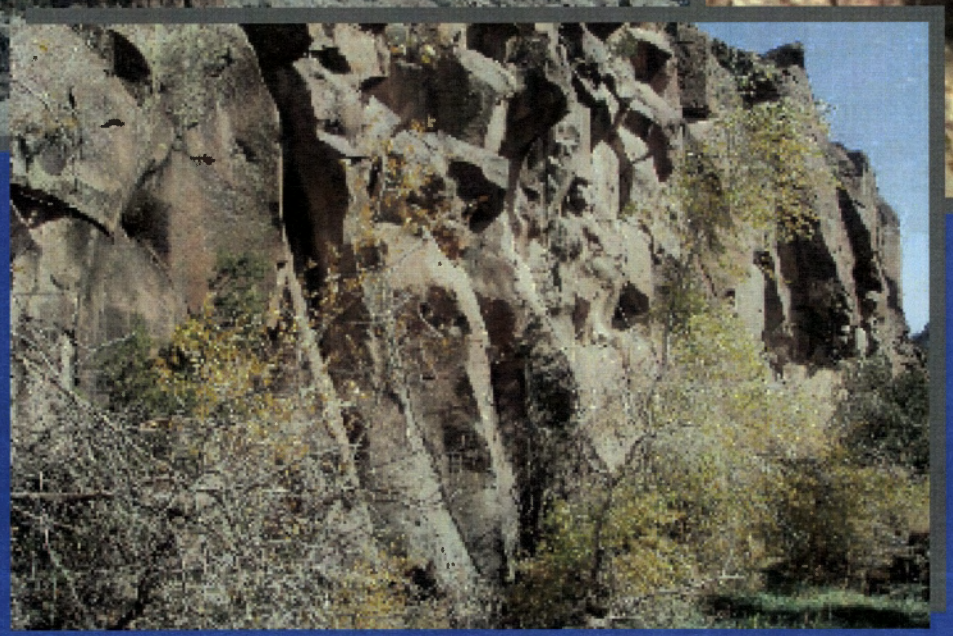
Ancestral Rio Grande Gravels and Sands

Puye Formation

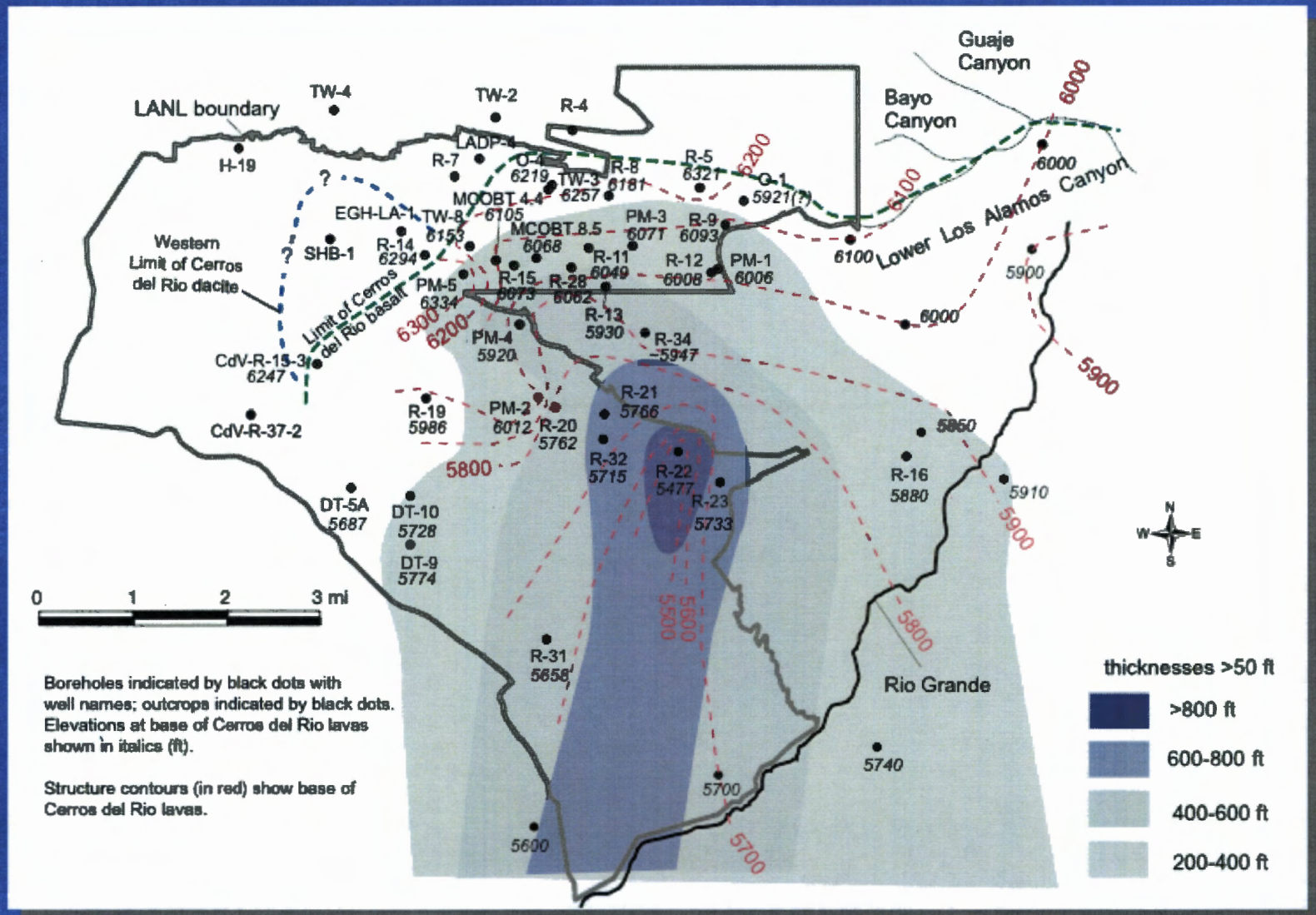
- Alluvial fans from Jemez Mountains
- Important aquifer unit
- Heterogeneous rock unit

Cerros del Rio volcanic field

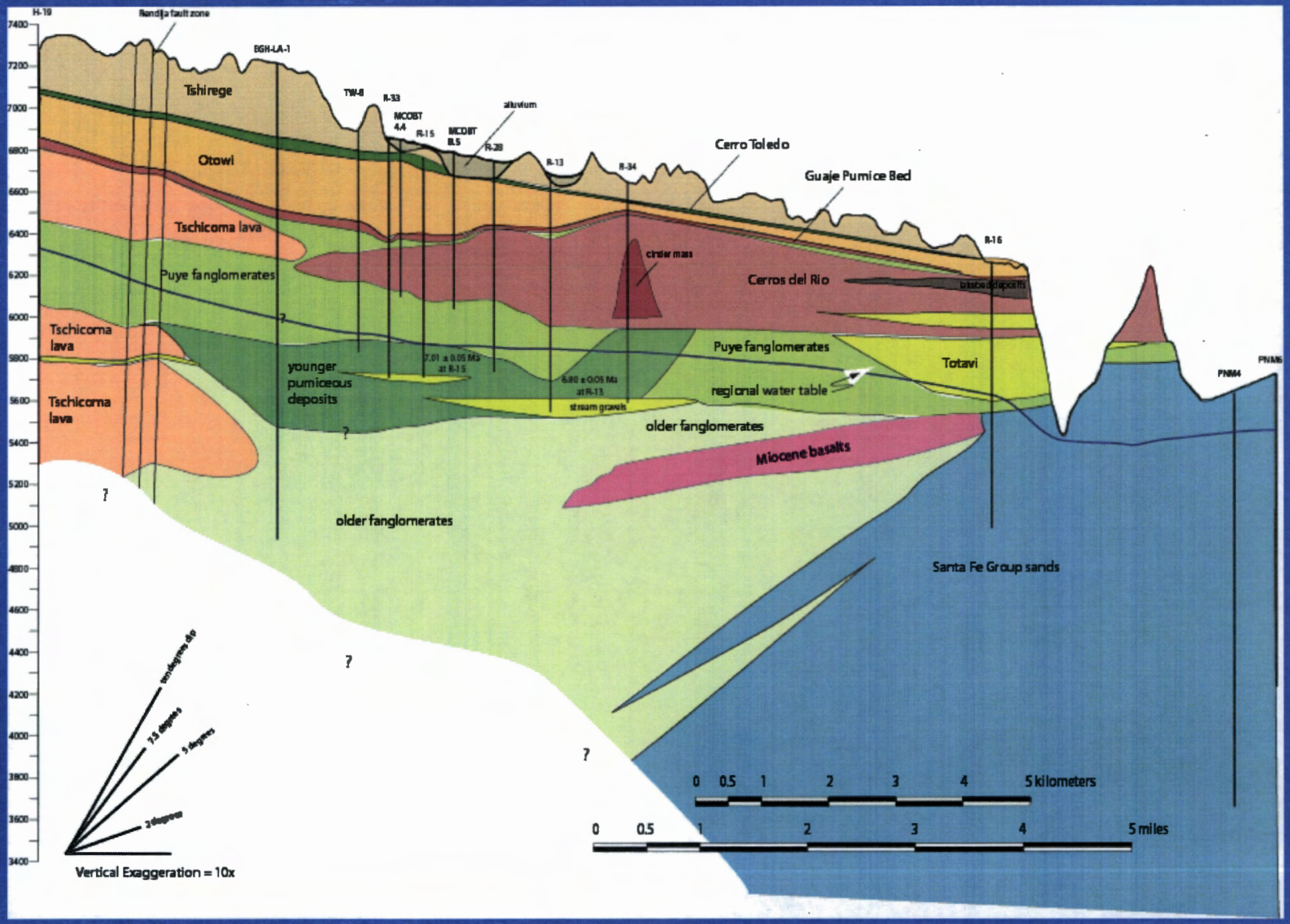




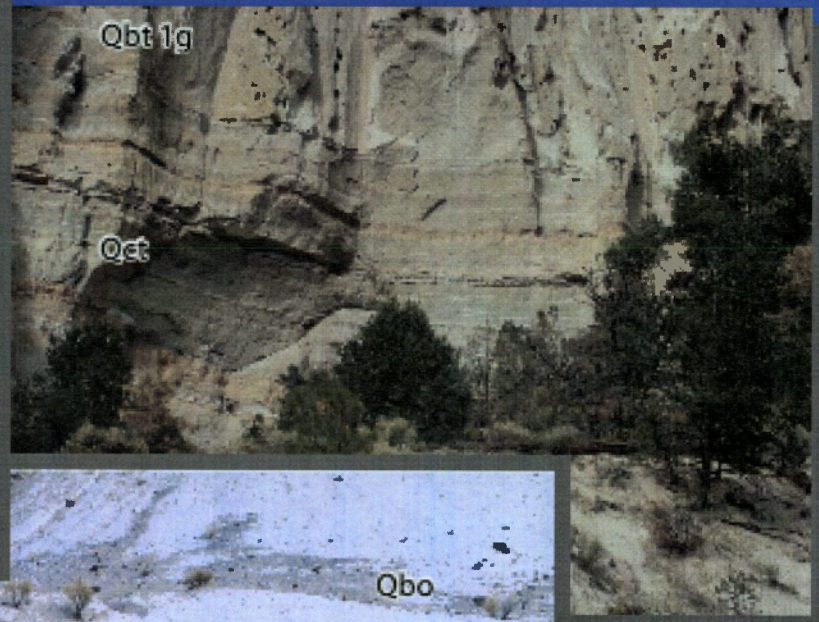
Cerros del Rio base and thickness



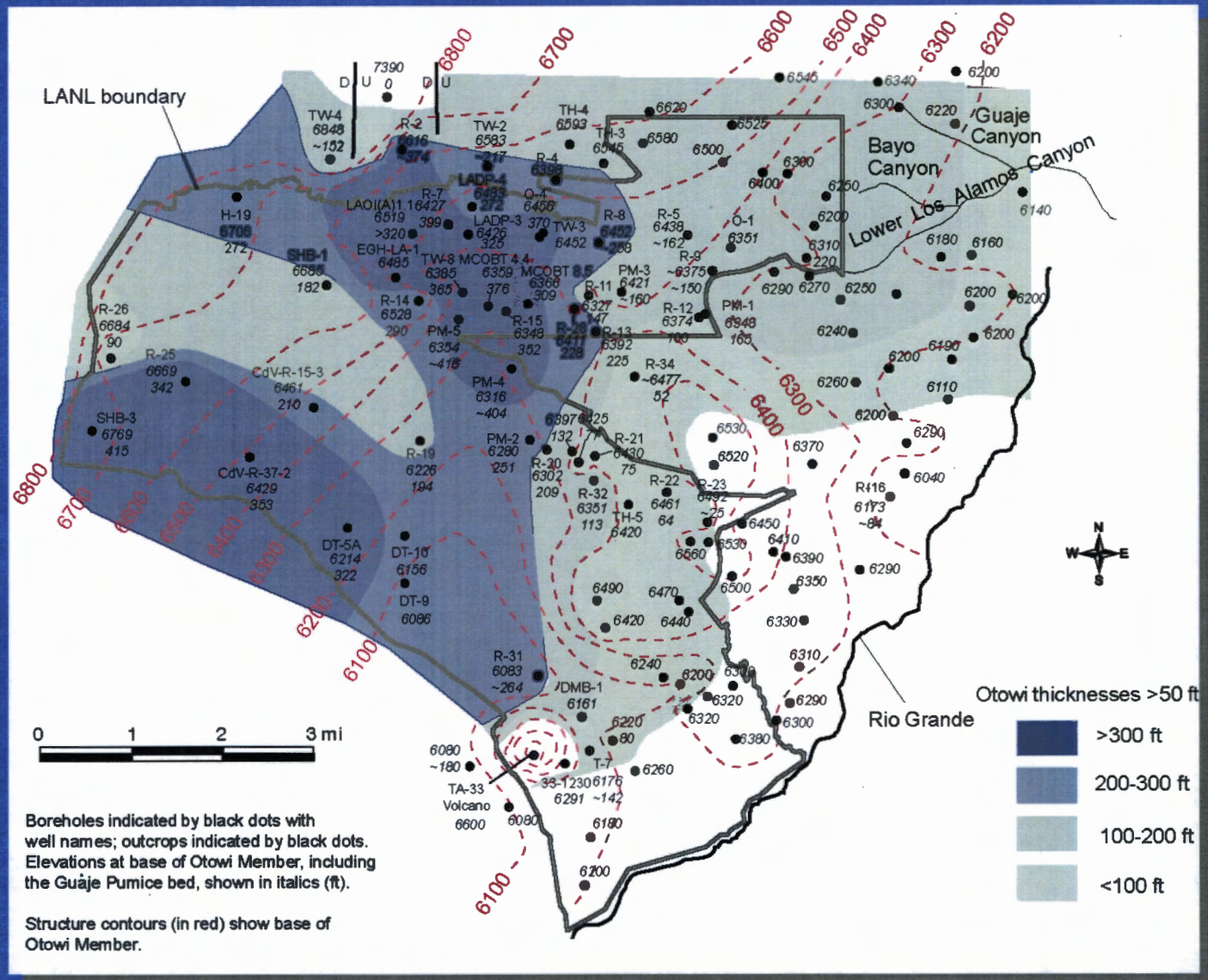
Geologic Cross Section (again)



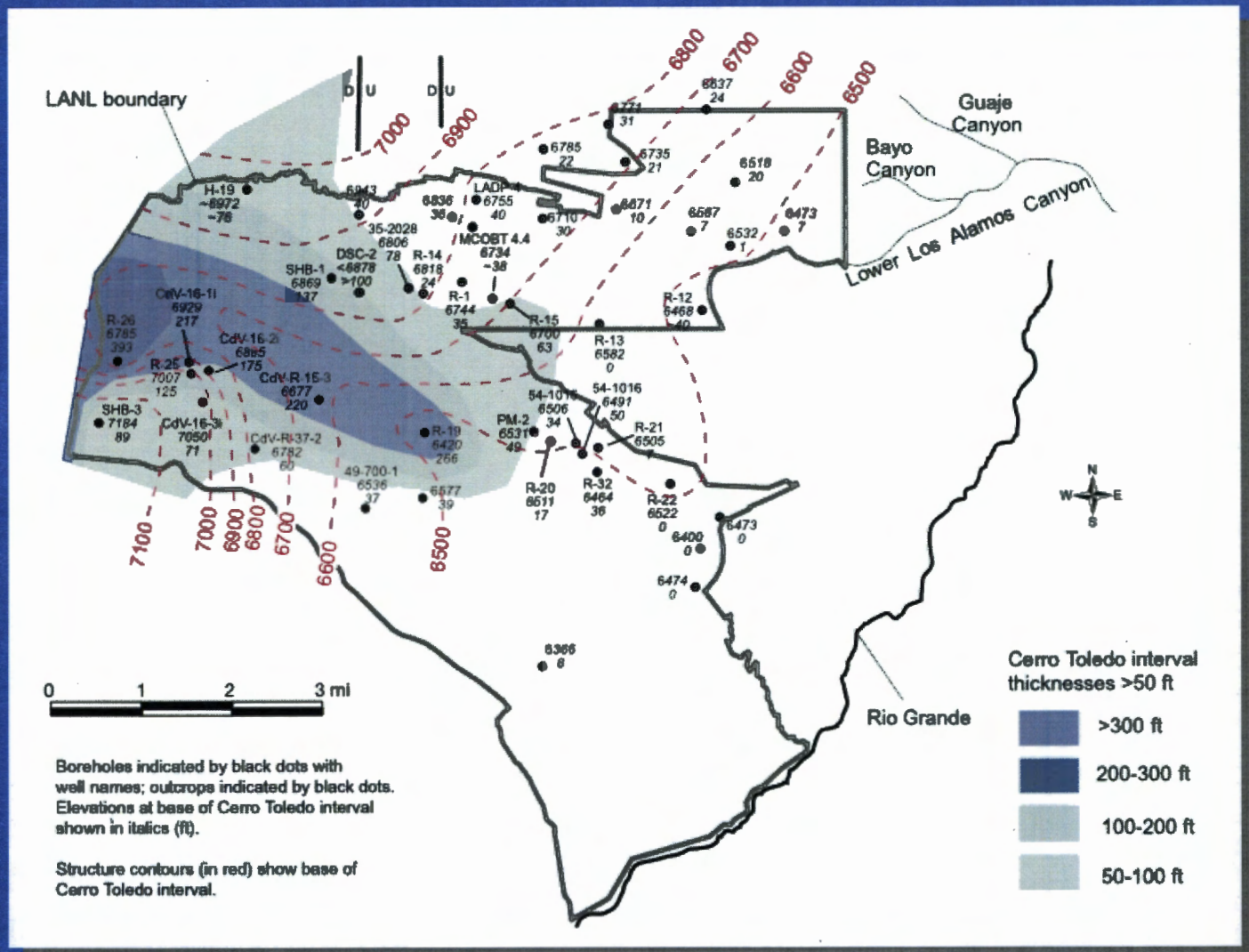
Bandelier Tuff



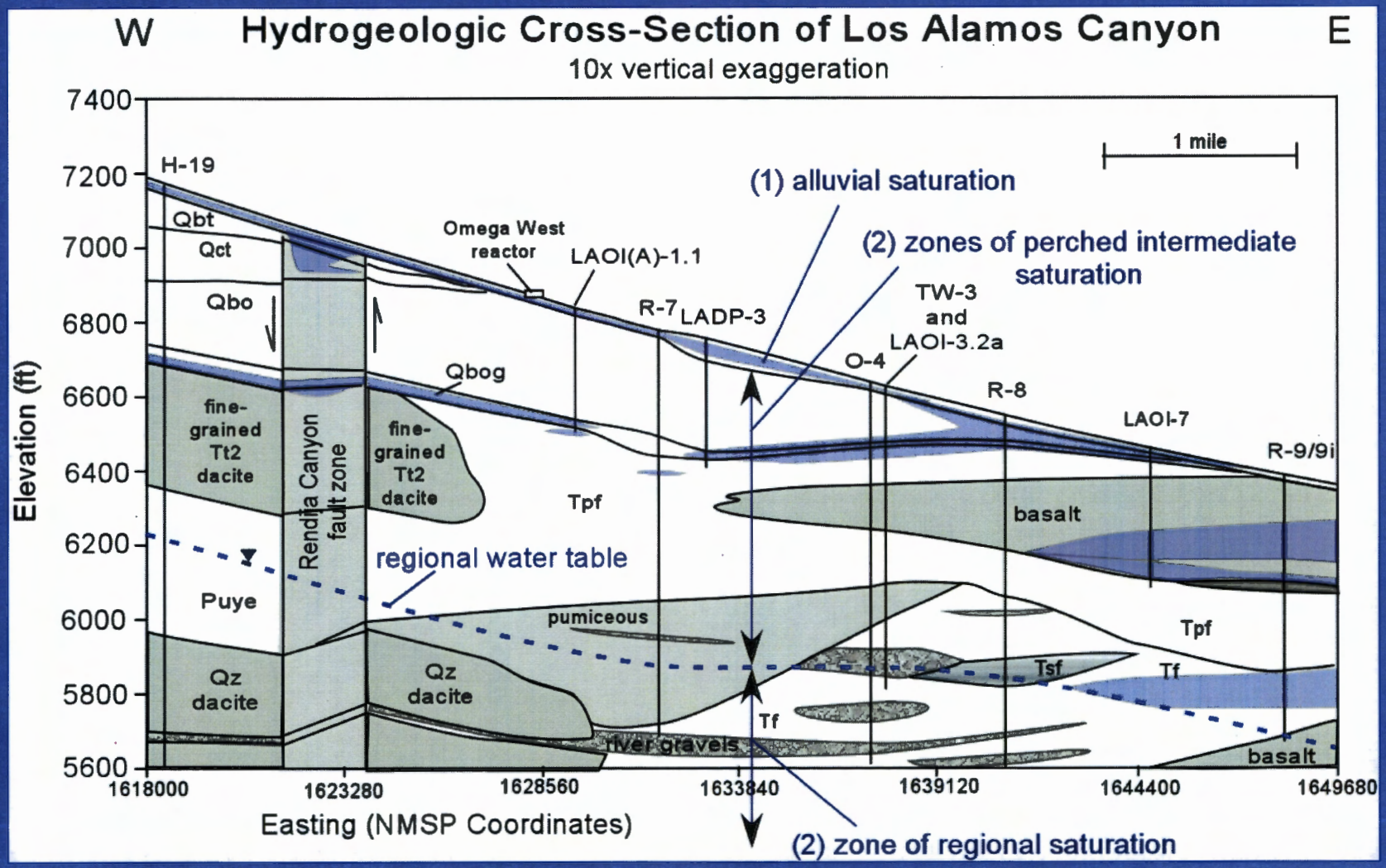
Otowi base and thickness



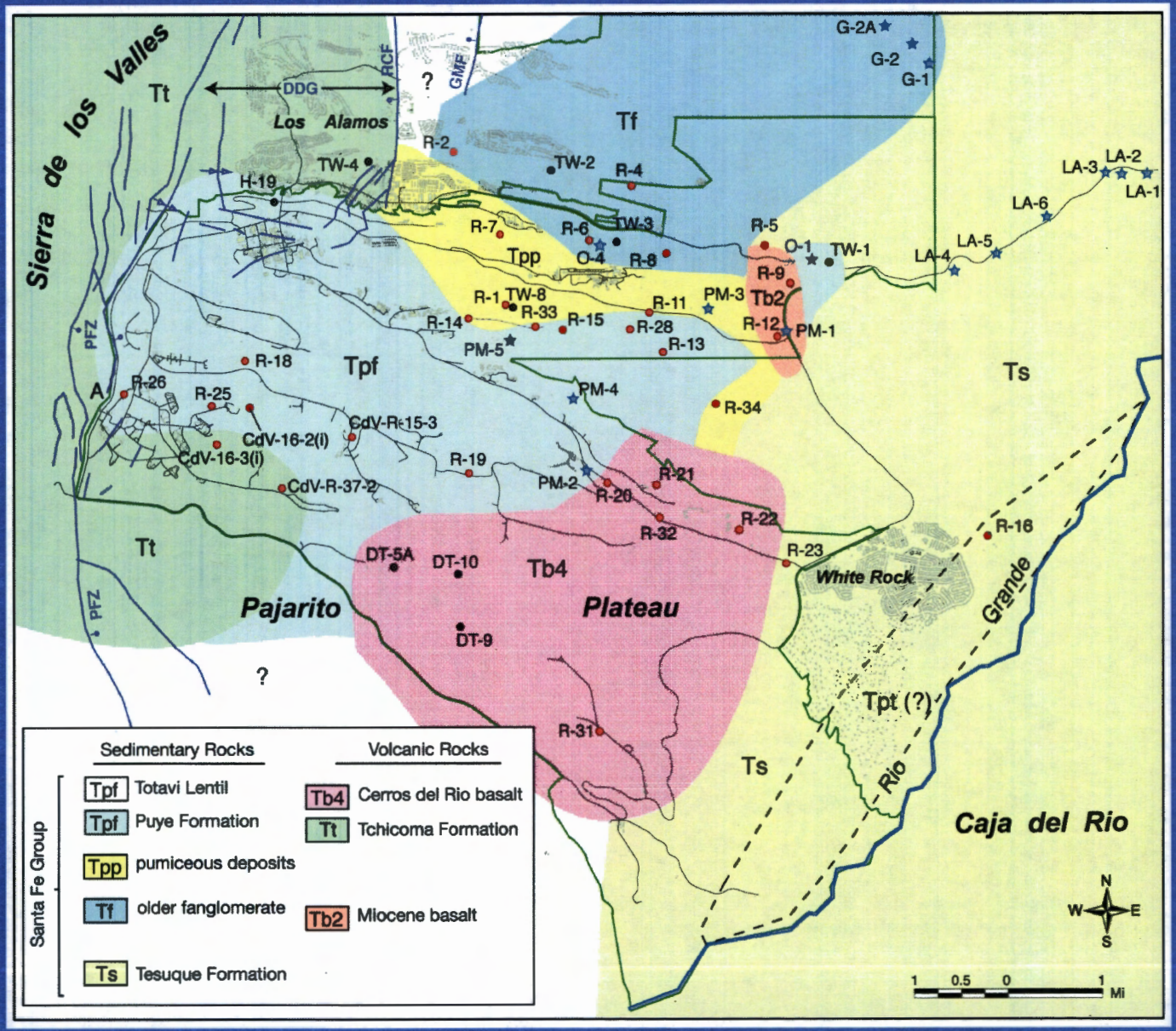
Cerro Toledo base and thickness



Groundwater Occurrences



Geology at the Water Table



Summary

- Bandelier Tuff overlies a complex sequence of Miocene and Pliocene sedimentary and basaltic rocks
- Interfingering of these geologic units reflects shifting foci of tectonism, sedimentation, erosion, and volcanism in an active rift margin
- Groundwater occurs in the vadose zone as perched systems above a variety of geologic aquitards - generally beneath wet canyons
- The regional aquifer is made up of heterogeneous sedimentary and volcanic deposits with most water production coming from a combination of coarse-grained fanglomerates and silty sands
- Deep, varied horizons of tuff, unconsolidated sand, gravel, dense lava, cinder deposits, lakebed clays, and fanglomerates create challenging drilling conditions and often require drilling additives (e.g., foam)
- Stratigraphic and hydrogeologic complexity call for sampling screens at multiple depths

Groundwater Data Adequacy Project

National Academy of Sciences Review

March 23-24, 2006

Presented by

Ardyth Simmons

on behalf of

LANL-ENV Environmental Remediation and Surveillance Program

Acknowledgments

- Mark Everett, ENV-ECR
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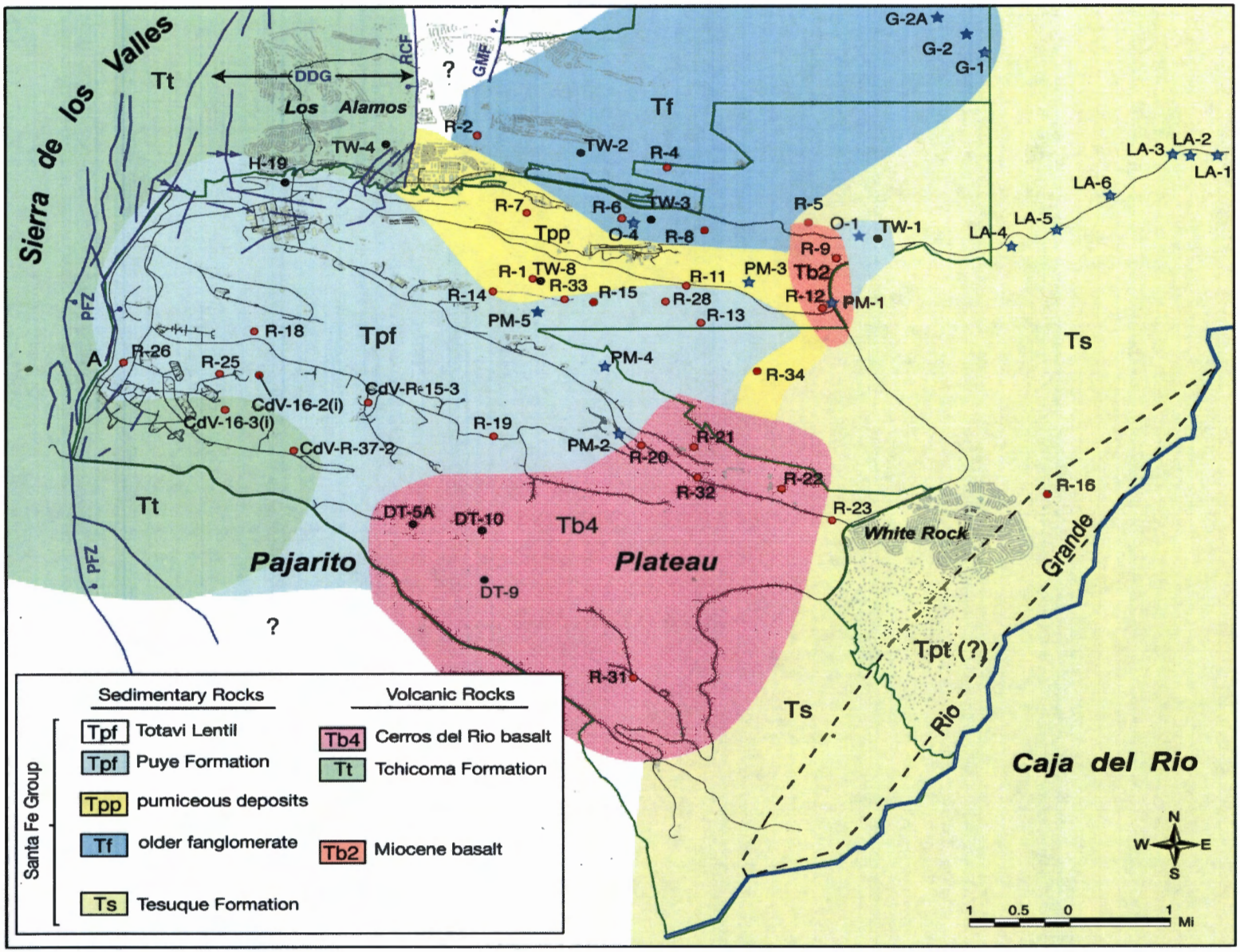
- June Fabryka-Martin, EES-6
- Bruce Gallaher, ENV-WQH
- Ioanna Anghel, NWIS/TA-54E
- Jean Dewart, ENV-PPP

Outline

- Introduction
- The problem with groundwater chemistry data
- Well screen analysis
- Groundwater data adequacy project


Sierra de los Valles
Tt
DDG
RCF
GMF
?
Los Alamos
Tf
G-2A
G-2
G-1
R-2
TW-4
H-19
TW-2
R-4
LA-3
LA-2
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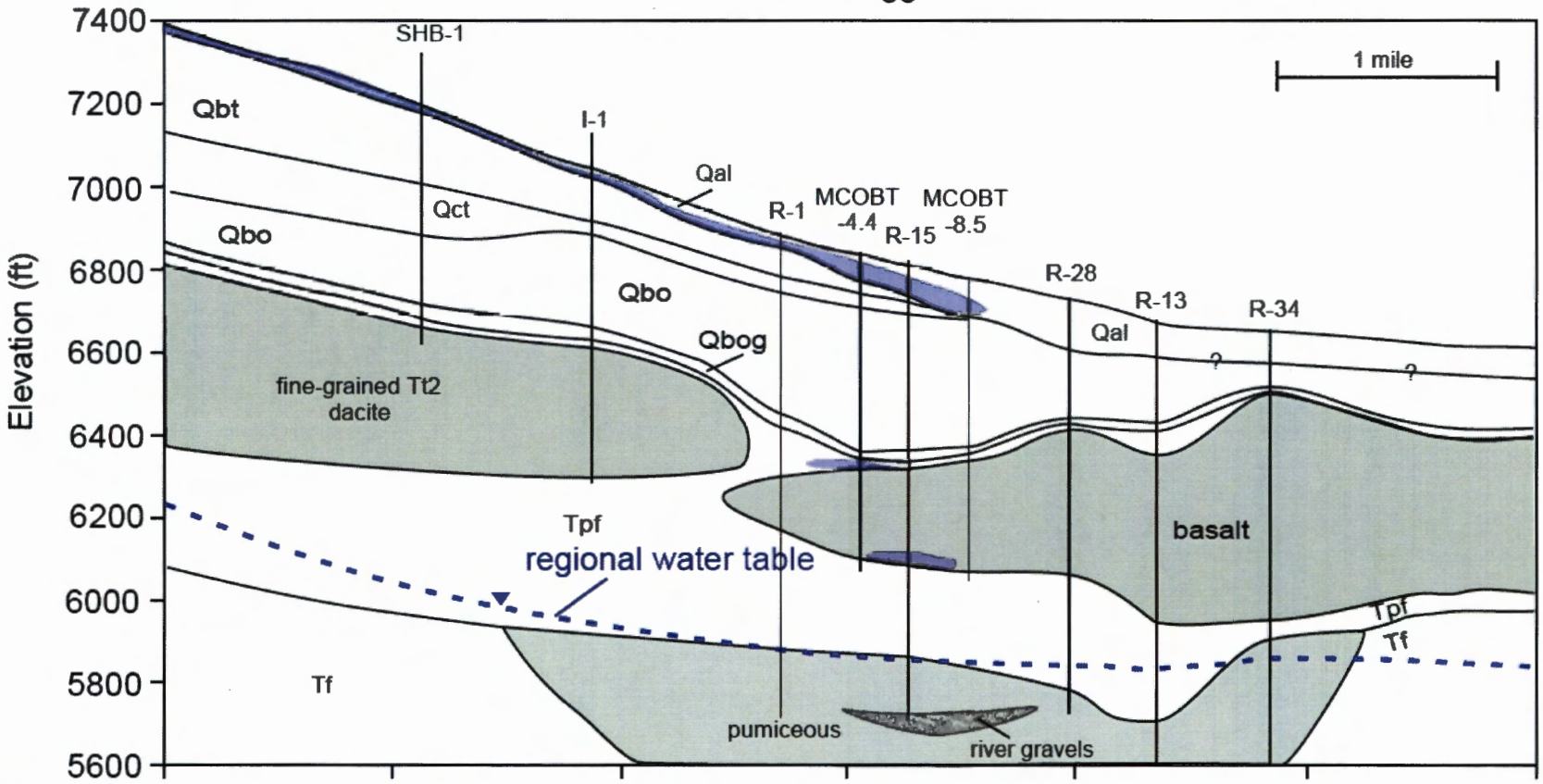
LA-6
LA-5
LA-4
R-7
R-6
TW-3
R-5
O-1
TW-1
Tpp
O-4
R-8
R-9
R-1
TW-8
R-33
R-15
R-11
PM-3
Tb2
R-14
R-28
R-12
PM-1
PM-5
R-13
R-18
Tpf
Ts
PZF
A
R-26
R-25
PM-4
R-34
CdV-R-15-3
CdV-16-2(i)
CdV-16-3(i)
R-19
PM-2
R-21
R-20
CdV-R-37-2
R-22
R-32
R-16
Tt
DT-5A
DT-10
Tb4
R-23
White Rock
Grande
Pajarito
Plateau
DT-9
?
Tpt (?)
R-31
Ts
Rio
Caja del Rio
Sedimentary Rocks
Volcanic Rocks
Santa Fe Group
Tpf Totavi Lentil
Tpf Puye Formation
Tpp pumiceous deposits
Tf older fanglomerate
Ts Tesuque Formation
Tb4 Cerros del Rio basalt
Tt Tchicoma Formation
Tb2 Miocene basalt
N
W
E
S
1 0.5 0 1 Mi

W

Hydrogeologic Cross-Section of Mortandad Canyon

E

10x vertical exaggeration



Introduction

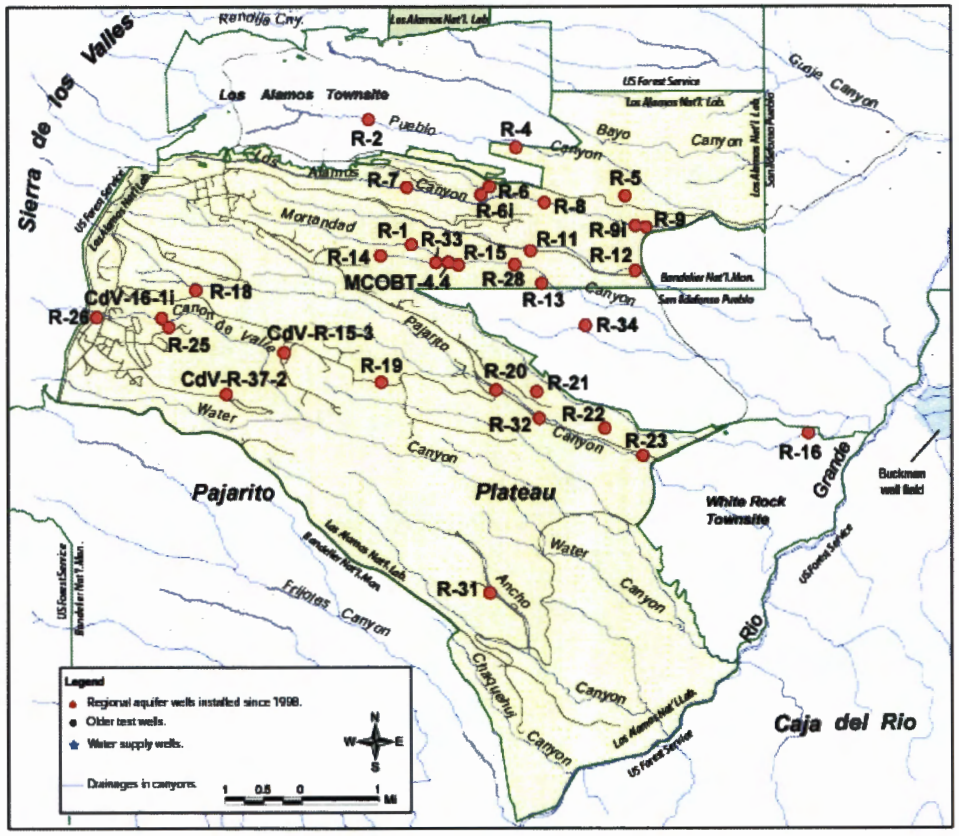
- Some of the wells completed under the Hydro-geologic Workplan do not provide reliable groundwater quality data.
- Analysis of the impacts of residual drilling fluids on the ability of the groundwater wells in the regional aquifer to provide representative measurements of contaminants completed (LA-UR-05-8615)
- NMED requested a well rehabilitation plan.
- Since November 2005 LANL has been developing a groundwater data adequacy plan, to ensure capability of providing reliable monitoring data. The plan includes:
  - Pilot well redevelopment
  - Plan for well rehabilitation and replacement
  - Work to complete the data qualification process
  - Chemical/hydrology testing/modeling to address some issues raised by EPA

Concern about Impacts of Residual Drilling Fluids on Water Chemistry

- Is water quality from the regional characterization wells reliable and representative of pre-drilling groundwater?

Questions raised by:

- LANL
- Citizens Advisory Board
- DOE
- Inspector General



Motivation and Purpose of Well Screen Assessment (LA-UR-05-8615)

- Evaluate whether the screens are producing data that are reliable and representative of the intermediate groundwater and regional aquifer
- Provide a summary: # of screens that are "good" (i.e., producing reliable data) and # of screens that are potentially impacted
- Of the impacted screens, identify those that appear to be cleaning up over time and those that are the most problematic
- Establish technical basis for real-time screening of new data for reliability

Assessment Objectives and Scope

- Objectives
  - For each screen, identify water quality data that are/are not reliable or representative
  - Use an assessment process that is transparent, reproducible, and robust
- Assessment scope (64 screens in 33 wells)
  - Characterization wells installed for Hydrogeologic Workplan
  - Screens in regional aquifer and intermediate perched zones
  - Current conditions (snapshot)
  - Focused on water chemistry, not physical indicators
  - Bentonite drilling mud (12 screens in 9 wells)
  - Organic drilling fluids (all 64 screens)

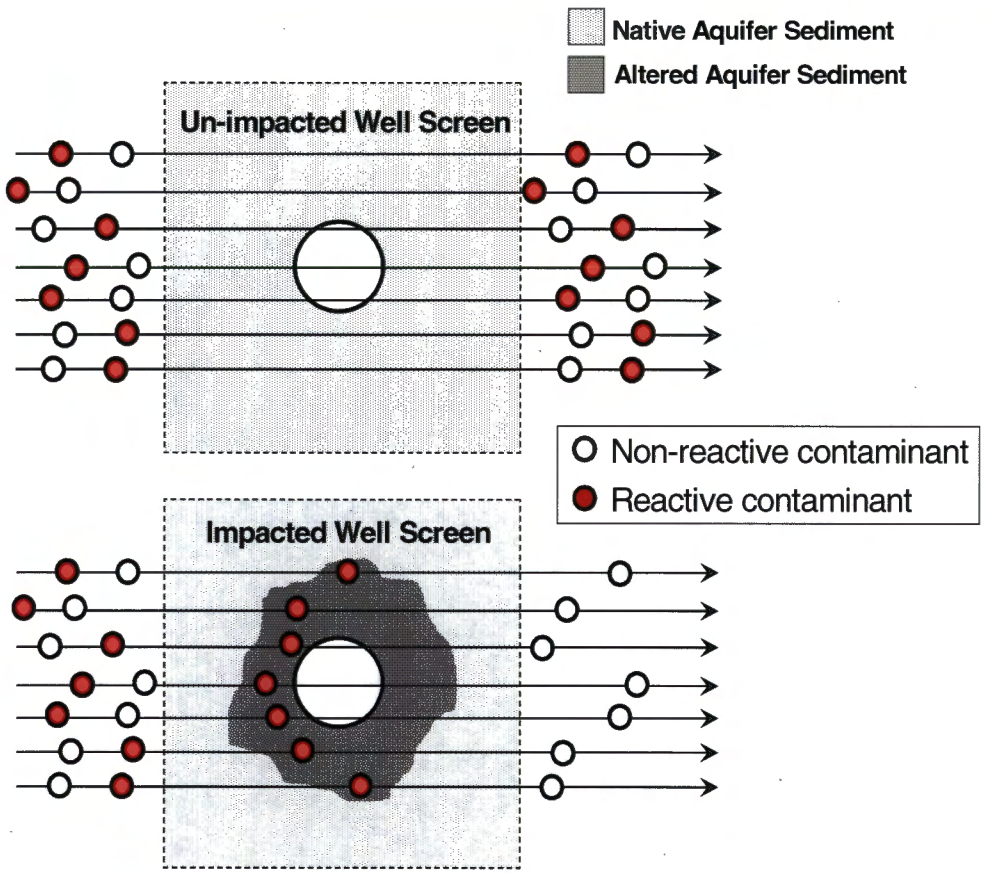
Assessment Approach

- Define conceptual models for effects of residual drilling fluid on water quality in screen intervals
- Select geochemical indicators for these effects
- Assess water samples against geochemical criteria
- Flag analytes that are not reliable or representative based on geochemical criteria
- Assign rating to each screen to indicate prognosis for providing reliable data indicative of pre-drilling conditions.
- Independent statistical method – principal component analysis to compare screens of wells drilled with fluids to non-fluid impacted groundwater data (e.g., springs, water supply wells)

Key Assumptions and Bounding Conditions

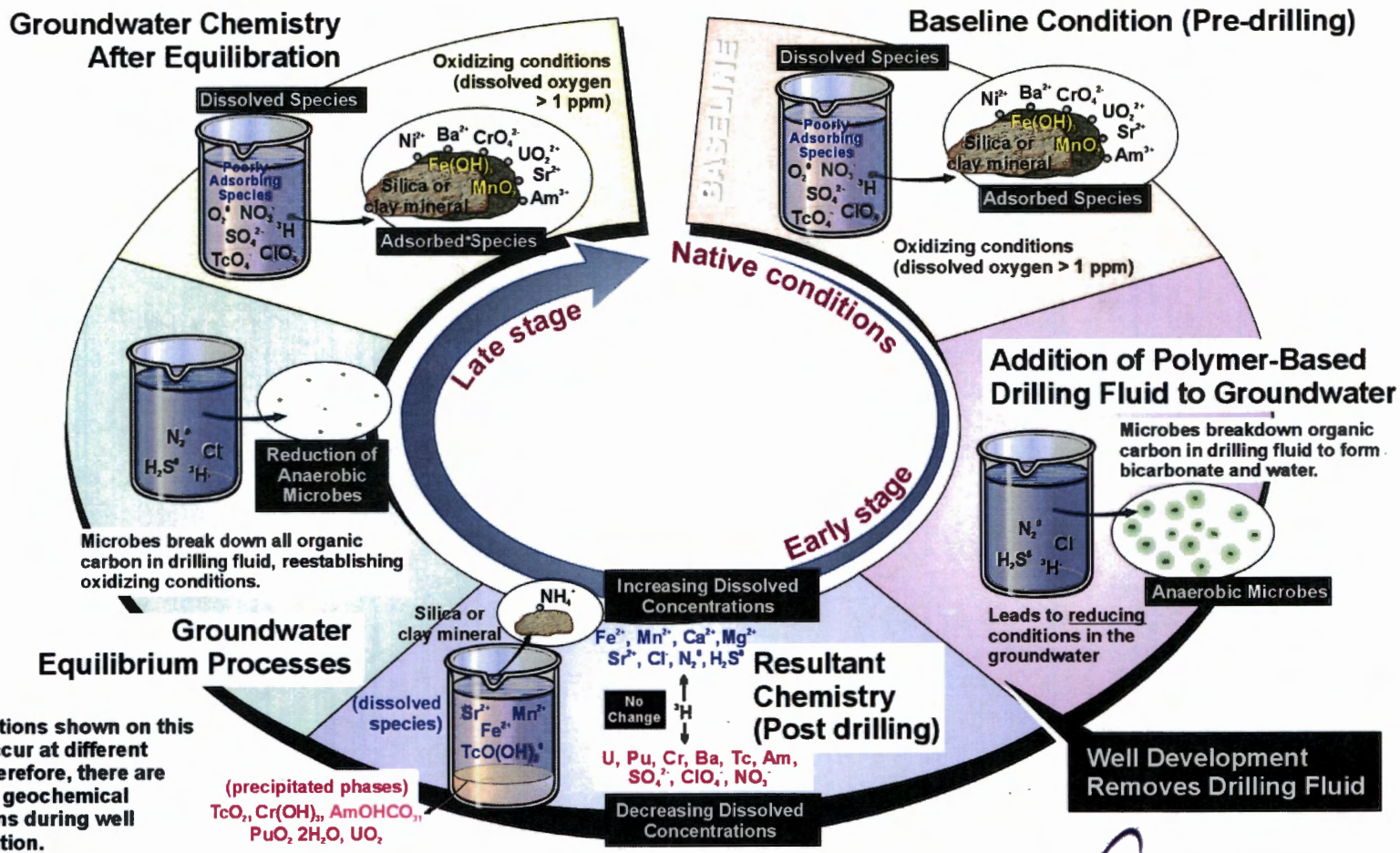
- Background geochemistry provides a systematic "baseline" against which to evaluate analytical results
- Review of the 3 most recent characterization/surveillance sample results for a screen is sufficient to yield an analysis outcome with a high level of confidence
- Bounded by consideration of use of materials in drilling, not in well construction
- Report does NOT make predictions for when a screen may clean up or methods of cleaning up screens – strictly a snapshot

Differential Transport Behavior of Analytes within Zone Impacted by Residual Drilling Fluids



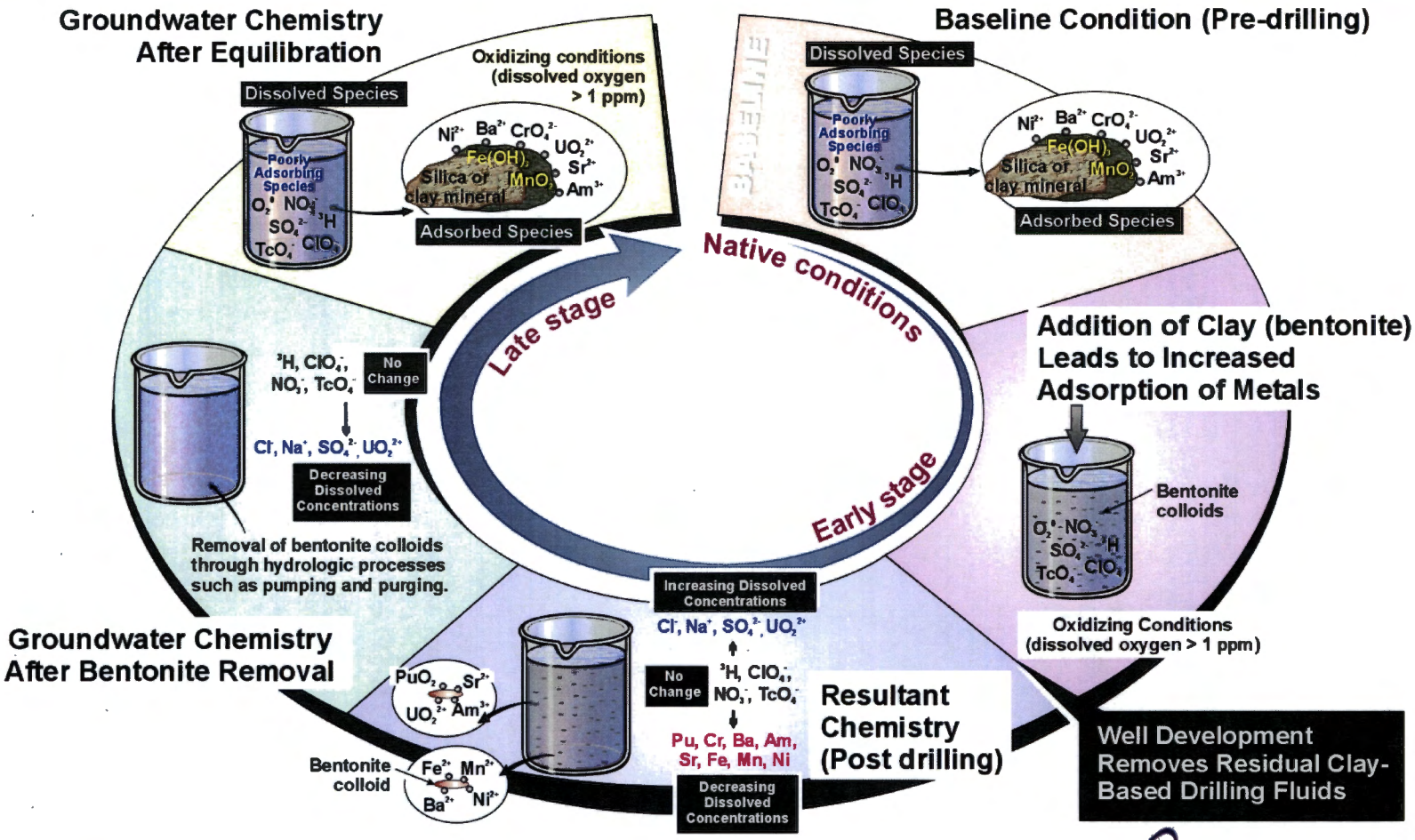
Source: Ford, Acree, Ross 2005

Effects of Polymer-Based Drilling Fluids on Groundwater Chemistry



Note:
The reactions shown on this figure occur at different rates; therefore, there are different geochemical conditions during well equilibration.

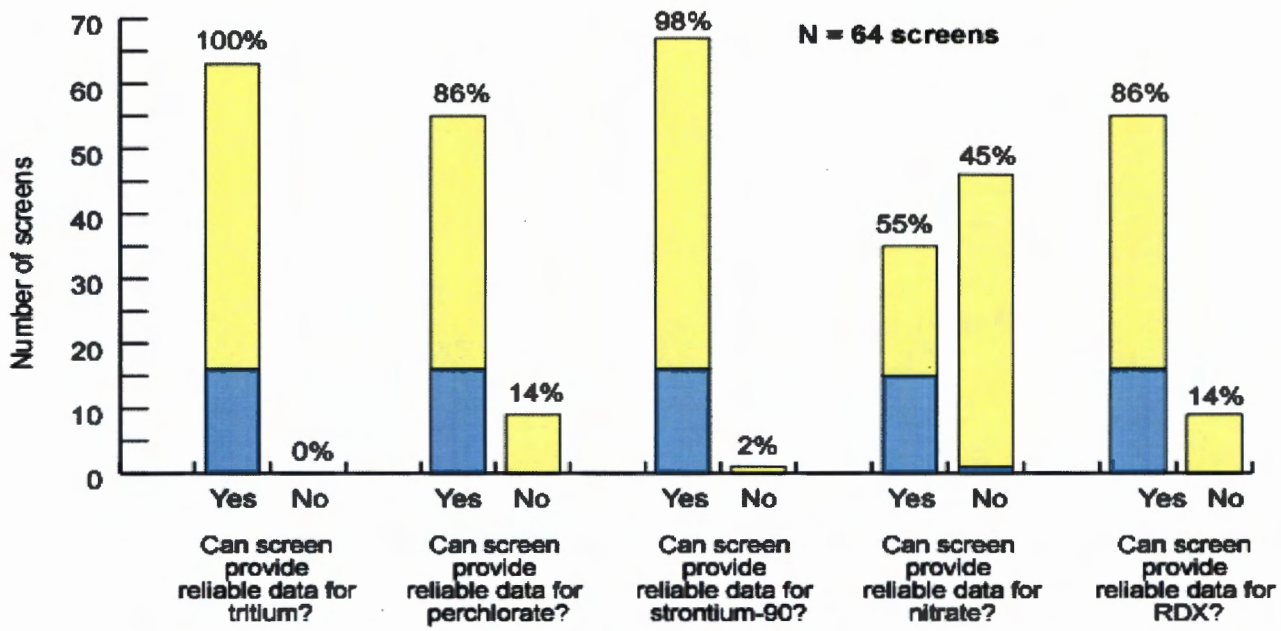
Effects of Bentonite-Based Drilling Fluids on Groundwater Chemistry



Effects of Residual Drilling Fluids on Water Chemistry in Screen Intervals

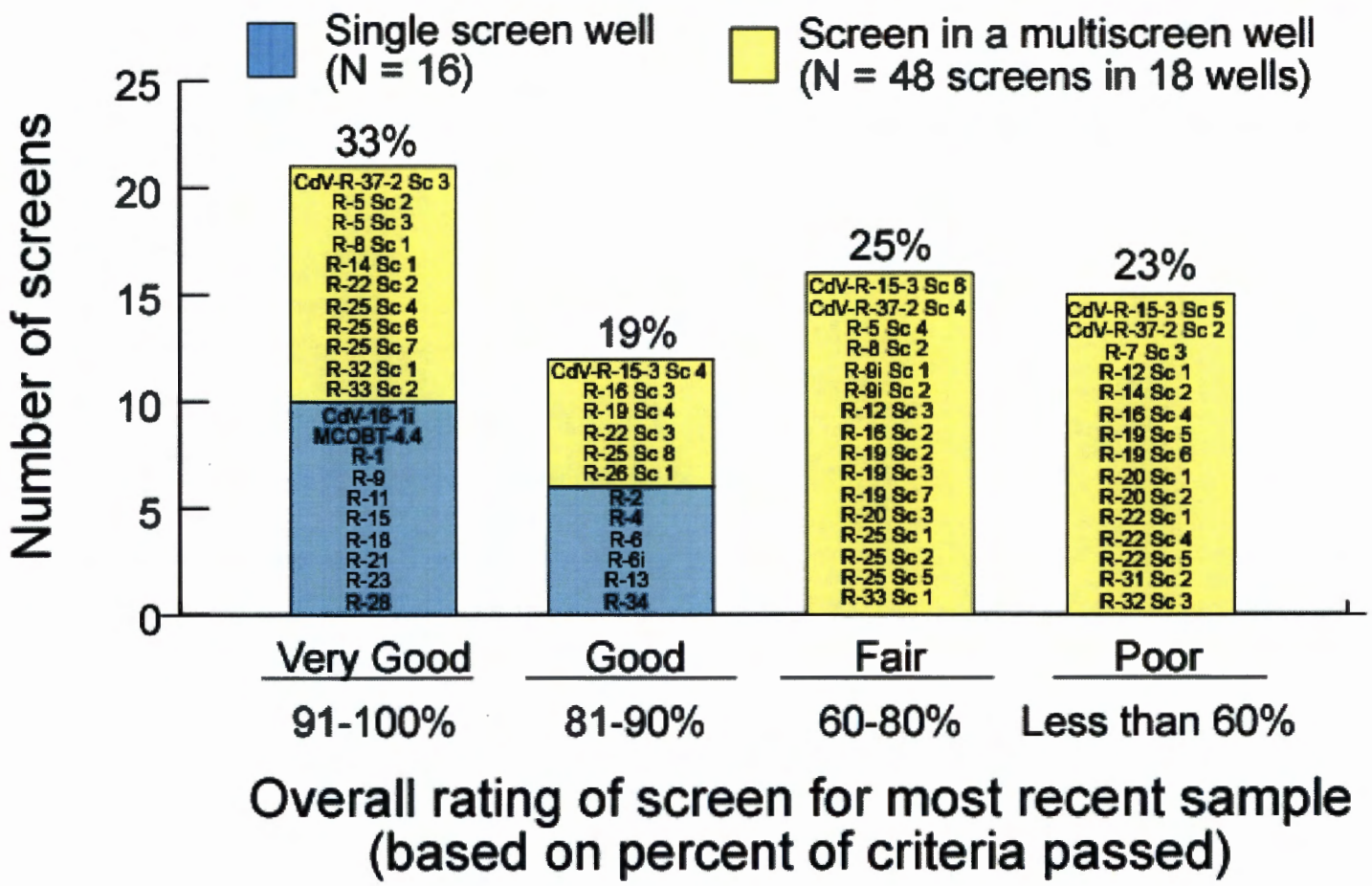
	Geochemical indicators
• Effects of bentonite drilling mud	
– Source of inorganic salts	Na, SO_4, B, U
– Sink for many metals, radionuclides, and organic species	Sr, U, Zn Note: No suitable analogue exists for very strongly sorbing species
• Effects of organic drilling fluids	
– Organic carbon in residual drilling fluids provides food for microbial growth	TOC, TKN, NH_3, acetone
– Redox-sensitive species are reduced	NO_3, SO_4, Fe, Mn
– Fe/Mn (oxy)hydroxide minerals are dissolved, and release adsorbed metals	Field parameters: pH, carbonate alkalinity, sulfide, dissolved oxygen, oxidation reduction potential

Results



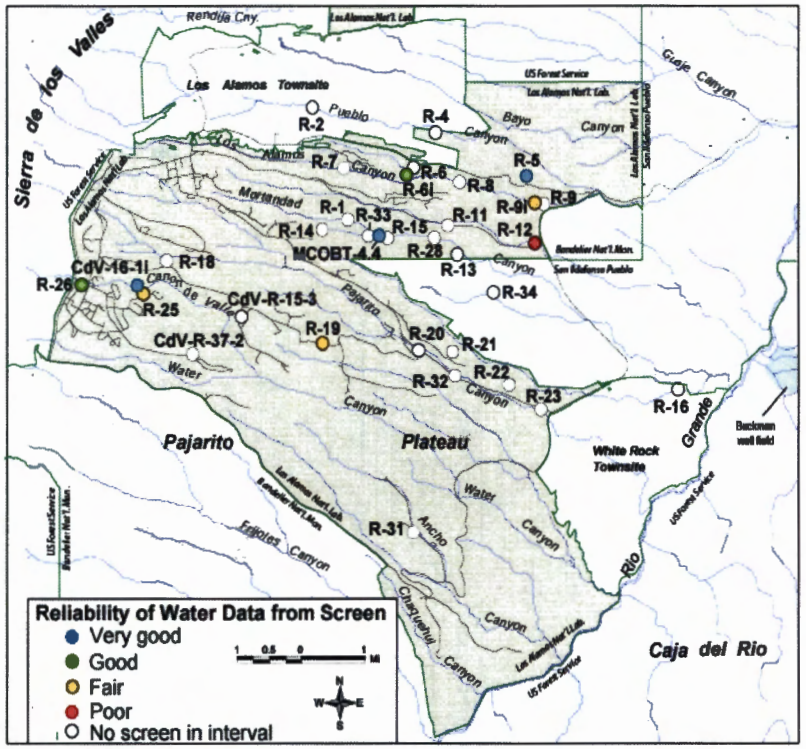
Based on Less Stringent and More Reliable Tier 2.2 Indicators:
(1) excludes field-based Tier 2 indicators (pH, alkalinity, ORP, sulfide, dissolved oxygen,
(2) defines the Tier 2.2-2 acceptance criterion for absence of sulfate reducing conditions as sulfate > 0.5 mg/L, and (3) assumes RDX is stable except under sulfate-reducing condtions.

Overall Ratings of Screen Intervals for Effects of Residual Drilling Fluids

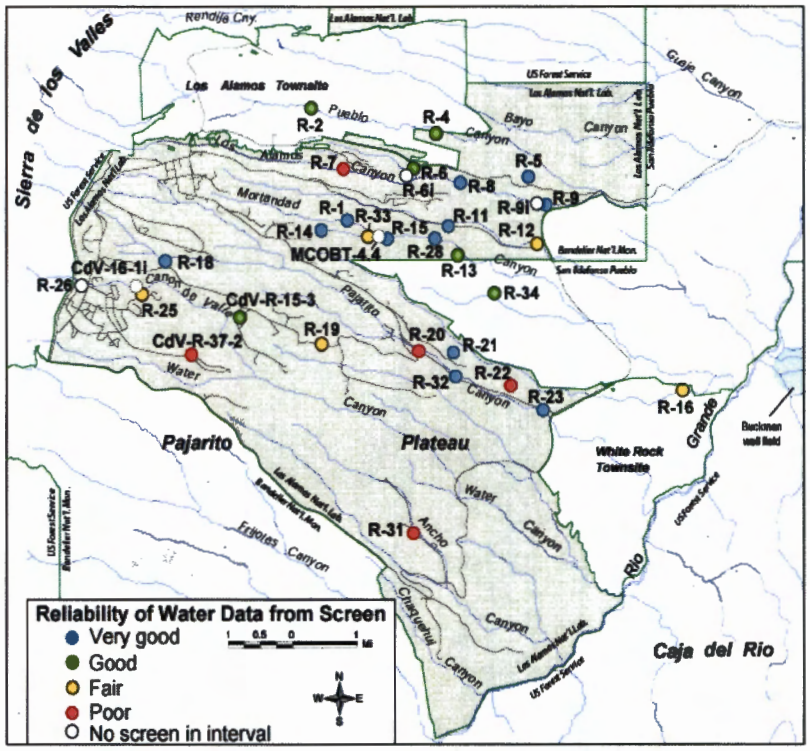


Rating of Wells - Effects of Residual Drilling Fluids

Perched intermediate zone
(N = 9 wells)



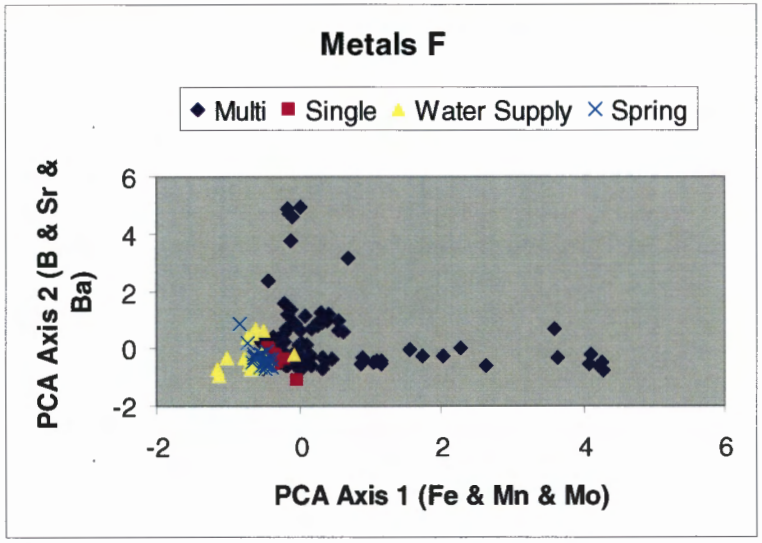
Regional aquifer at the water table
(N = 28 wells)



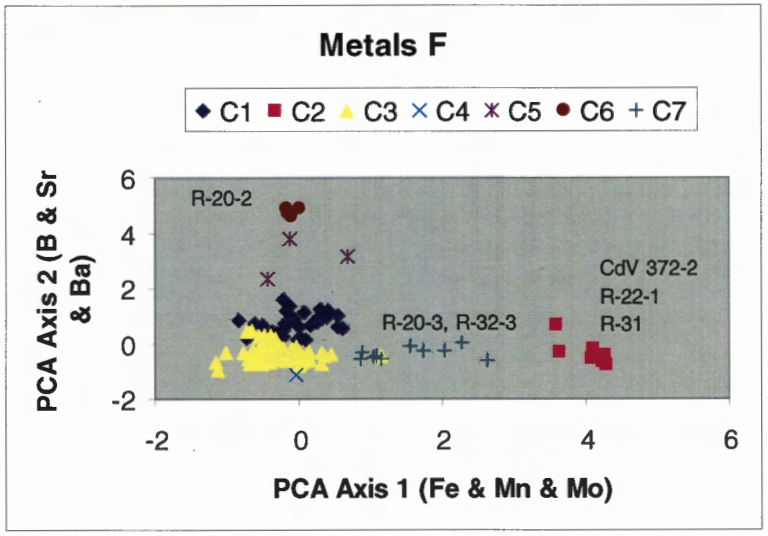
Independent Statistical Analysis

- Used Multivariate Statistical Methods
  - Principal Component Analysis (PCA)
  - Cluster Analysis (CA)
  - Nine metals, nine major ions, filtered and non-filtered data
- Unique chemical signature for each sample
- Compare R-wells against controls
  - White Rock Canyon springs (16)
  - LA County Municipal Supply Wells (10)
  - LANL Test Wells (5)
- Statistical identification of unusual signature(s)

Example Result—Filtered Metals Data



Water supply wells consistent with springs, indicating minimal or no residual drilling impacts. Many single completion R-wells consistent with springs and supply wells.



Cluster Interpretation:

C3 = Consistent with WRC springs or existing wells
C1 = Possible or slight impacts
C5, C7 = Moderate impacts
C2, C4, C6 = Significant impacts

Summary of Screen Assessment

- Overall, 33% of the well screens provide very good chemical data
- The most common drilling artifact is the presence of reducing conditions
- Single-screen wells show the least impact from residual drilling fluids
  - All 16 single-screen wells are rated as Good to Very Good for reliability of water chemistry data.
- The majority of the screens in multi-screen wells are impacted by residual drilling fluids
  - However, nearly all multi-screen wells have at least one screen interval rated as good or very good

Further

- Geochemical and statistical analyses map into same categories
- The statistical analysis does not depend upon background concentrations – thus lending strength to the geochemical model
- No suitable analog was found to represent highly sorbing radionuclides – americium and plutonium
- Other lines of evidence will have to be employed to determine representativeness of data from these wells for highly sorbing radionuclides.

Response to the Report

- EPA
  - Revise conceptual model for mineral alteration products in reducing environment adjacent to screen
  - Large uncertainty in assessment outcomes due to comparison against uncertain background conditions
  - Unreliability of sulfate data due to inappropriate sample collection and preservation
  - Proposed push-pull tracer tests to test for effects on sorbing species
  - Proposed flowmeter surveys to characterize vertical flow fields in wells with long screens
- NMED DOE Oversight Bureau
  - Use of field-derived parameters controversial
  - Assessment of past data from screen intervals that are currently dry
  - Expansion of data set used to define background chemistry
  - Proposed tracer tests to evaluate flow-through rates in multi-screen wells

Next Steps

- The screen assessment report establishes a technically defensible foundation for several follow-on tasks:
  - Selection and prioritization of screens for rehabilitation or other corrective action
  - Revision of sample collection protocols
  - Assignment of data qualifiers in WQDB for past, present, and future water-quality data
  - Establishment of additional data quality objectives for monitoring network

Groundwater Data Adequacy Plan - I

Activity	Well Directed	Other Lines of Evidence	Data Qualification	Support Tasks
Well Rehab/Redrill				
Pilot Test	X			
Well Condition Review	X			
Well Rehabilitation	X			
Testing				
Hydrologic Test of Skin Effects		X		
Aquifer Mineralogy		X		

Groundwater Data Adequacy Plan - II

Activity	Well Directed	Other Lines of Evidence	Data Qualification	Support Tasks
Modeling				
Speciation and redox		X		
Transport		X		
"What if" models		X		
Field Data Collection				
Compare field sampling techniques				X
Evaluate and select methods of sulfide analysis				X

Groundwater Data Adequacy Plan - III

Activity	Well Directed	Other Lines of Evidence	Data Qualification	Support Tasks
Data Qualification				
Qualification scheme			X	
Internal Review of scheme and process			X	
NMED review			X	
Ongoing data qual			X	
Historical data qual			X	

Pilot Study

- Pilot will test re-development of existing wells – less expensive than re-drilling
  - Pull the Westbay sampling system
  - Redevelop the well
  - Sample during redevelopment to determine effectiveness
  - Reinstall the Westbay – sample the well, assess the screened intervals
- Why will this re-development work?
  - Each screen will be packed off for redevelopment
  - Each screen will be developed during well construction and after well completion
  - Improved surging tools will be used
- An alternative sampling system is being tested in R-10 that allows purging before sampling in a multiple-screen well

Testing

- Hydrologic testing of the aquifer to determine change in transmissivity
- Literature quantification of effect of bentonite on trace element and contaminant mobility
- Analysis of reactive mineral assemblages at selected wells

Modeling

- Speciation modeling to quantify geochemical processes controlling groundwater representativeness at specific wells
- Kinetic modeling to quantify rates of reaction
- Application of site-scale flow and transport model to estimate movement of constituents from specific sources

Data Collection Methods

- Determine whether field parameters can be used quantitatively
- Improve Westbay sampling methods to purge atmospheric oxygen
- Evaluate field and laboratory methods of sulfide analysis

Data Qualification

- Develop qualification scheme for water quality data
- Discuss with NMED
- Automate the qualification process
- Apply process to newly collected data
- Apply process to all historical data
- Update well screen assessment report

Summary

- Data adequacy has a positive feedback with monitoring and is a function of monitoring data objectives
- Data adequacy determination relies on multiple lines of evidence
- Implementation of data adequacy plan will encompass FY06 – FY08
- Implementation may include revision based on insights from testing and modeling
- Communication with stakeholders will take place frequently during implementation

Data Adequacy Questions for NAS

- Is our approach to determining data adequacy *effective* and *practical*?
- Does our plan incorporate best practices for well rehabilitation?
- Is our conceptual approach to determining data adequacy appropriate and sufficiently comprehensive?

Groundwater Monitoring at Los Alamos National Laboratory

National Academy of Science Review

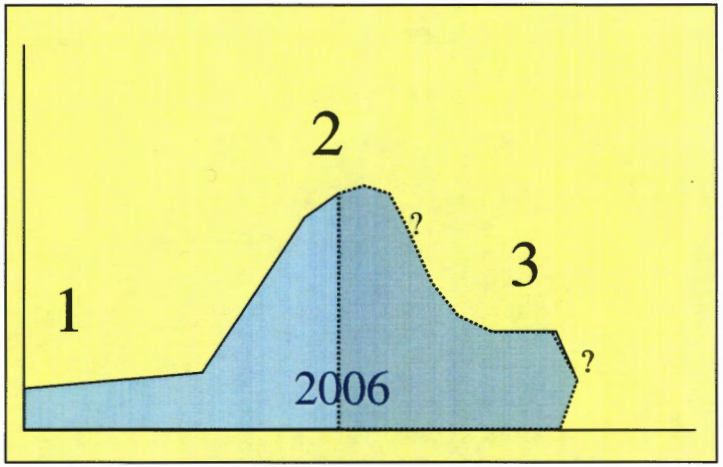
Presented by: ***Armand Groffman***

March 2006

Groundwater Monitoring Timeline

1. Groundwater quality monitoring of water supply wells, observation wells, and springs (USGS). Work focuses on canyon Bottoms.

2. Hydrogeologic work plan installed 33 intermediate and regional wells for characterization Purposes.



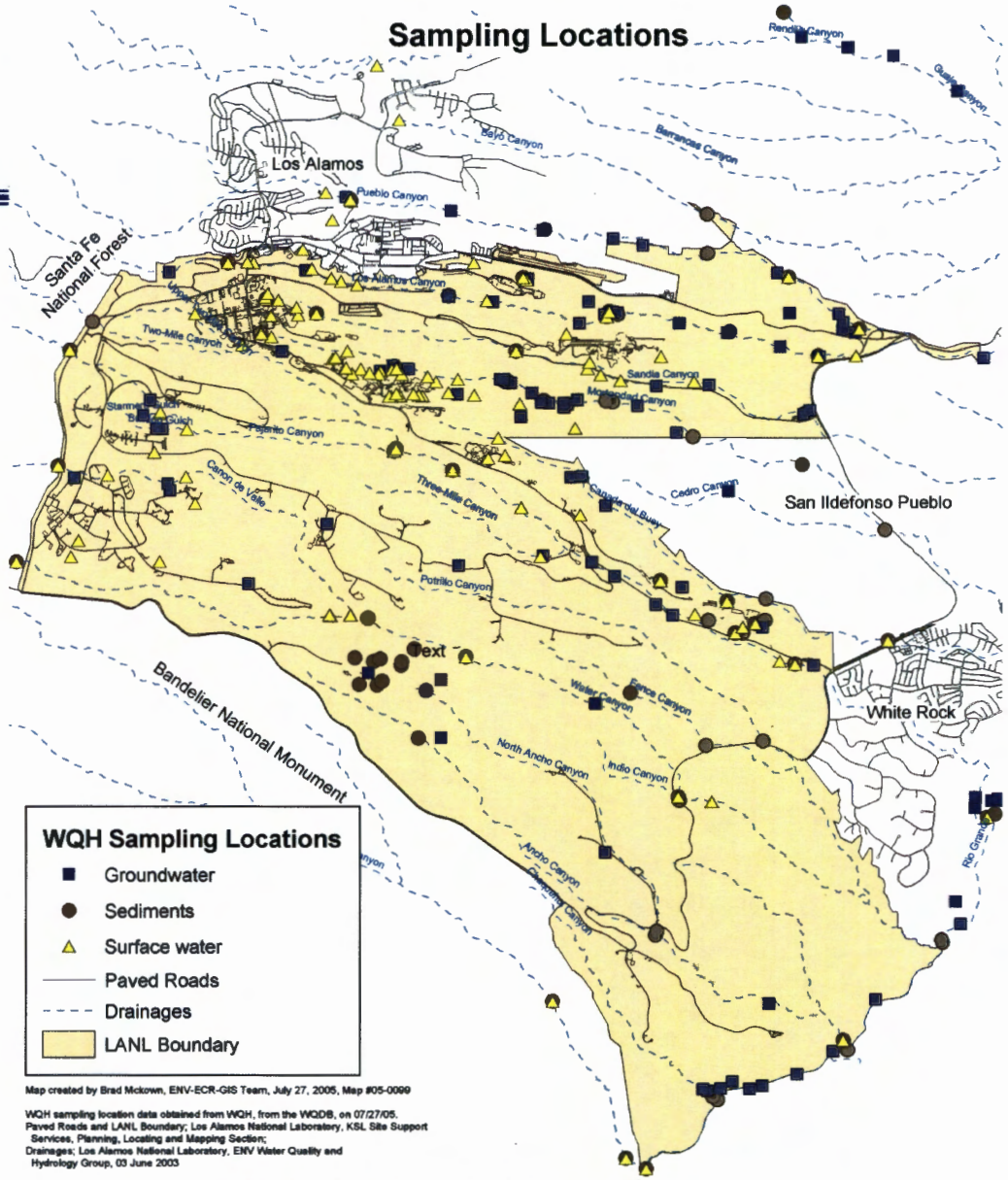
3. Goal is to transition to long term groundwater monitoring in all watersheds throughout the Laboratory

Interim monitoring starts in 2006

1949 | 1997-2006 | 2015

Potential Groundwater Monitoring Locations

- Alluvial 201 wells
  shallow wells in canyon bottoms
- Intermediate 33 wells
  access perched groundwater
- Regional 71 wells
  single & multiple screen wells
- Springs 180 locations
  receptor locations



Map created by Brad Mckown, ENV-ECR-GIS Team, July 27, 2005, Map #05-0099

WQH sampling location data obtained from WQH, from the WQDB, on 07/27/05.
Paved Roads and LANL Boundary; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section;
Drainages; Los Alamos National Laboratory, ENV Water Quality and Hydrology Group, 03 June 2003

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Groundwater Regulatory Requirements

DOE Environmental Protection Programs

•Surveillance groundwater monitoring within Laboratory boundaries and at offsite locations (Los Alamos/Santa Fe Counties and San Ildefonso).

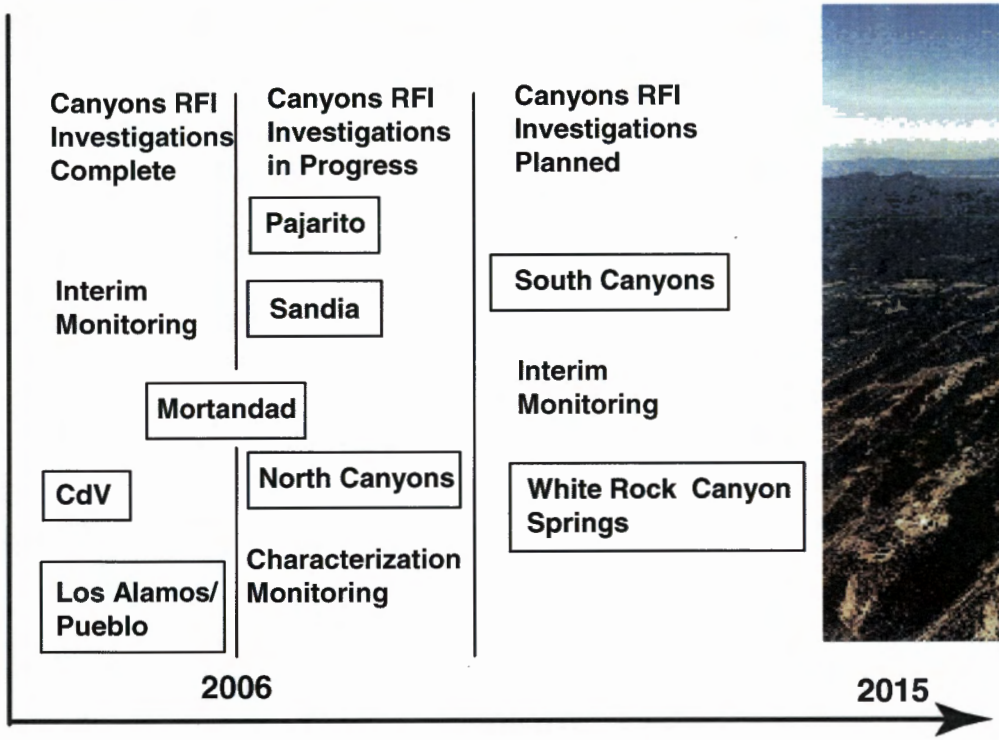
Additional Monitoring:

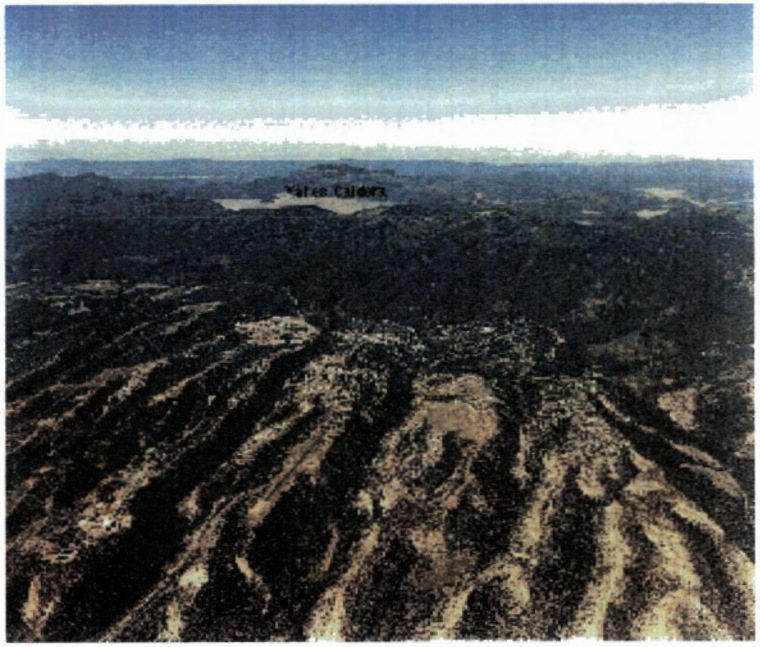
•New Mexico Environment Department Consent Order
•New Mexico Water Quality Control Commission (Groundwater Discharge)
•Hazardous Waste Facility Permit (RCRA Monitoring)

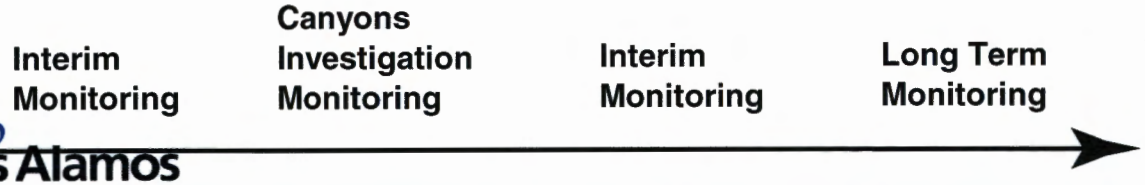
In the future, facility-wide groundwater monitoring will be described in an integrated document and updated annually.

LANL Groundwater Monitoring Strategy

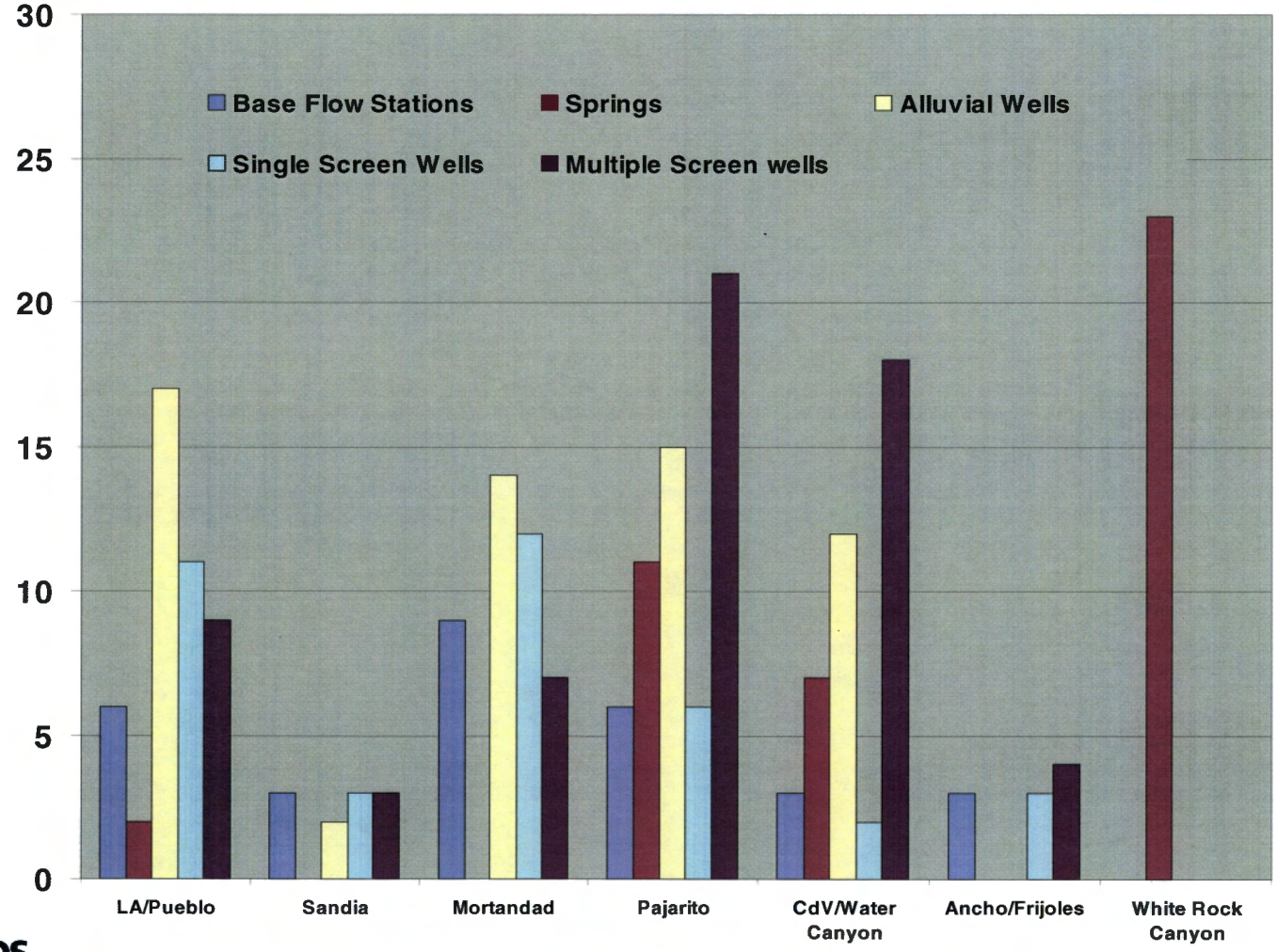
Current (2006) Watershed Status and Groundwater Monitoring Modes







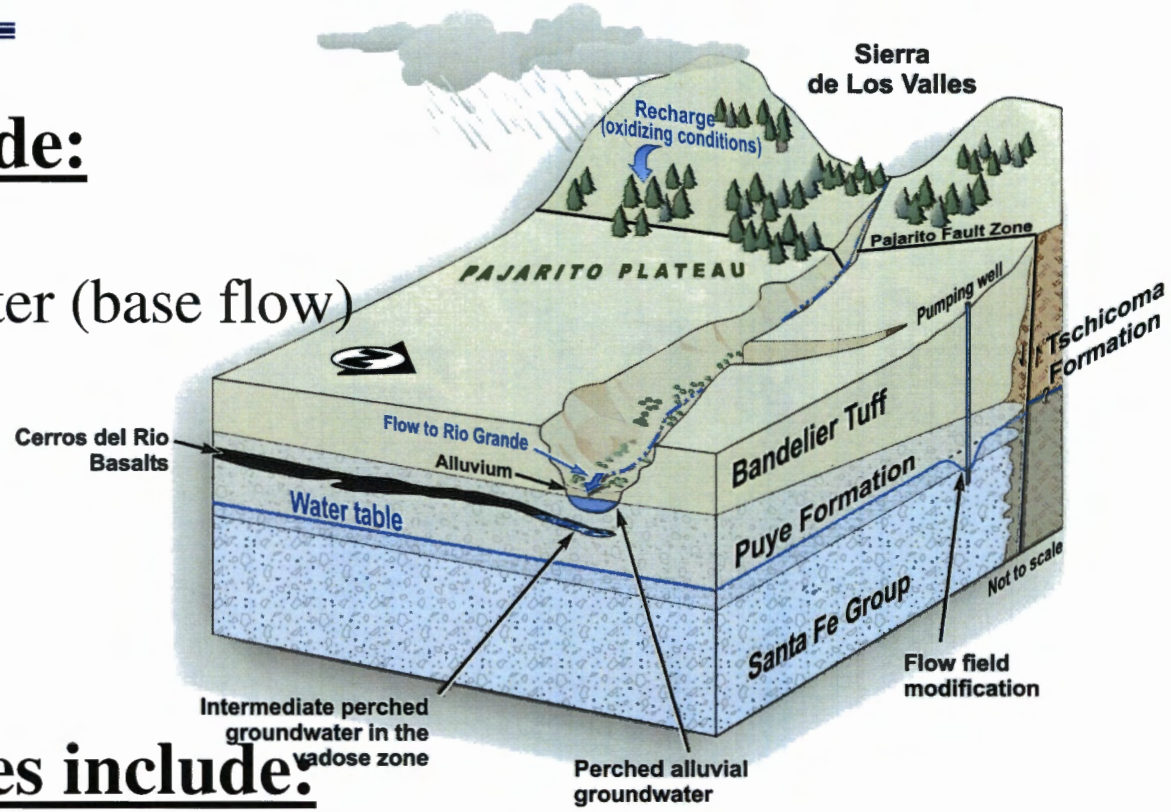
FY06 Watershed Monitoring Locations at LANL



Monitoring Media

Media types include:

- *Groundwater*
- Persistent surface water (base flow)
- Springs



Groundwater types include:

- Shallow alluvial groundwater in canyon bottoms
- Intermediate groundwater in localized zones
- Regional groundwater plateau wide

Typical Analytical Suites

Analytical suites include:

Radionuclides (gamma-spec [Co, Cs, Np], alpha-spec [Pu, Am, U), H-3 [LLEE, LSC], TIMS)

General chemistry (cations/anions, perchlorate)

Metals (23 TAL metals & cyanide)

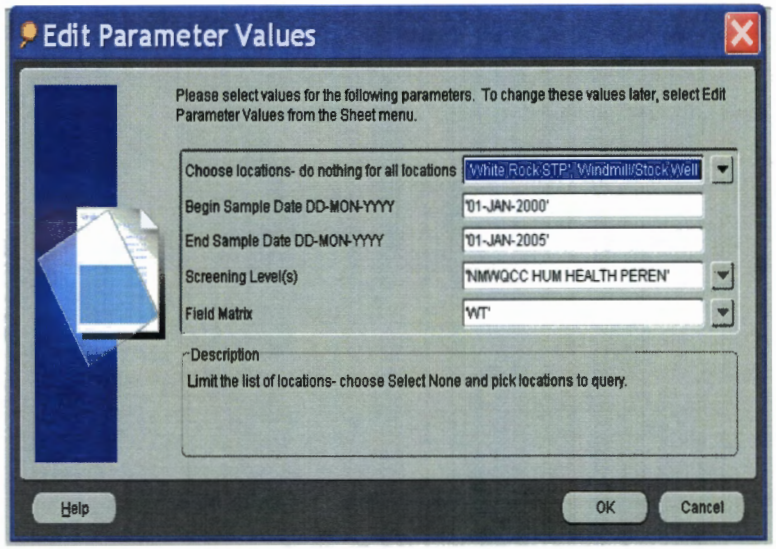
Organics (VOA/SVOA)

Field parameters (pH, ORP, DO, T, EC, turbidity, etc)

Public Access to Environmental Water Data

Water Quality Database

http://wqdbworld.lanl.gov/discoverer



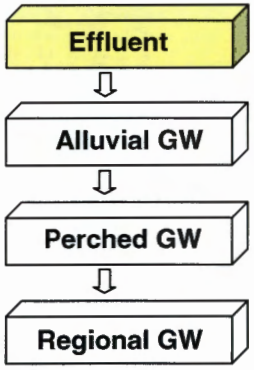
Write your own queries

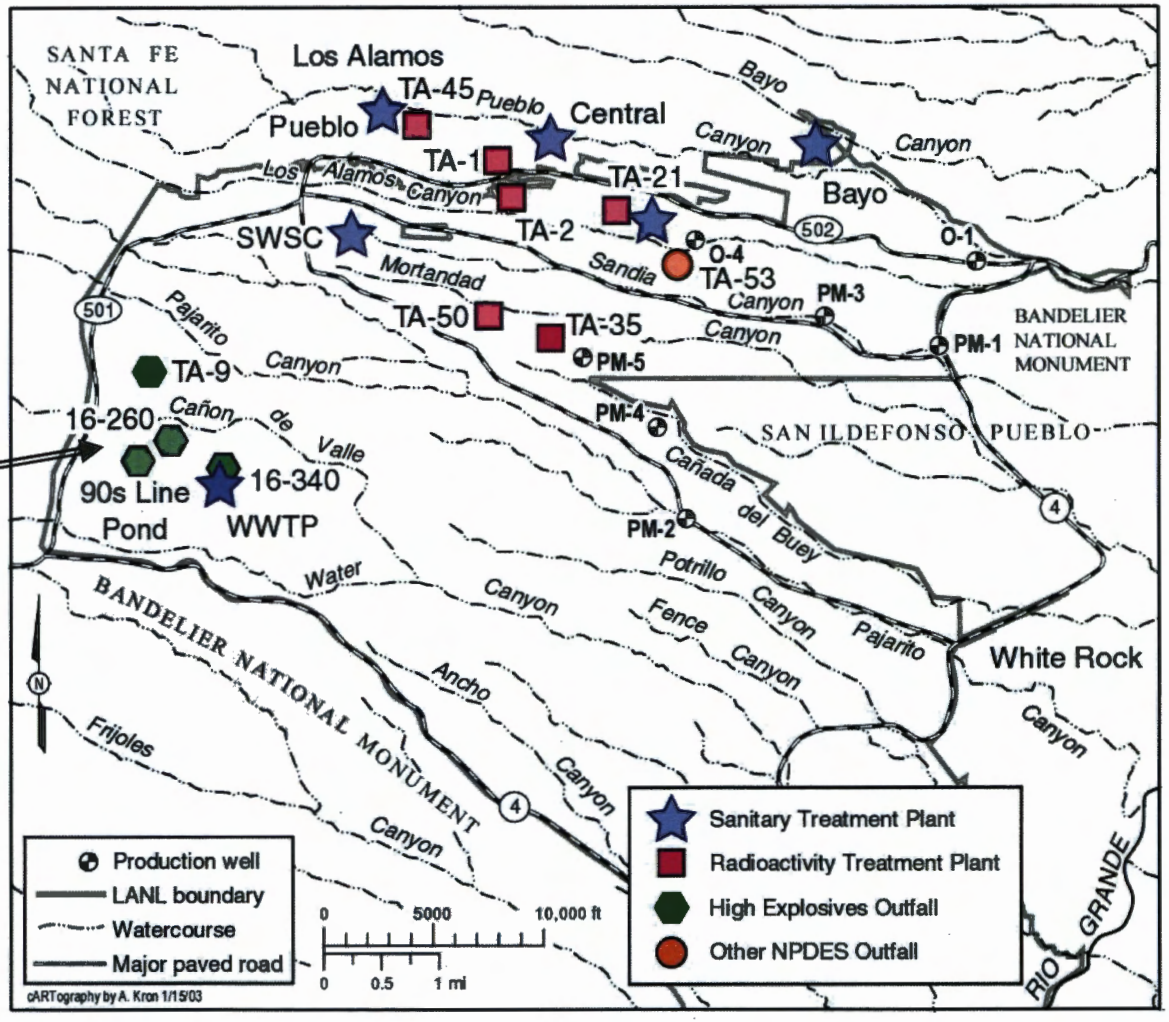
Screen data against standards

DOE Focus on Monitoring: Does the current monitoring Approach effectively identify contaminants that may migrate at unacceptable levels to public receptor locations?

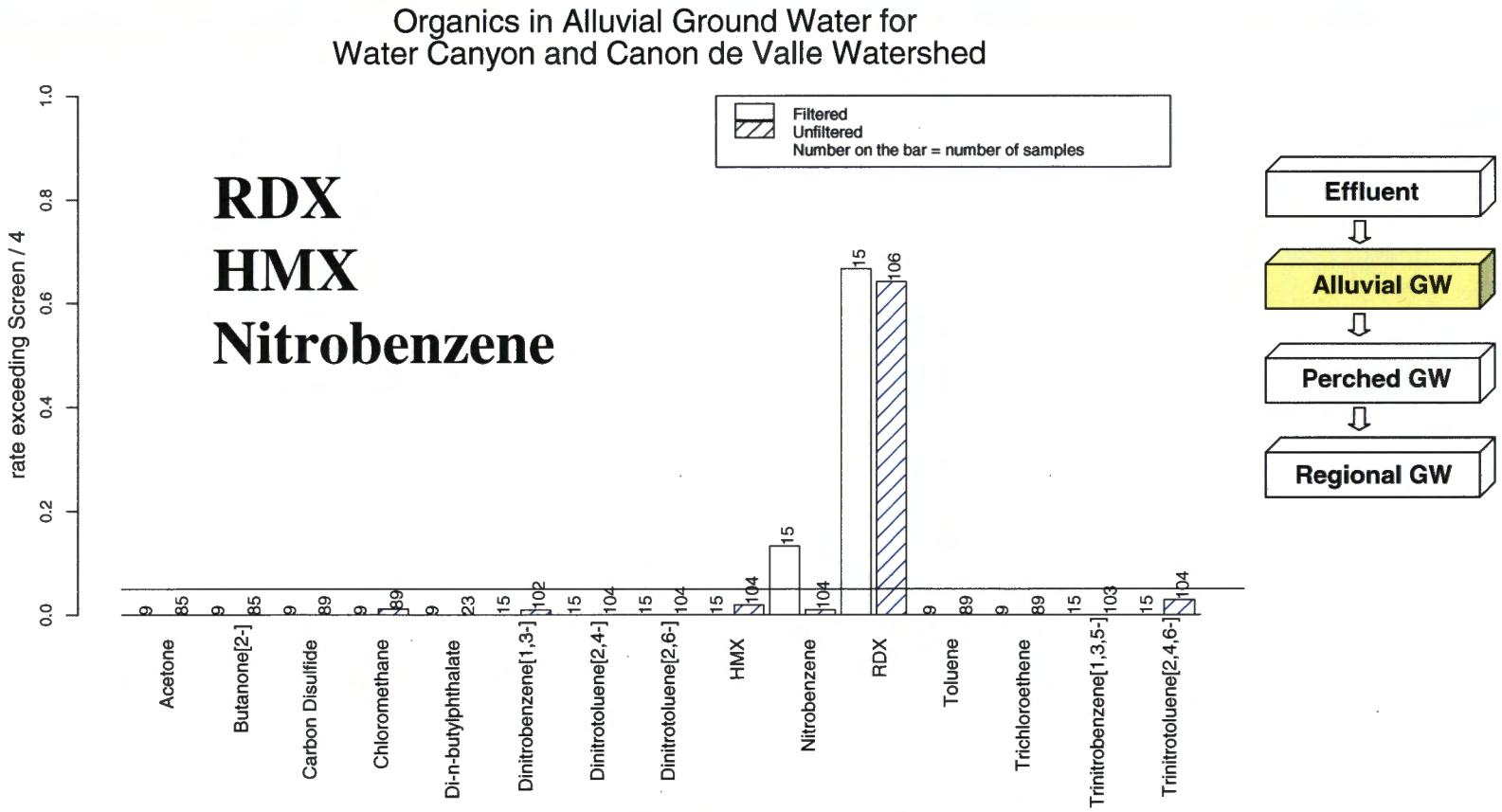
Groundwater contaminants reflect the type of effluent source [HE, HMX, RDX, Ba]

TA-16 HE outfall



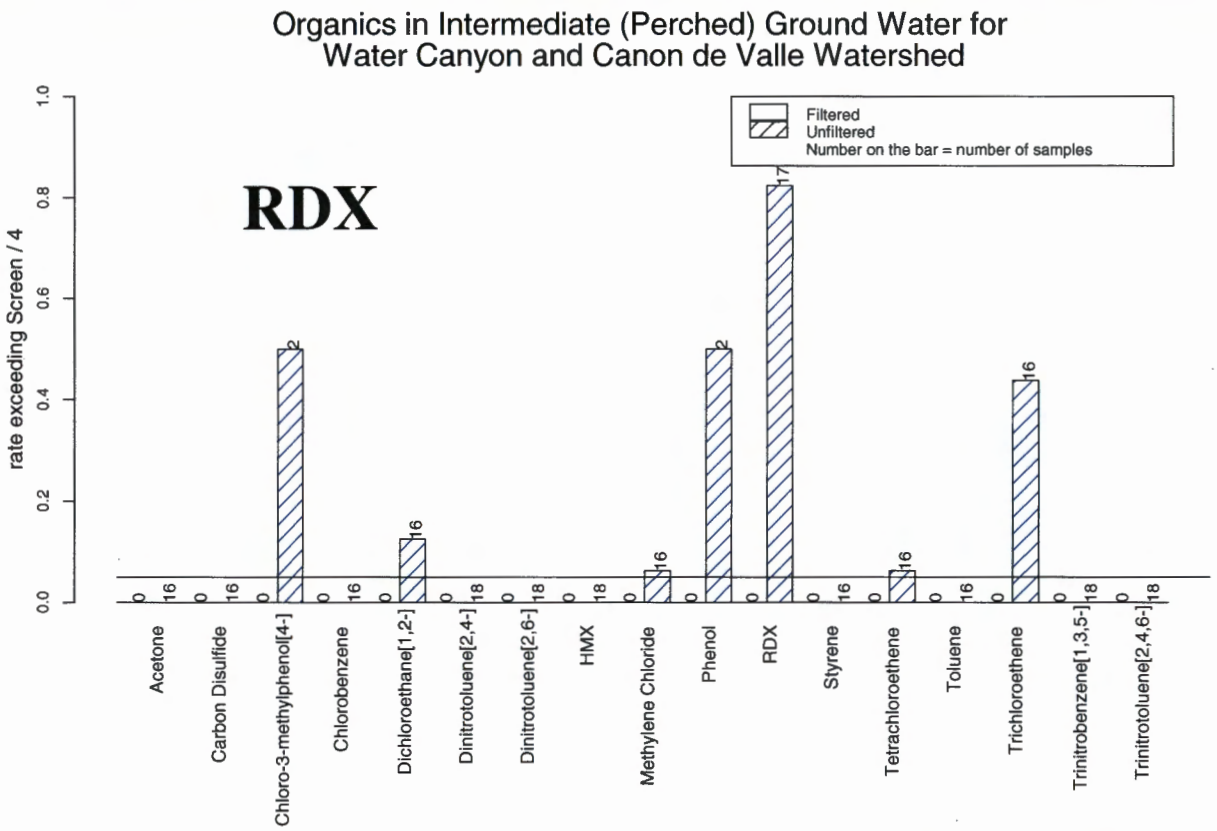


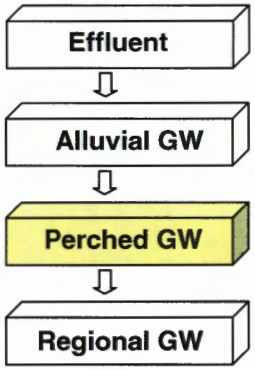
DOE Focus on Monitoring: Does the current monitoring Approach effectively identify contaminants that may migrate at unacceptable levels to public receptor locations?



Contaminants are identified through a data screening process

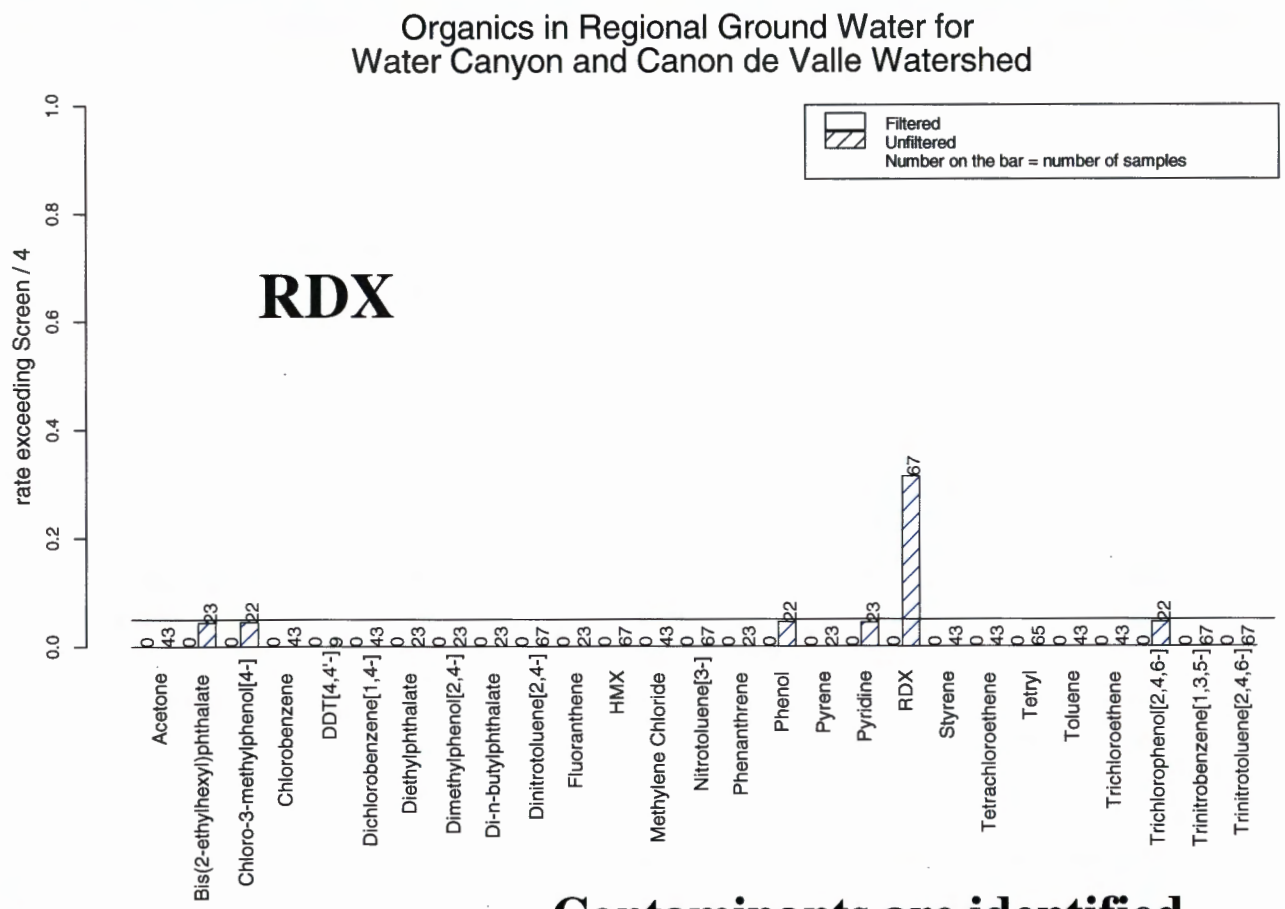
DOE Focus on Monitoring: Does the current monitoring Approach effectively identify contaminants that may migrate at unacceptable levels to public receptor locations?

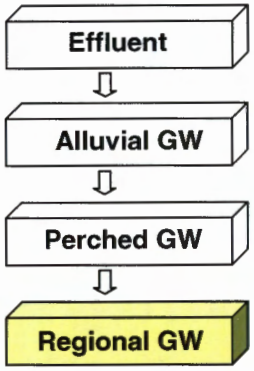




Contaminants are identified through a data screening process

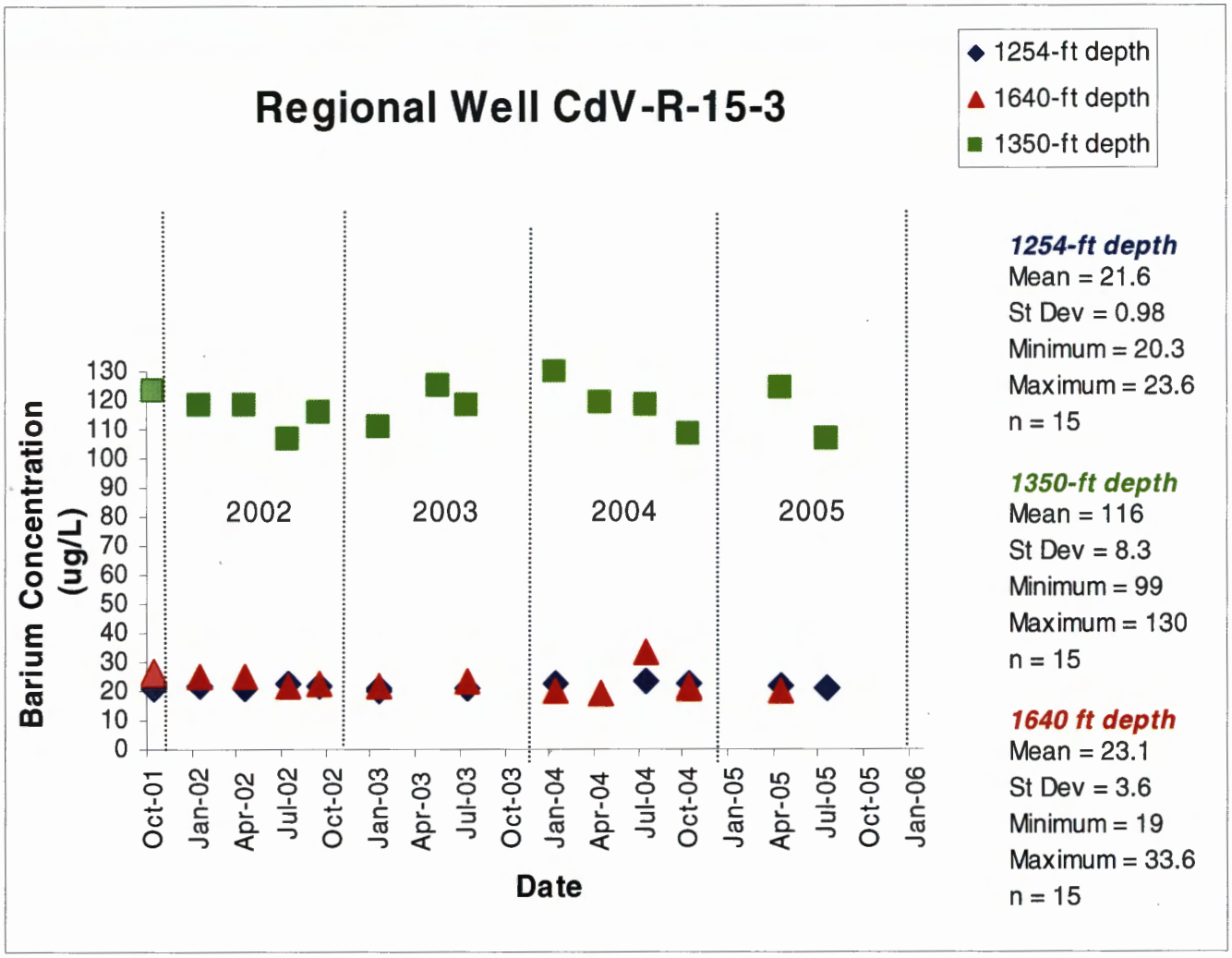
DOE Focus on Monitoring: Does the current monitoring Approach effectively identify contaminants that may migrate at unacceptable levels to public receptor locations?





Contaminants are identified through a data screening process

Key Monitoring Issues: Where are we monitoring too little or too much?



DOE Focus

- Groundwater Monitoring
  - Does the current monitoring approach effectively identify contaminants that may migrate at unacceptable levels to public receptor locations?
    - –Where are we monitoring too little or too much?
    - **–Certain characterization wells are not yet reliable. What are best practices for measuring reliability, and for rehabilitation where necessary?**

LANL Groundwater Contaminants: Sources and Transport

David B. Rogers, Presenter

LANL ENV-Environmental Remediation and Surveillance Program

March 23, 2006

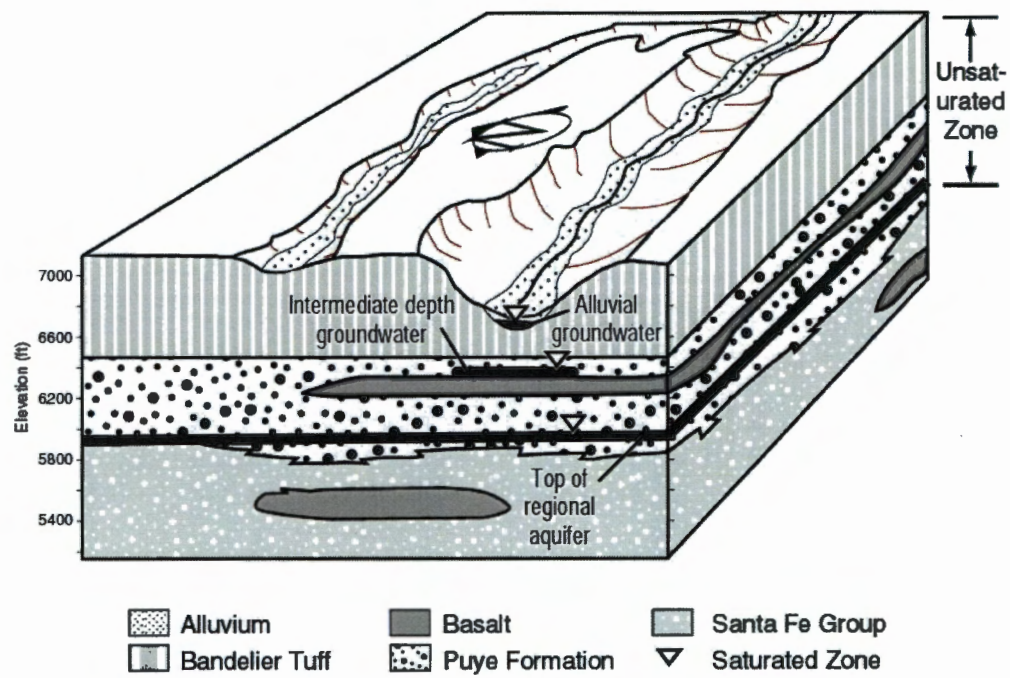
LA-UR-06-2146

Presentation topics

- Conceptual model for LANL groundwater contaminant movement.
- Mortandad Canyon example of groundwater contaminants.
- Present-day LANL groundwater contaminants.

Water availability and movement control contaminant movement

- Deep percolation occurs beneath wet canyons and disturbed mesas.
- Flow is enhanced by LANL discharges.
- Recharge is small but influences deep groundwater quality.



Water availability and movement control contaminant movement

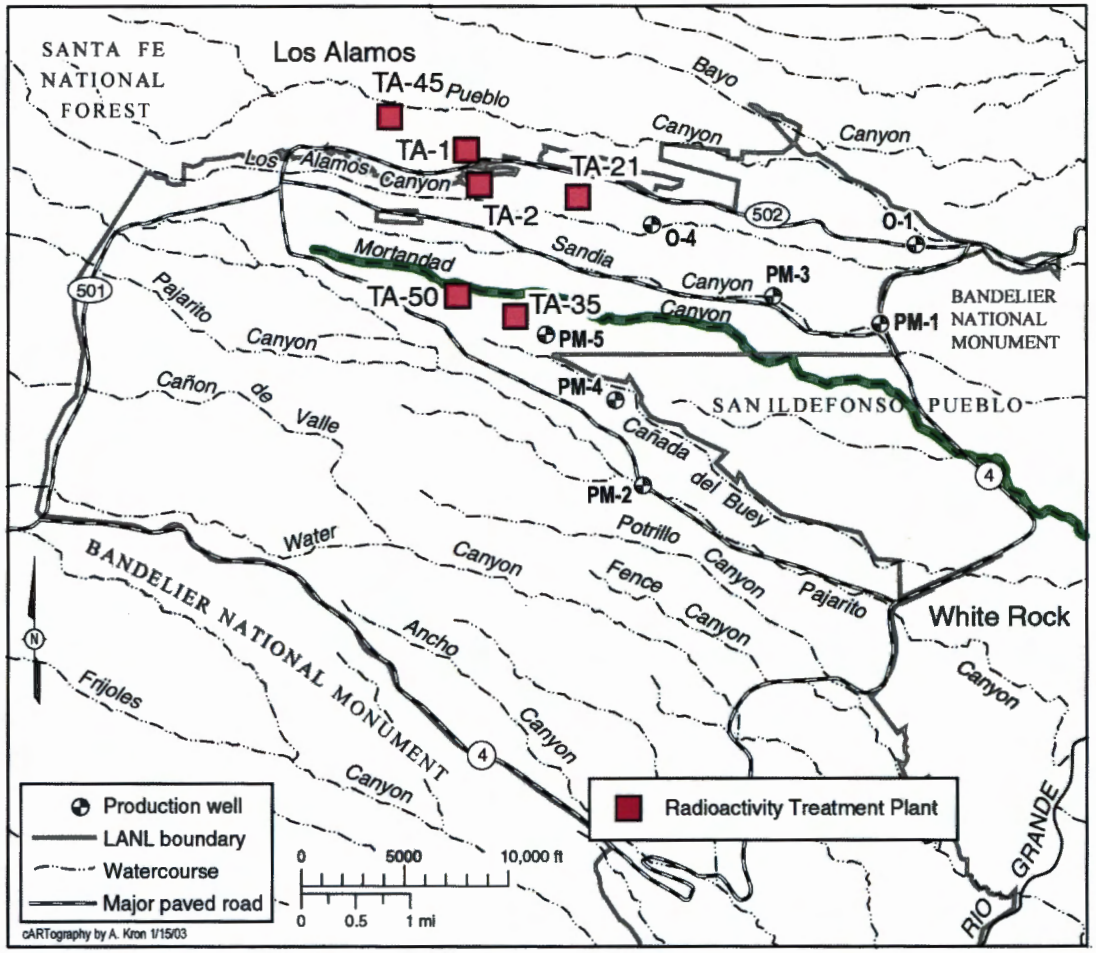
- Outfalls are the main source of groundwater contamination.
- Major LANL contaminant impacts on groundwater are due to past large-volume liquid effluent releases.
- Wastes buried on mesa tops have little groundwater contamination impact
  - Little water movement through waste.
- Hydrogeologic Workplan drilling confirms this conceptual model.

Contaminant mobility in groundwater

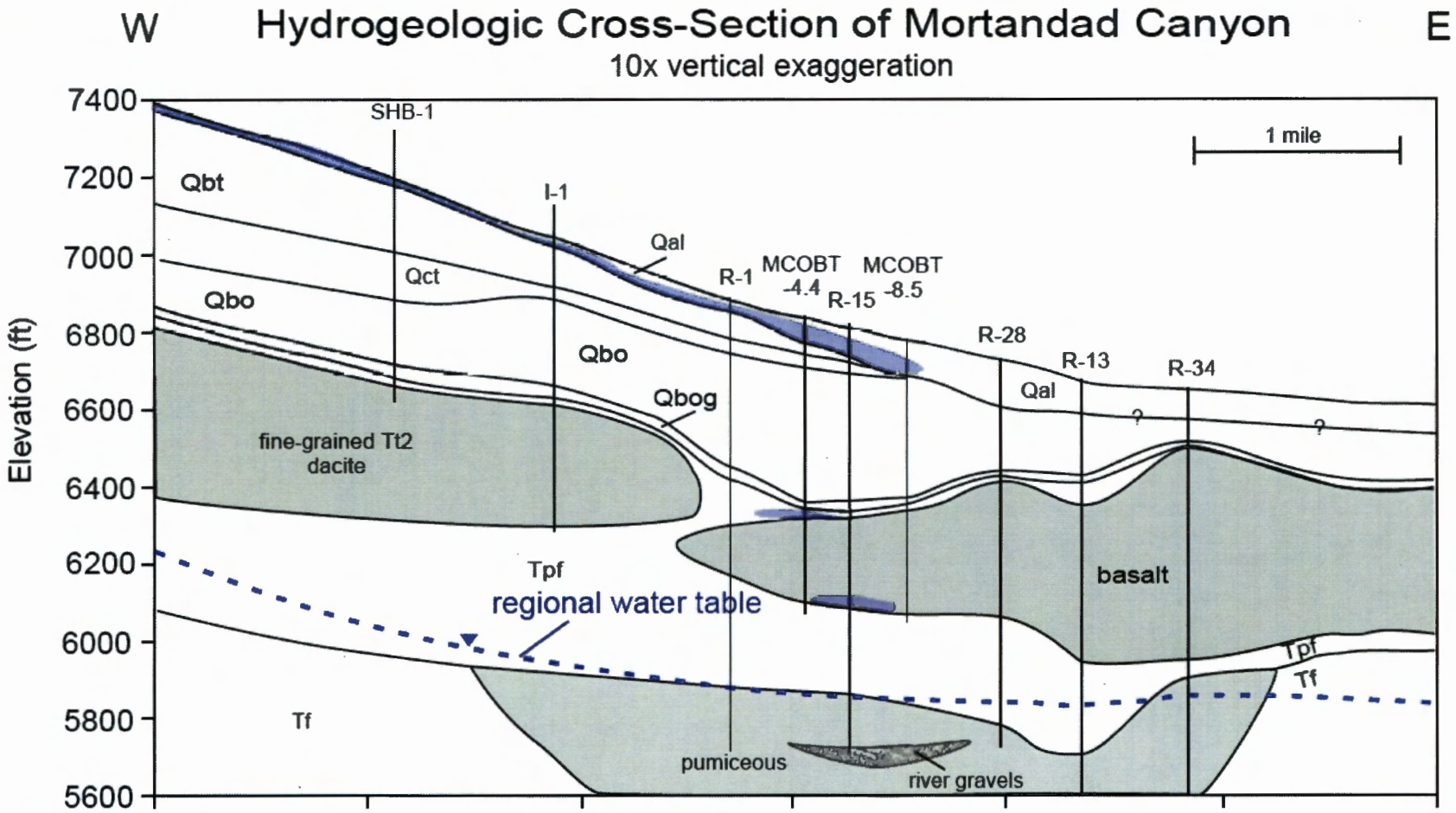
- Contaminant movement in groundwater is determined by chemical behavior.
- Conservative (nonreactive) species move readily with groundwater:
  - RDX, tritium, perchlorate, nitrate, chromium (6+).
- Adsorbing or reactive species are much less mobile, and largely remain near the surface:
  - Strontium-90, plutonium, cesium-137.
- These conclusions are based on field and experimental observations.

Hydrology of Mortandad Canyon

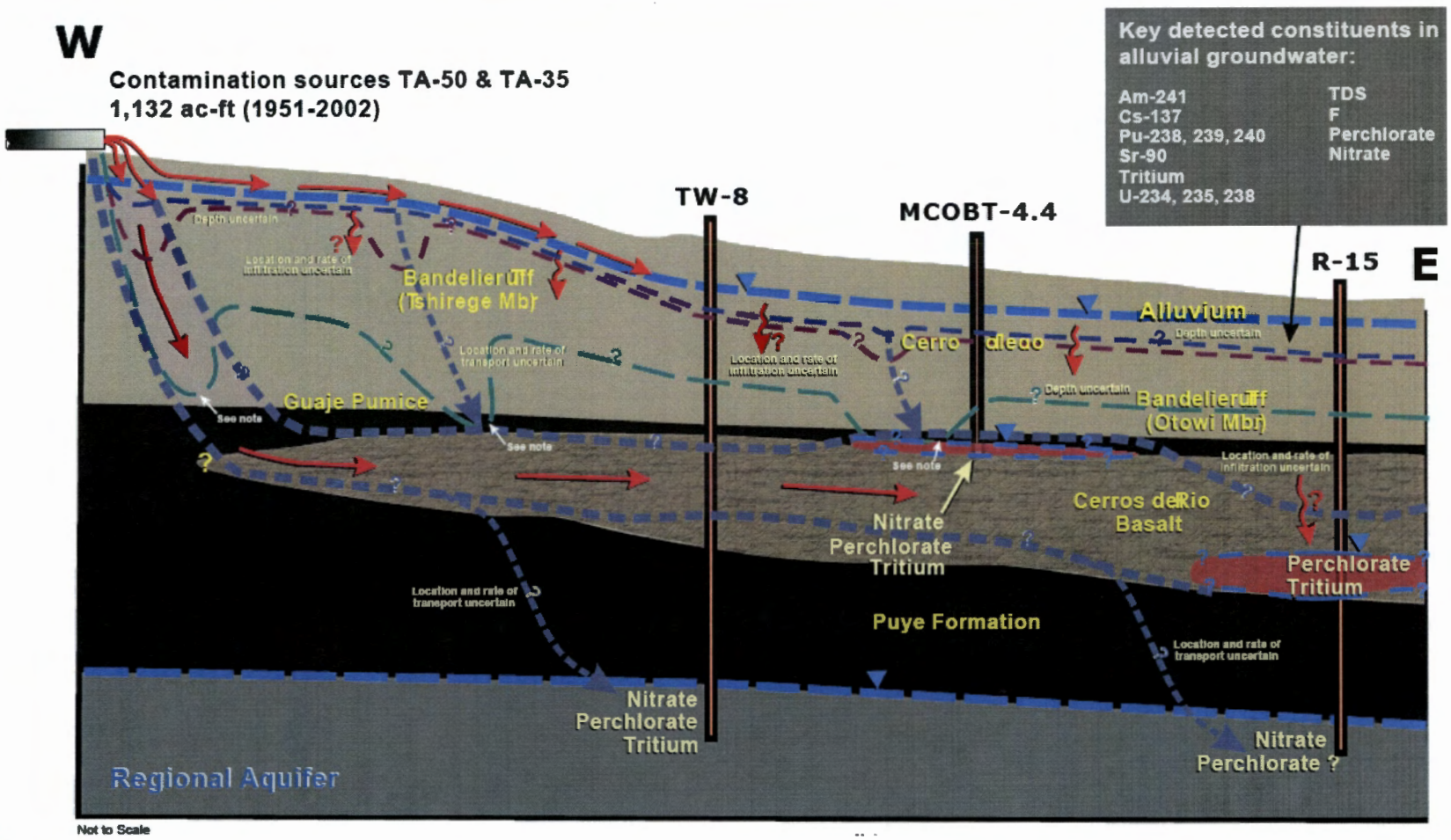
- The Radioactive Liquid Waste Treatment Facility has operated since 1963.
- Since 1986, RLWTF is the only LANL liquid radioactive effluent discharge.



Mortandad Canyon Groundwater



Mortandad Canyon Groundwater



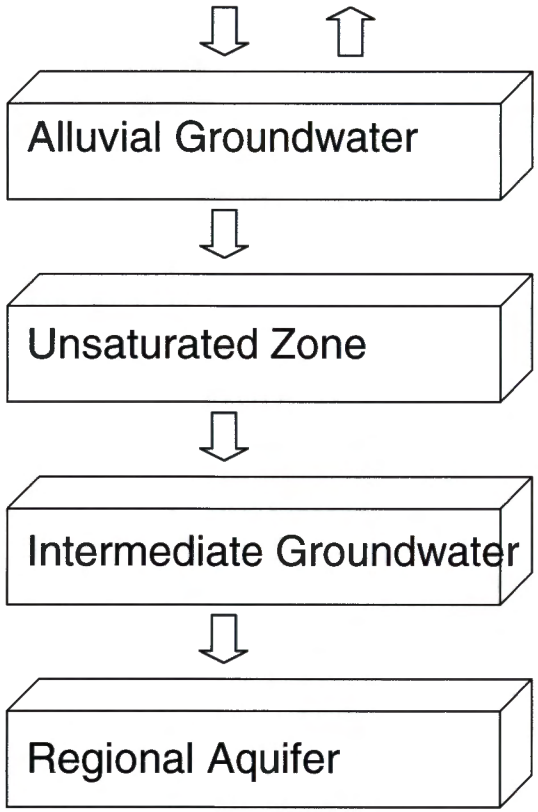
Hydrology of Mortandad Canyon

- Middle canyon at alluvial well MCO-5.
- Alluvial ground-water is 25 ft deep.
- Infrequent stream flow.

Hydrology of Mortandad Canyon

- Lower canyon at LANL boundary.
- No alluvial groundwater.
- Poorly defined channel, infrequent surface flow.

Example: Deep percolation below Mortandad Canyon



- Effluent enters alluvium- water remains in alluvium only a year or so:
- Some water lost by evaporation.

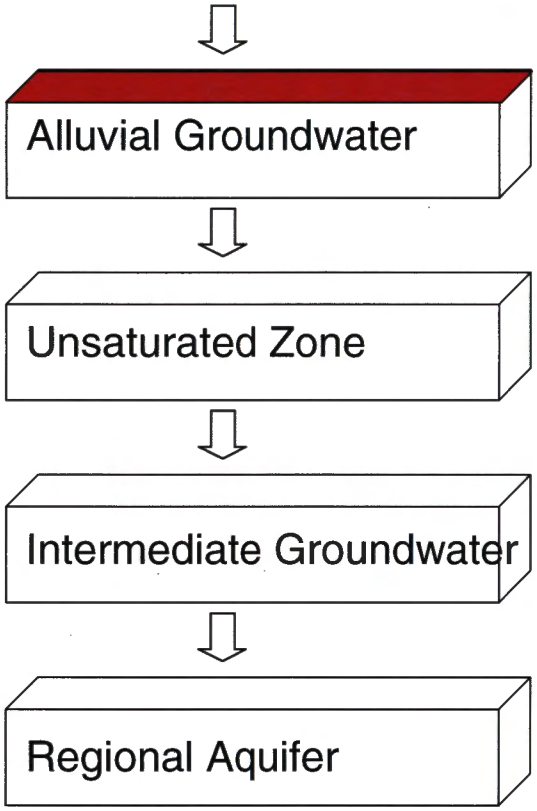
- Water infiltrates through unsaturated zone.

- Some water accumulates temporarily in perched intermediate groundwater.

- Within 10 to 20 years, some water reaches the regional aquifer.

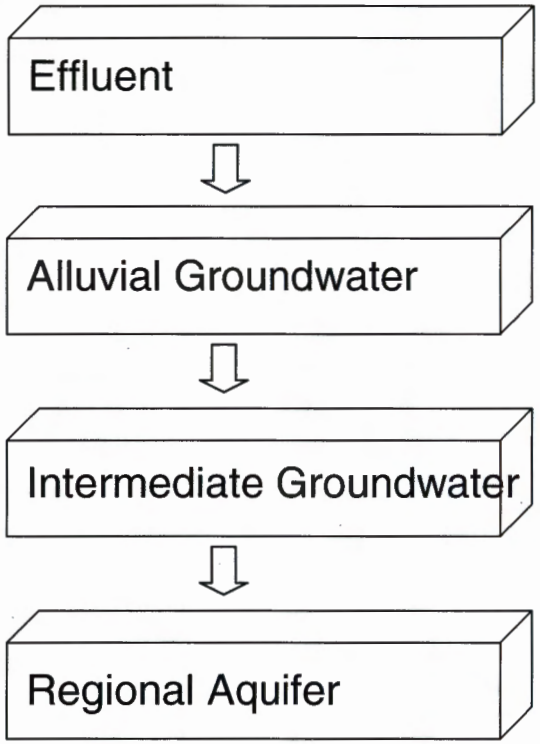
Groundwater contaminant movement in Mortandad Canyon

- Where do contaminants end up?



- Plutonium, cesium-137, strontium-90, americium-241 are mainly in sediments.
- Nitrate, perchlorate, tritium, chromium.
- Nitrate, perchlorate, tritium, chromium.
- Nitrate, perchlorate, tritium, chromium.

Contaminants decrease with groundwater depth



~ 160,000 pCi/L

~ 50,000 pCi/L

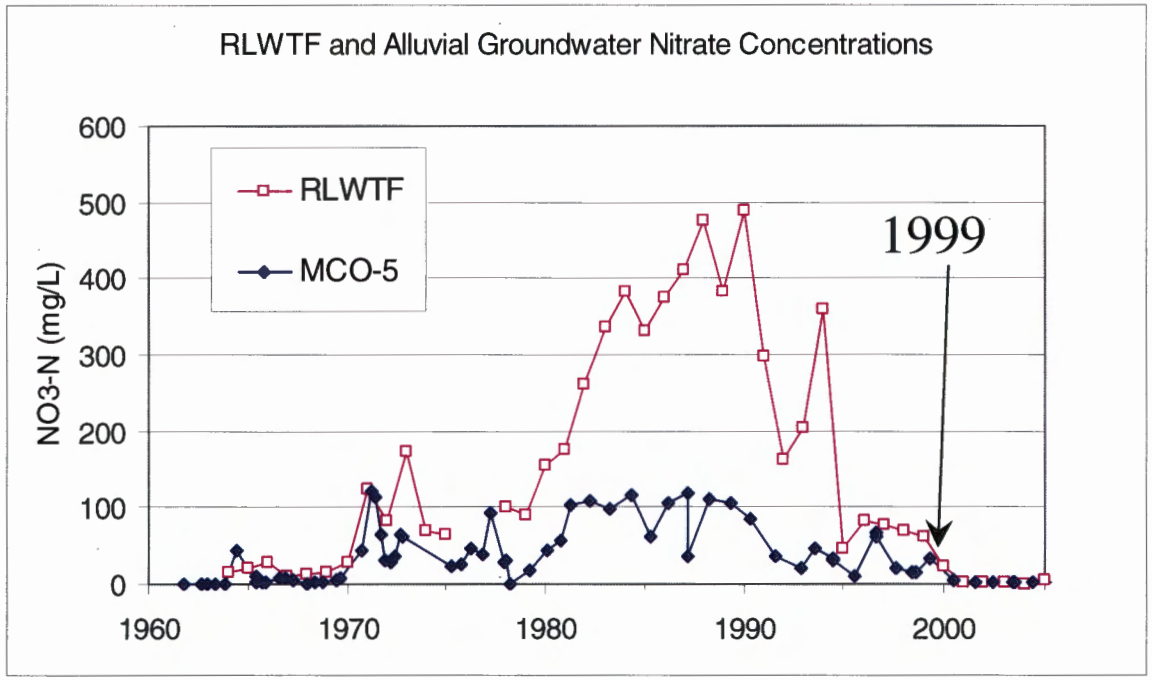
~ 10,000 pCi/L

~ 10 pCi/L

- Average tritium activity in Mortandad Canyon from 1990 through 2005.
- Small recharge volume relative to deep groundwater volume (dilution).

Example: How effluent quality improvement affects groundwater quality

- Nitrate concentrations in Mortandad Canyon alluvial groundwater fell sharply following 1999 effluent improvement.



Groundwater contaminant movement in Mortandad Canyon

- Core profiles indicate a large inventory of tritium, perchlorate, and nitrate in vadose zone.
- Preliminary estimates suggest 415 to 1250 kg of perchlorate in the upper 300 ft of the vadose zone.

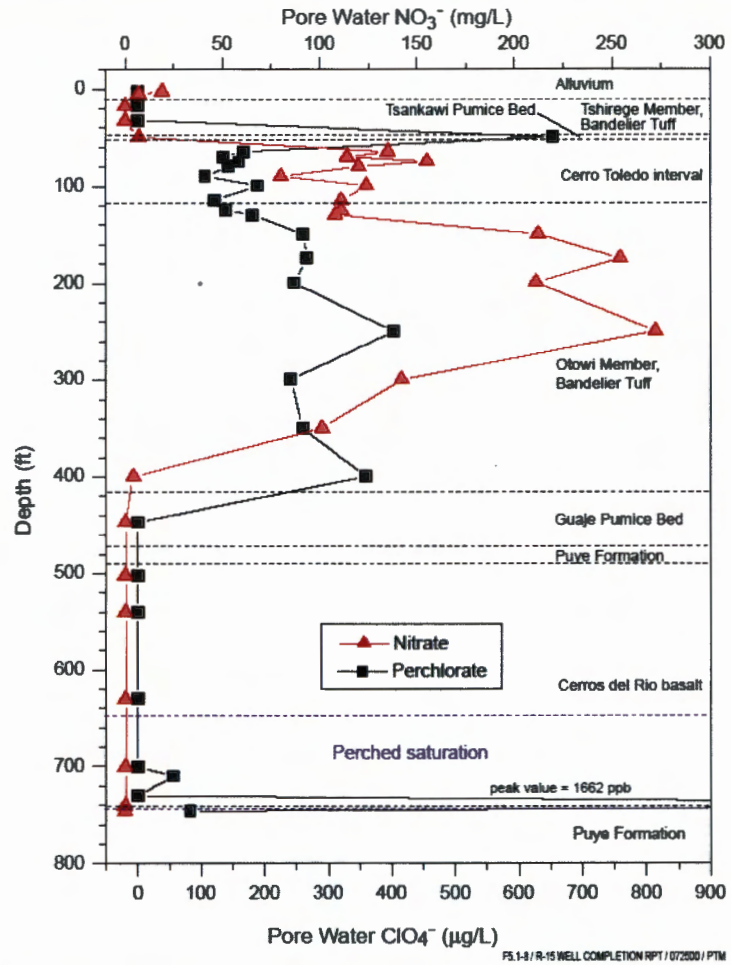


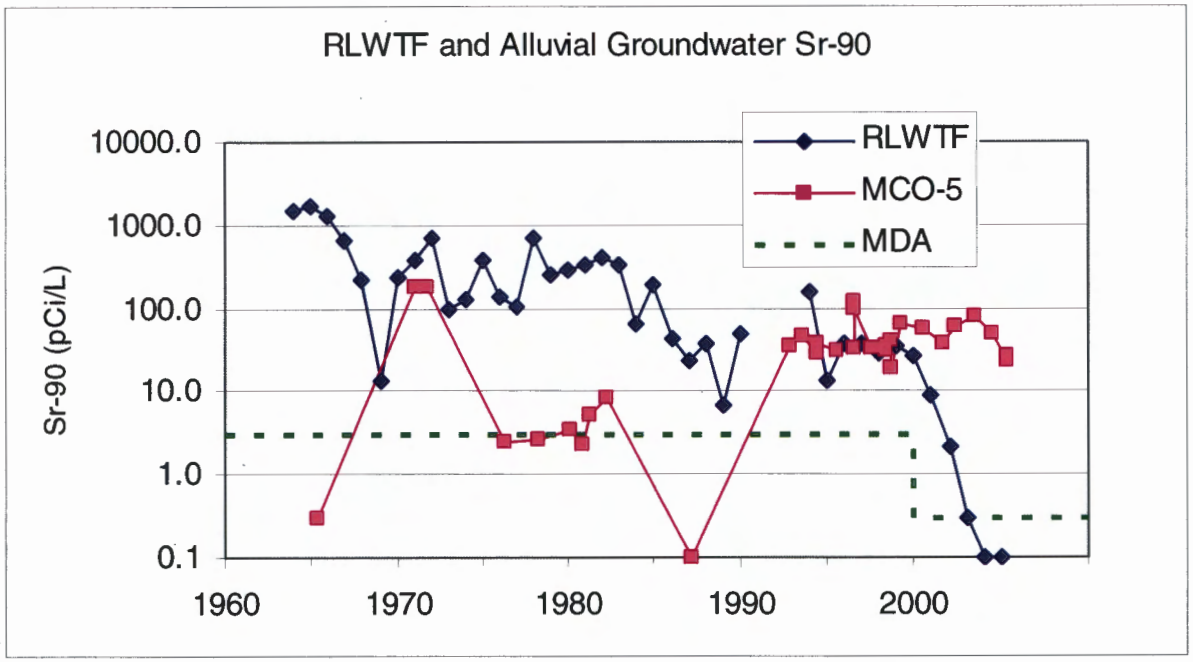
Figure 5.1-8. Pore water nitrate and perchlorate concentrations for borehole R-15

Groundwater contaminant movement in Mortandad Canyon

- A 500 ft perched zone has tritium, perchlorate, nitrate, and chromium at high levels relative to drinking water standards:
  - tritium 13,000 pCi/L, nitrate 13 mg/L, perchlorate 142 µg/L, dissolved chromium 56 µg/L.
- Most of these chemicals have not yet appeared in the regional aquifer in large amounts:
  - tritium 23 pCi/L, nitrate 2 mg/L, perchlorate 6 µg/L,
  - except for chromium at 400 µg/L.

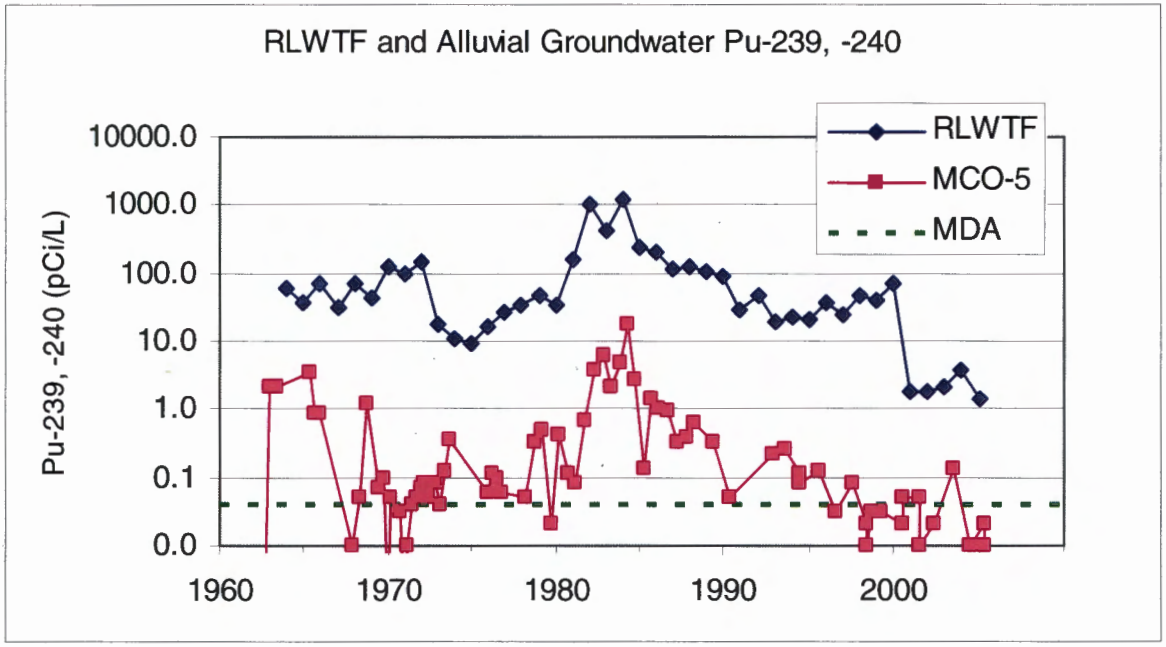
Example: How effluent quality improvement affects groundwater quality

- Strontium-90 activity in alluvial groundwater remains high after 1999 improvements.
- Source is cation exchange from sediments.



Example: How effluent quality improvement affects groundwater quality

- Plutonium activity in alluvial groundwater has fallen due to overall reduction in effluent and 1999 improvements?

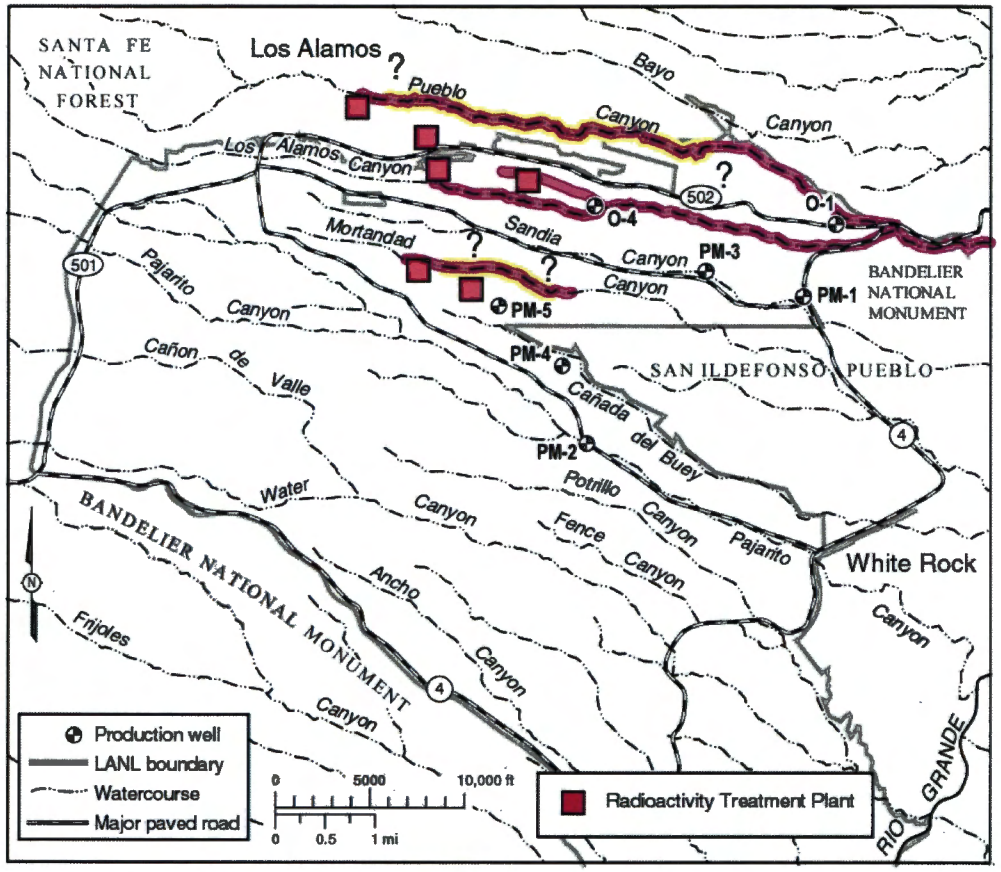


Groundwater Contamination from LANL Effluent Sources

- LANL groundwater contaminant sources include:
  - Radioactive, high explosive, sanitary, and NPDES effluents.
- Contaminants exceeding groundwater standards or risk levels at LANL include:
  - Tritium, strontium-90, total radionuclides, perchlorate, nitrate, RDX, chromium, and molybdenum.
- Conservative contaminants will bound the maximum extent of groundwater contamination from LANL liquid sources.

Past Tritium in Groundwater at LANL

- Map shows inferred past extent of tritium above 20,000 pCi/L.
- Tritium now exceeds this level only in Mortandad Canyon.
- Source elimination has decreased groundwater tritium levels.



Location of Groundwater Contaminants

Perched Alluvial

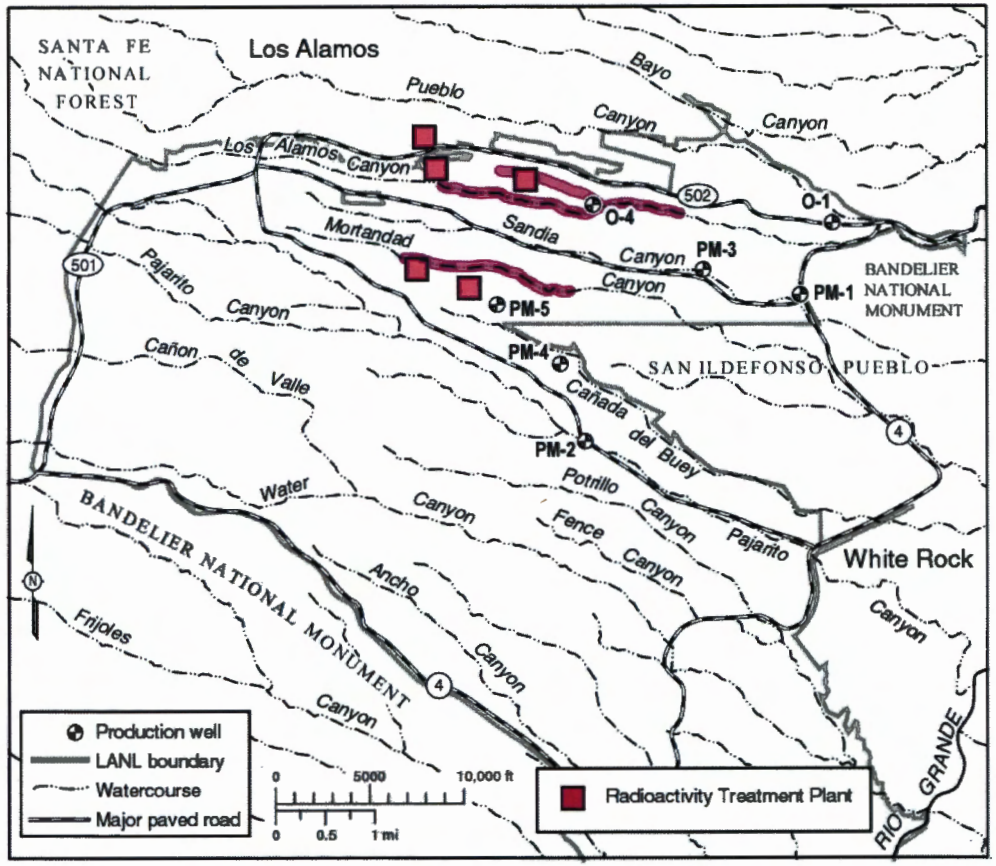
Perched Intermediate

Regional Aquifer

LA-UR-06-2146

Strontium-90 in Groundwater at LANL

- Map shows strontium-90 above 8 pCi/L MCL.
- Strontium-90 is persistent due to cation exchange.
- No strontium-90 ever consistently detected in deeper groundwater.



Location of Groundwater Contaminants

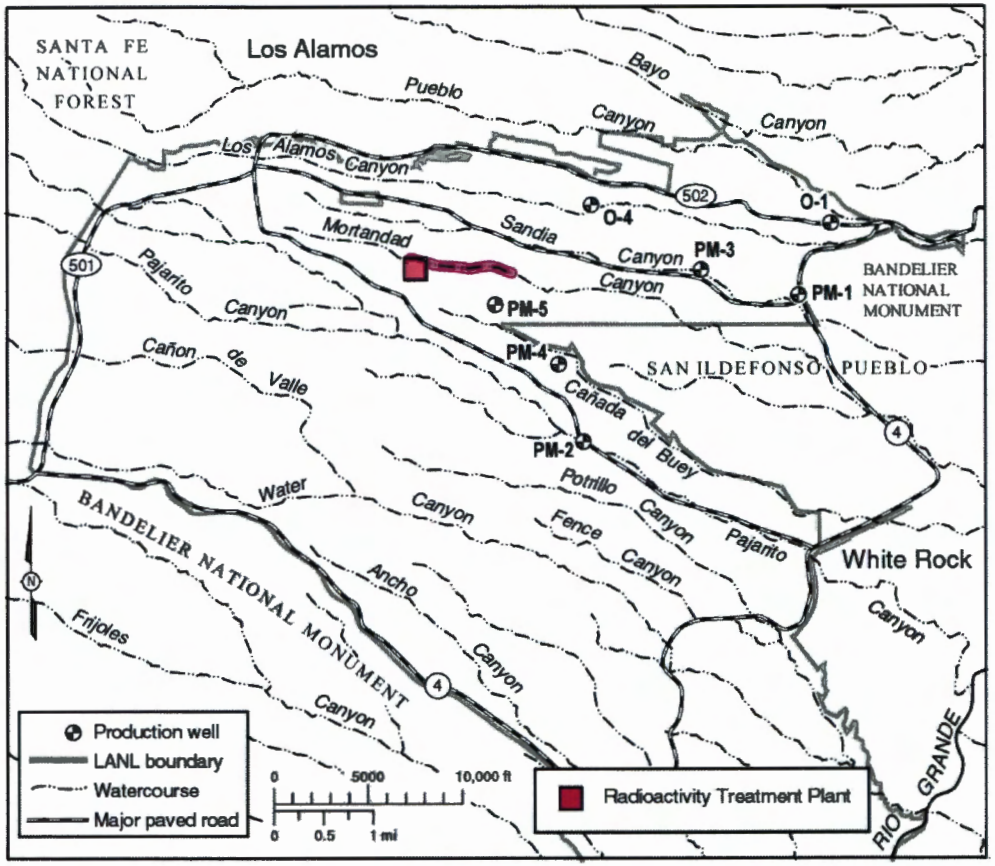
Perched Alluvial

Perched Intermediate

Regional Aquifer

Radionuclides exceeding 4 mrem dose in Groundwater at LANL

- Map shows where sum of Sr-90, Pu-238, Pu-239, and Am-241 exceed 4 mrem.
- Strontium-90 exceeded the 4 mrem DCG at one location.
- Samples are unfiltered.



Location of Groundwater Contaminants

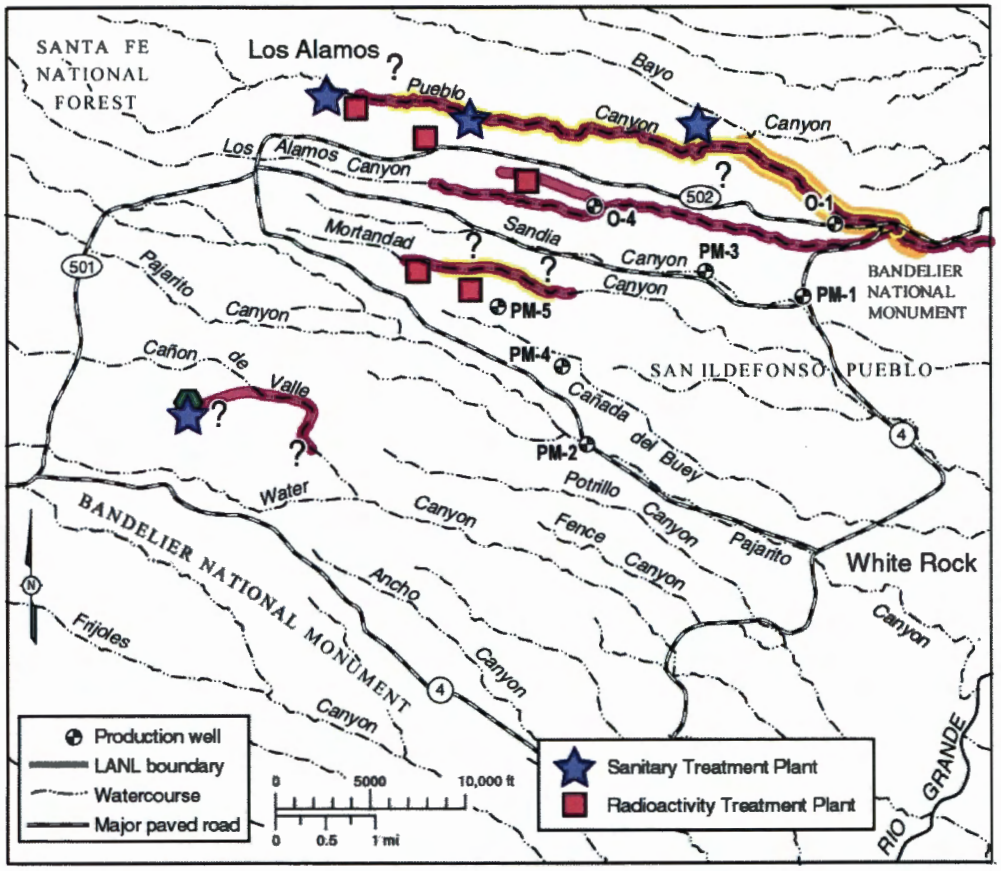
Perched Alluvial

Perched Intermediate

Regional Aquifer

Past Nitrate in Groundwater at LANL

- Map shows inferred past extent of nitrate (as nitrogen) above NM GW standard (10 mg/L).
- Sources are radiochemistry, HE, and sanitary effluents.



Location of Groundwater Contaminants

Perched Alluvial

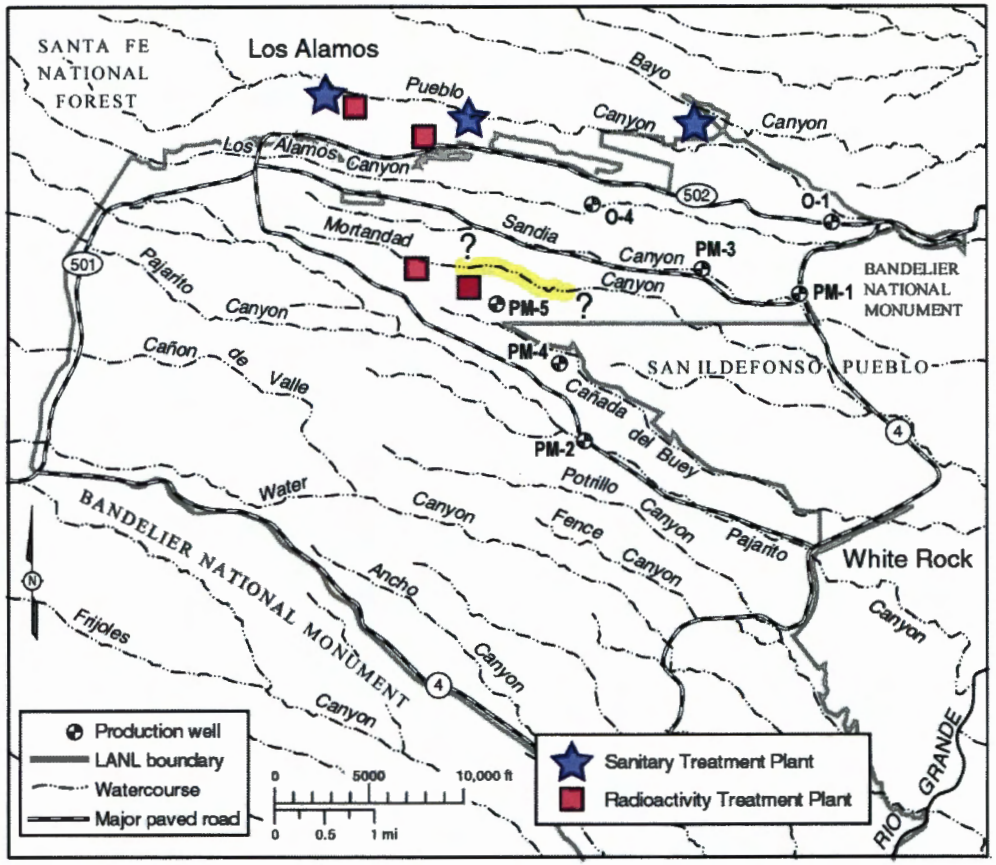
Perched Intermediate

Regional Aquifer

LA-UR-06-2146

Nitrate in Groundwater at LANL

- Map shows present nitrate (as nitrogen) above NM GW standard (10 mg/L).
- Source elimination and effluent improvement decreased groundwater nitrate levels.



Location of Groundwater Contaminants

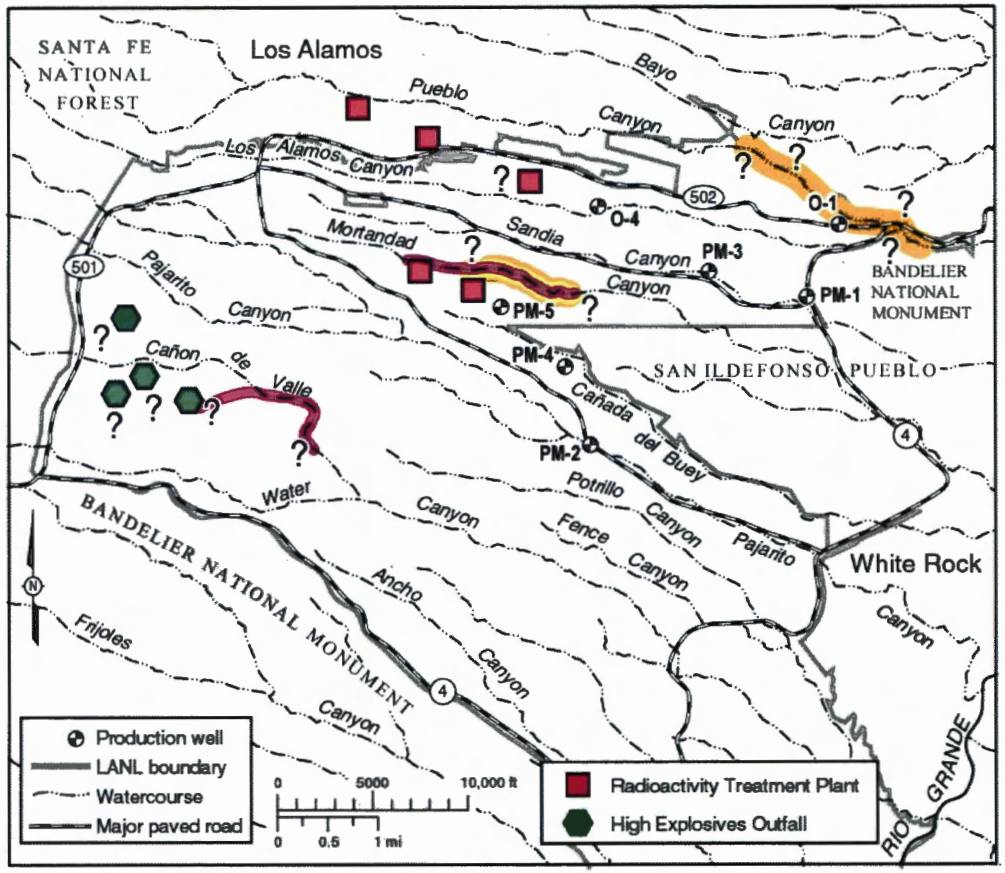
Perched Alluvial

Perched Intermediate

Regional Aquifer

Perchlorate in Groundwater at LANL

- Map shows perchlorate above 3.7 ppb (EPA Region VI HI = 1).
- EPA has new drinking water equivalent level of 24.5 ppb.
- Supply well O-1 in Pueblo Canyon has 2.8 ppb.



Location of Groundwater Contaminants

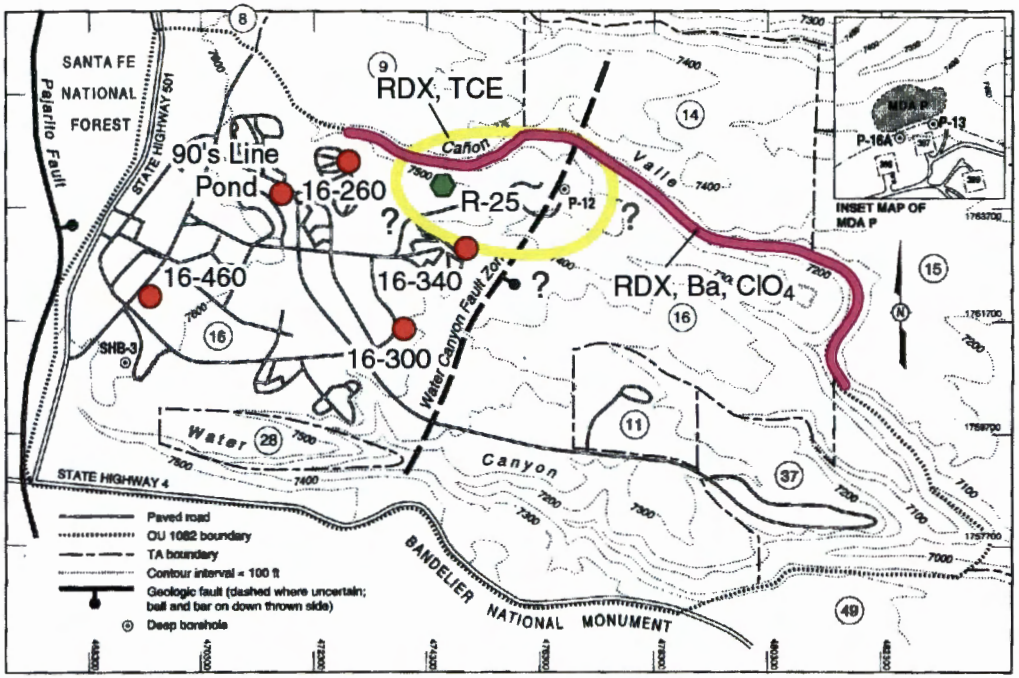
Perched Alluvial

Perched Intermediate

Regional Aquifer

RDX in Groundwater at LANL

- Map shows RDX above EPA 10^{-5} risk level of 6.1 ppb, and
- Barium above the NM GW Limit.
- Sources are High Explosives processing effluents.



Possible Historic HE Source

Well

Location of Groundwater Contaminants: Perched Alluvial, Perched Intermediate, Regional Aquifer

Source locations from Don Hickmott 11/98

Conclusions: conceptual model for LANL groundwater contamination

- LANL groundwater contamination is due to past effluent releases, which increased infiltration;
- Most of the contamination is found beneath canyons, where they have moved from alluvial groundwater;
- Geology and discharge rates affect contaminant travel rates;

Conclusions: conceptual model for LANL groundwater contamination

- Conservative contaminants (nitrate, perchlorate, tritium, RDX, chromium) have migrated to deeper groundwater;
- Reactive contaminants are held near the surface;
- Cessation of discharges results in rapid alluvial groundwater water quality improvement for conservative contaminants, as contaminated water moves deeper;
- Water quality improvement is slower for reactive contaminants.

Site-wide Hydrology

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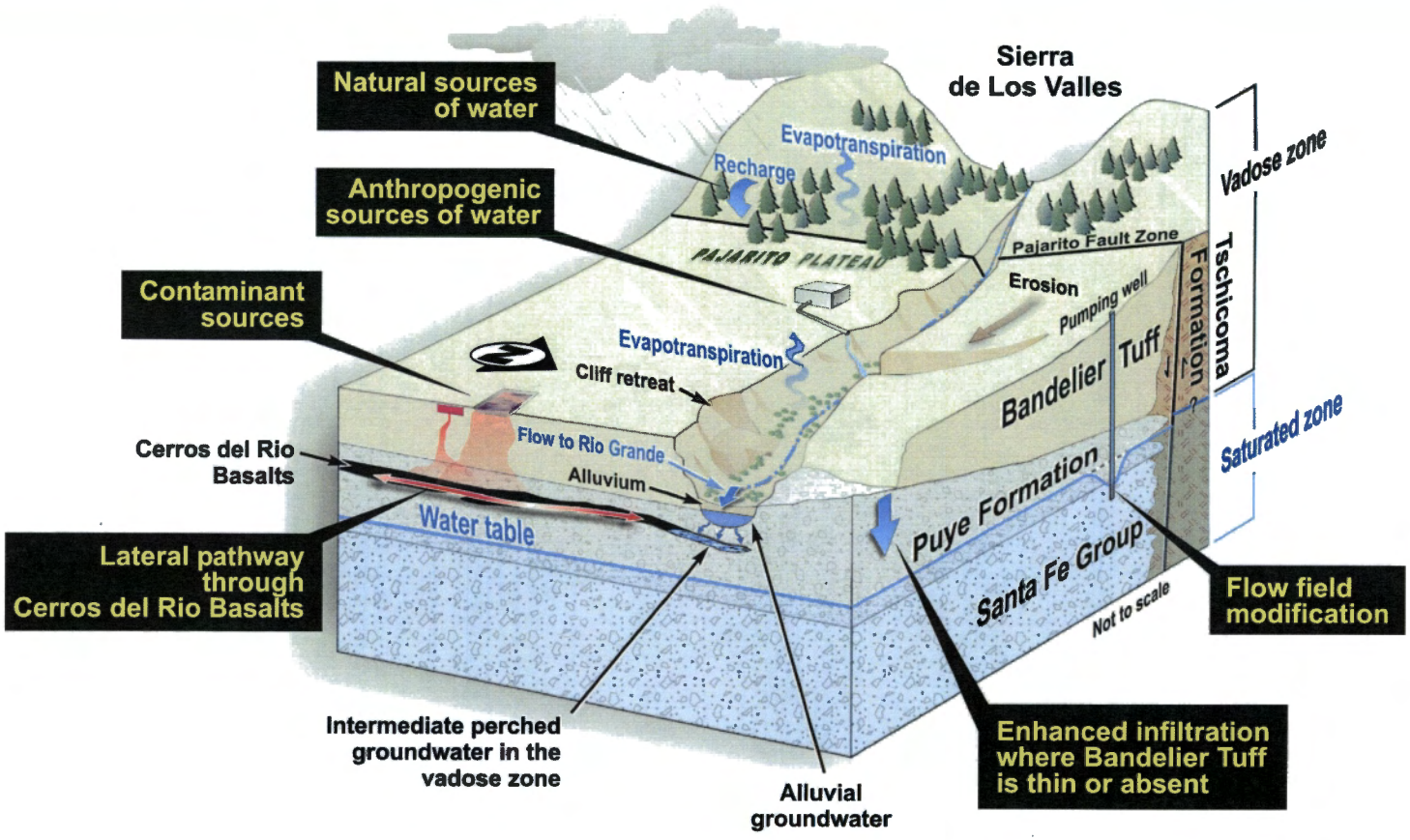
Purpose

- To describe the hydrologic conceptual model as determined from hydrologic studies on the Pajarito Plateau.
  - Alluvial groundwater
  - Vadose zone
  - Regional aquifer

Technical Approach

- Deep well drilling
  - –Geologic characterization
  - –Geophysical logs
  - –Identification of perched water
  - –Geochemistry sampling
  - –Contaminant sampling
- Hydrologic Measurements
  - –Head measurements
  - –Hydrologic testing
- Analysis and Interpretation
  - –Identification of recharge zones
  - –Travel times
  - –Refinement of conceptual models
  - –Numerical modeling to quantify conclusions

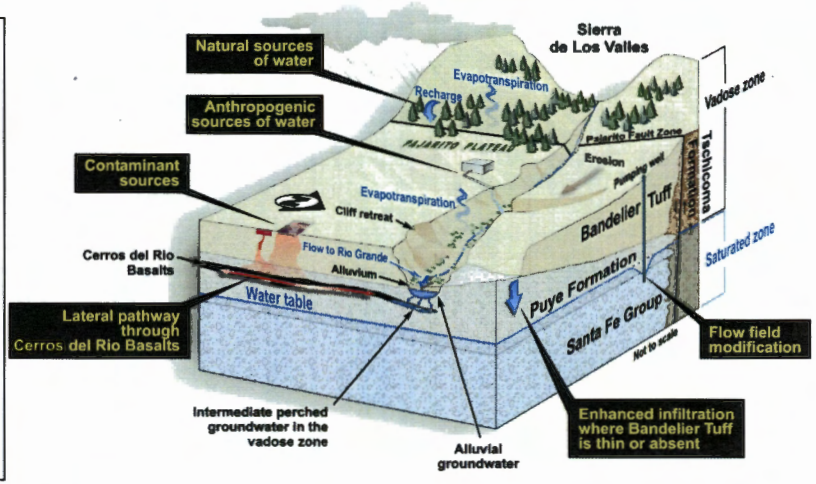
Hydrologic Conceptual Model



Hydrologic Conceptual Model

Alluvial Groundwater

- Alluvial groundwater is a significant lateral fast pathway
- Conservative contaminants are rapidly flushed from the alluvial groundwater into the deeper vadose zone
- Sorbing contaminants tend to remain close to the source in the alluvial system



Tritium and Chloride Tracer Test in Mortandad Canyon
Purtymun, 1974, LA-5716-MS

	Distance, m	Tritium		Chloride	
		Transit Time, days	Transport Velocity, m/y	Transit Time, days	Transport Velocity, m/y
MCO-5 to MCO-6	393	20	7300	25	5800
MCO-6 to MCO-7	320	77	1500	63	1900
MCO-7 to MCO-7.5	290	66	1600	52	2000
MCO-7.5 to MCO-8	183	109	620	79	840

Hydrologic Conceptual Model

Vadose Zone

Dry Canyons and Mesas

Downward percolation rates are low (<10 mm/y)

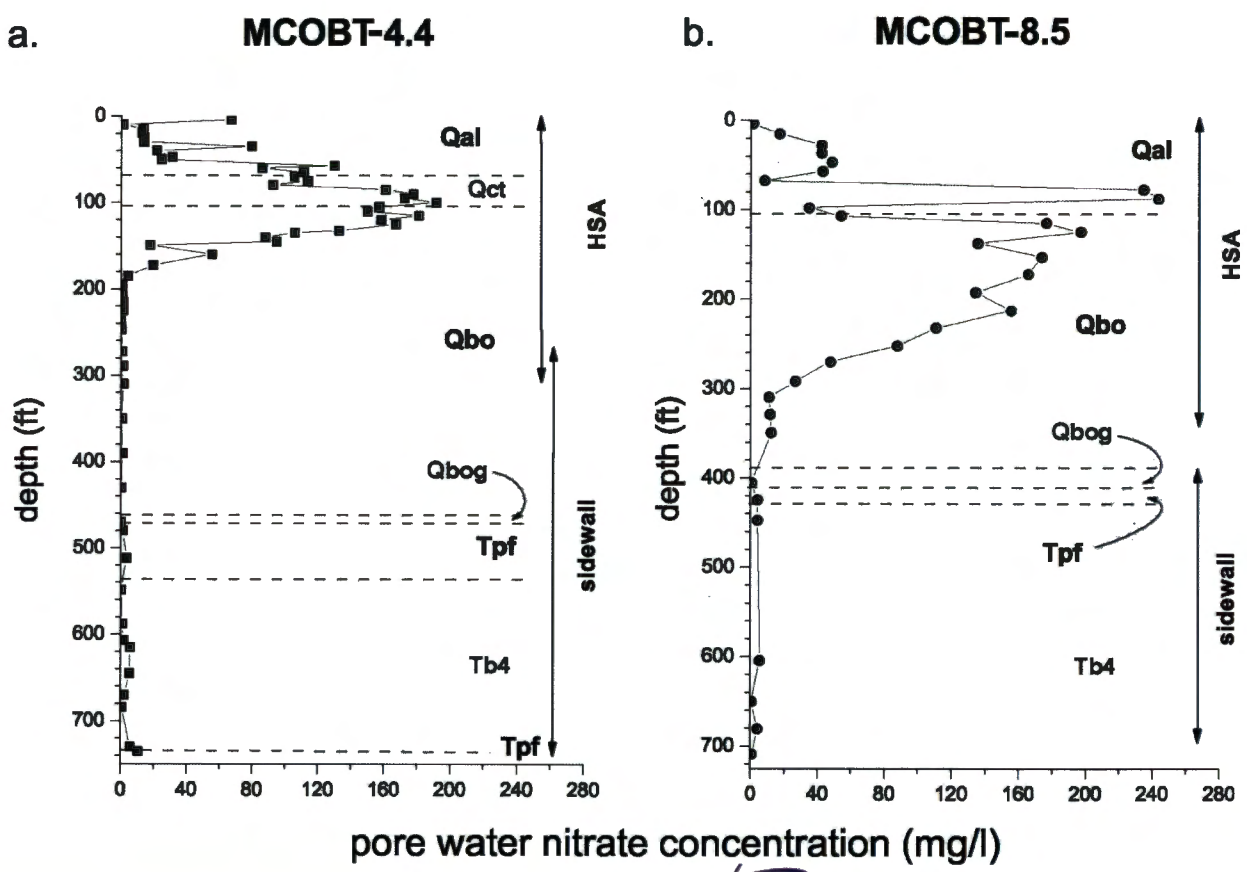
Wet Canyons

Downward percolation rates are high (1000 mm/y)

Hydrologic Conceptual Model

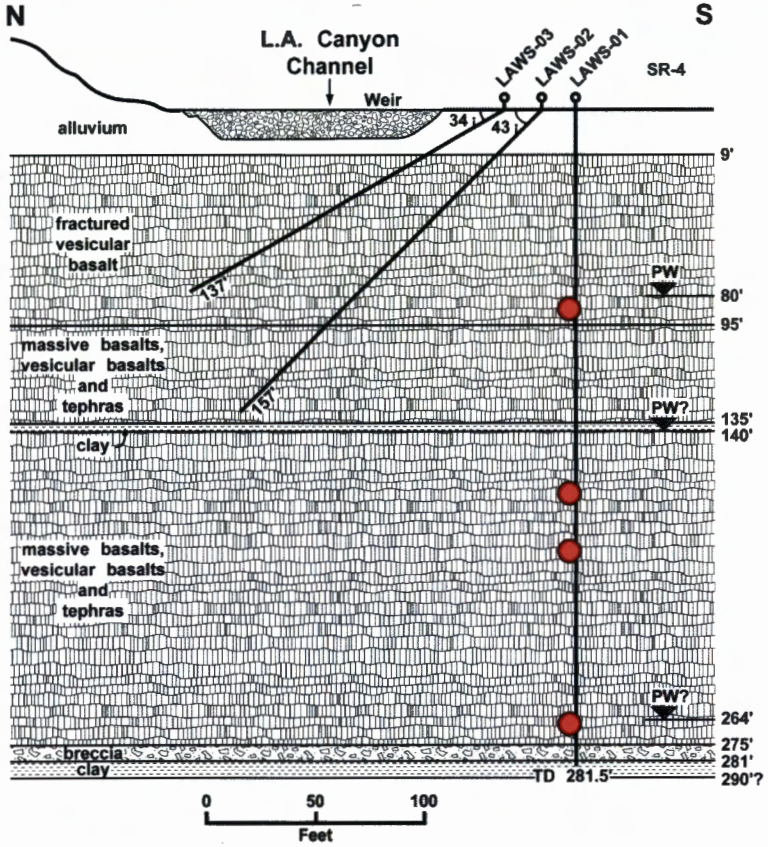
Vadose Zone – Transport through Bandelier Tuff

- Percolation occurs principally through the rock matrix
- Travel times are on the order of decades from the canyon bottoms, in excess of 1000 years from dry, undisturbed mesas



Hydrologic Conceptual Model

Vadose Zone – Transport through basalts

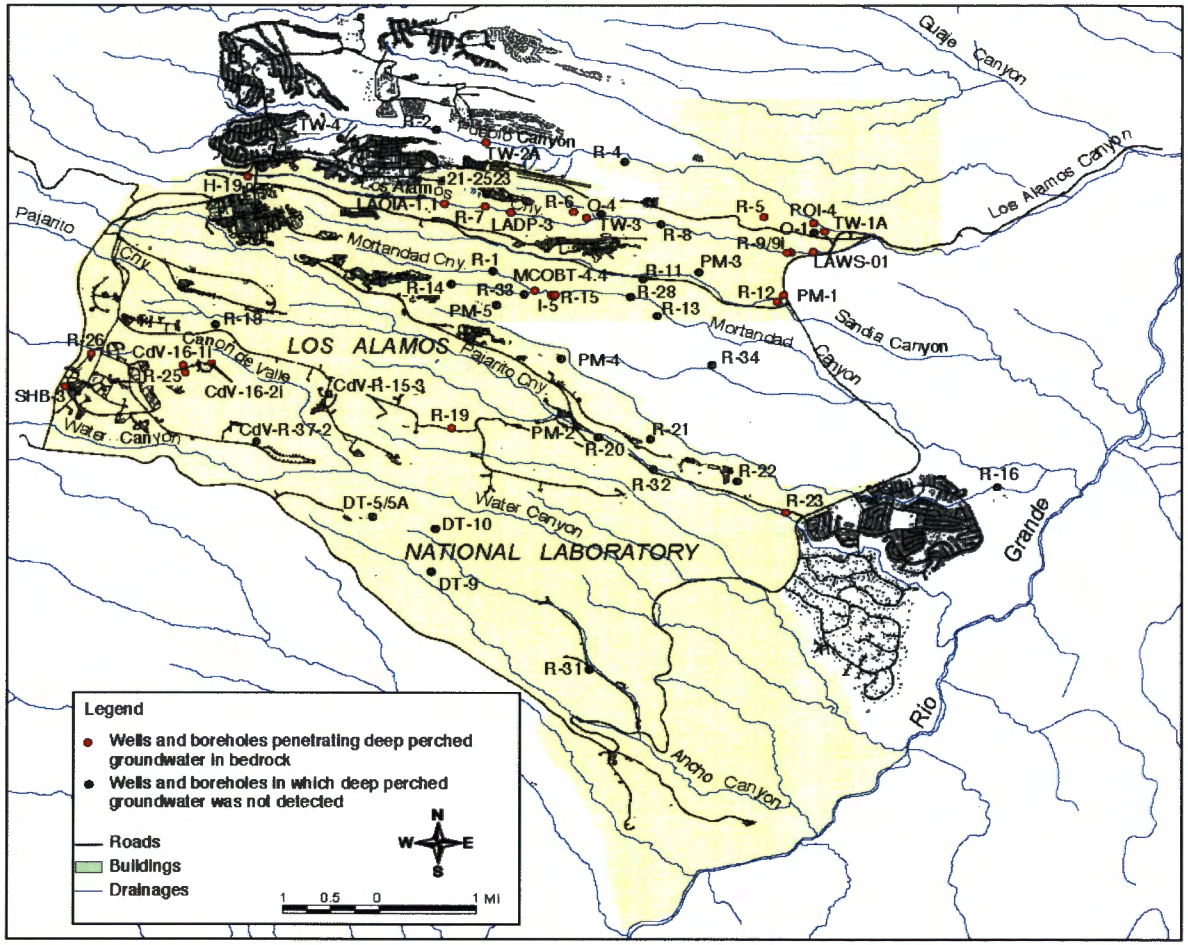


- For basalts, the measured transport times from the surface to significant depths are on the order of days to months
- Flow and transport occurs exclusively through fast paths

Hydrologic Conceptual Model

Vadose Zone – wells encountering perched water

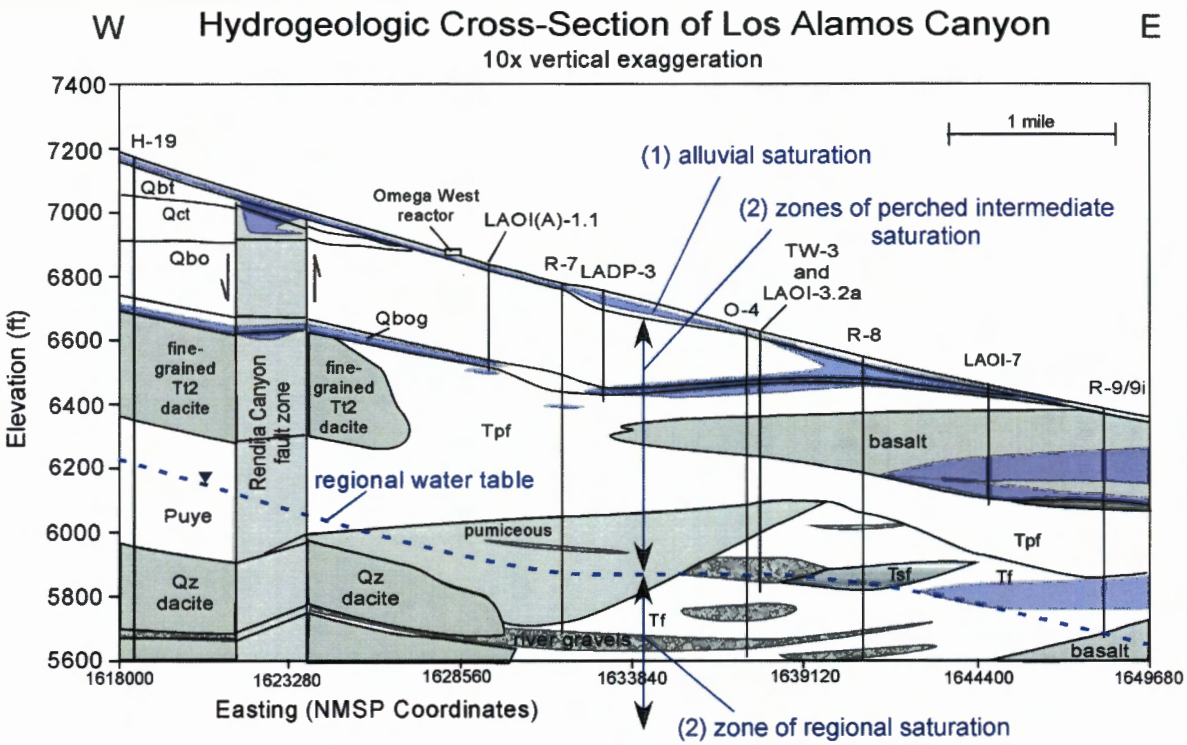
- Perched water often found beneath canyons where infiltration rates are highest
- Perched water much less often found beneath mesas
- Anthropogenic chemicals are typically found in perched water, indicating contaminant transport to significant depths



Hydrologic Conceptual Model

Vadose Zone – perched water conceptual model

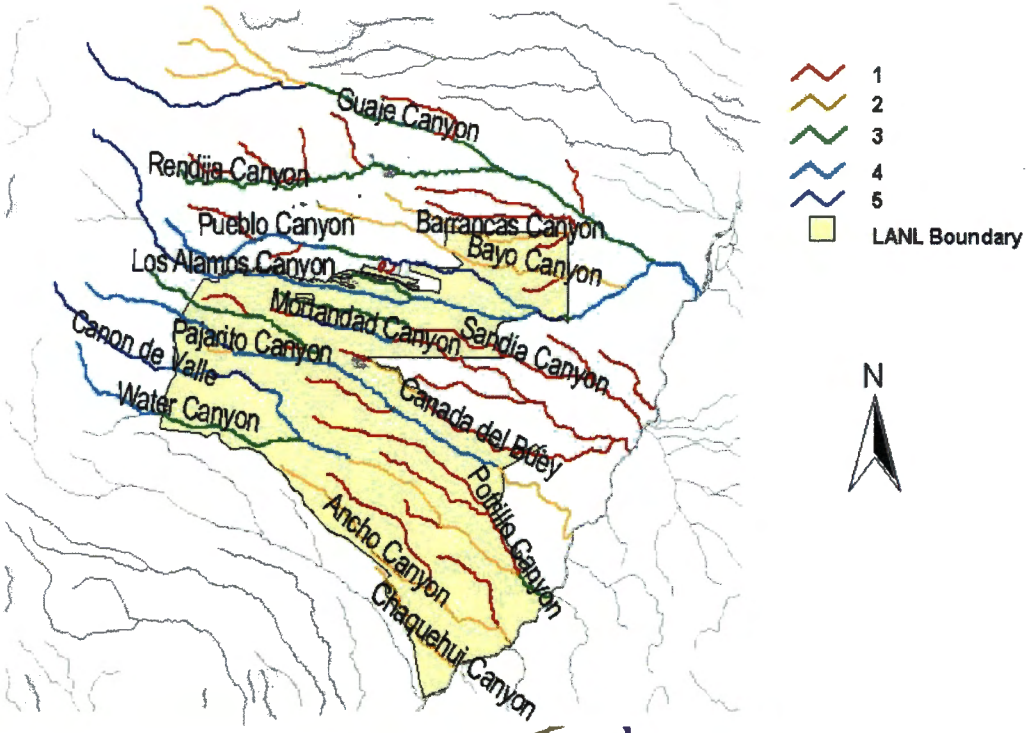
- Perched zones usually are controlled by local hydrostratigraphy – perching horizons include unfractured basalts, clay-rich interflow zones in basalts, buried soils, clay-altered tuffaceous sediments
- Flow conditions within perched zones are difficult to characterize. End-members are:
  - –Low-velocity, nearly stagnant water
  - –High-velocity, laterally migrating fluid



Vadose Zone Travel Times

- Infiltration is a function of the surface hydrologic conditions in individual canyons
  - –Origin of headwaters
  - –Human-induced water sources
  - –Surface disturbances
- Relative infiltration rates are set based on these criteria

Infiltration Index for Canyons

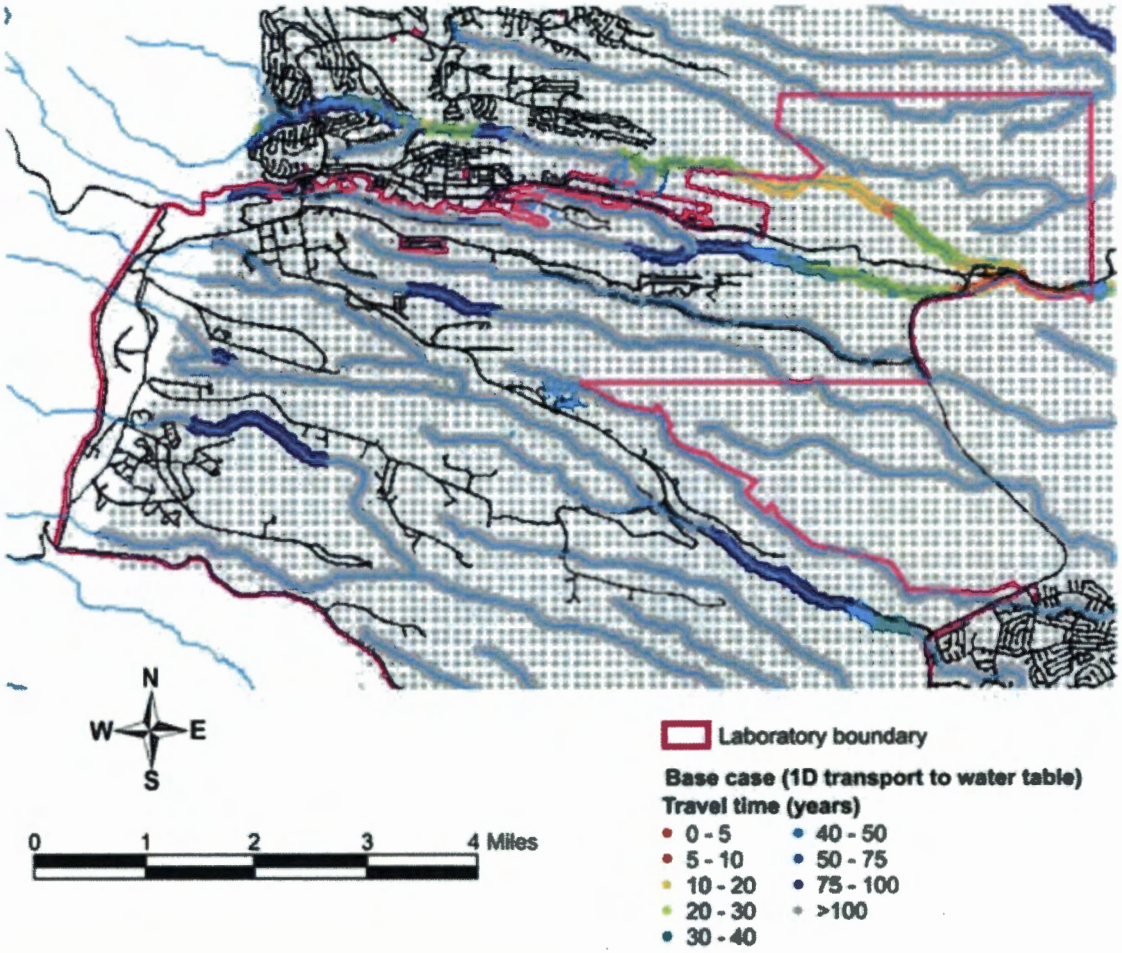


Vadose Zone Travel Times

Canyons

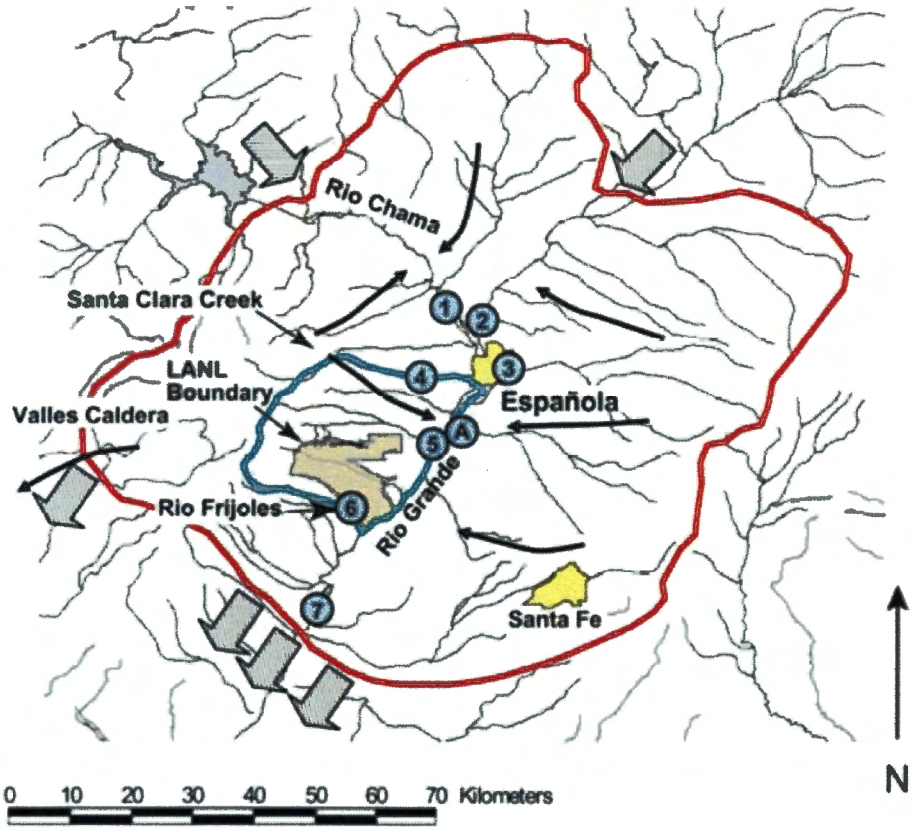
Vadose zone travel times to the regional aquifer water table are a function of:

- Infiltration rate
  - Long travel times from mesas
  - Short travel times from naturally wet canyons or canyons with large water inputs due to LANL or municipal water discharges
- Hydrogeology
  - Bandelier Tuff leads to slow percolation
  - Basalts lead to fast pathways through the vadose zone



Hydrologic Conceptual Model

Regional Aquifer – Espanola Basin

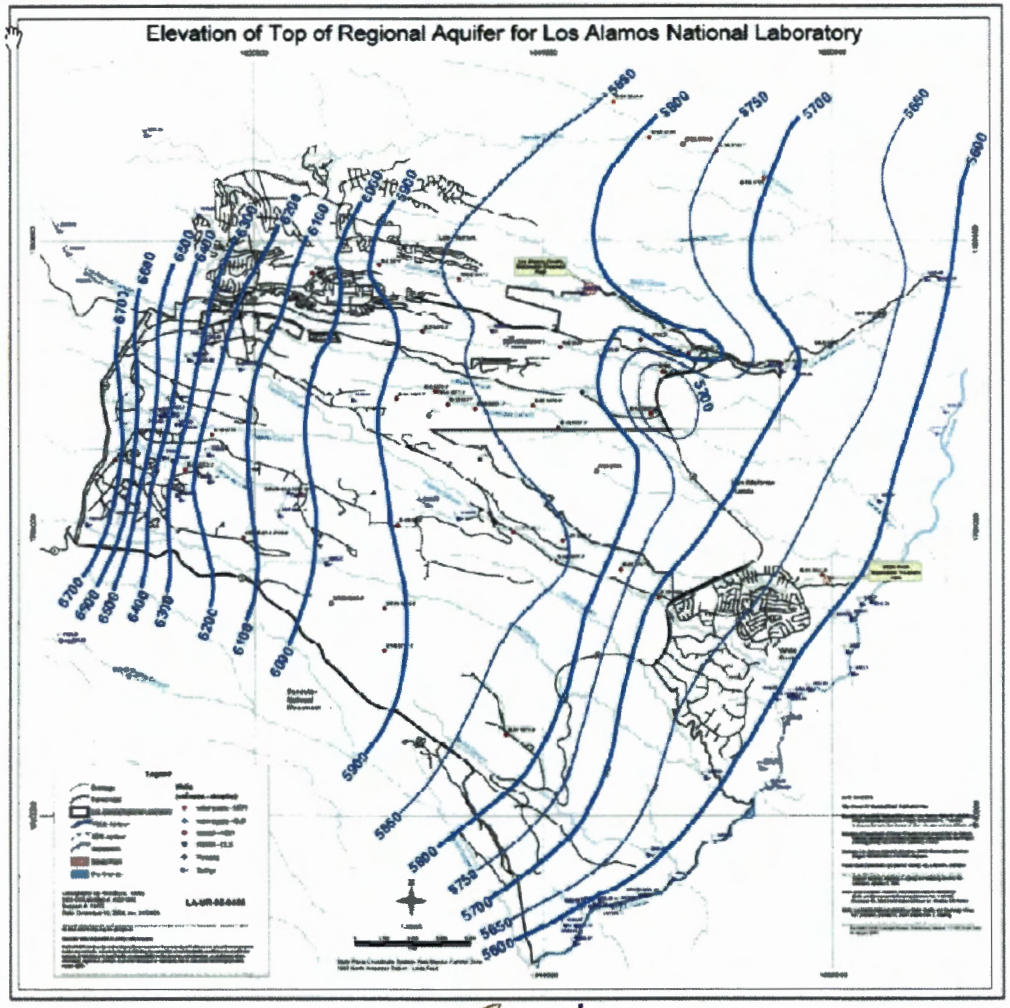


- Regional aquifer is a major source of municipal and agricultural water supply for Northern New Mexico
- Basin-scale flow paths are from Mountainous regions to the Rio Grande
- Regional water table is typically 0-60 m below ground surface, but is much deeper beneath the Pajarito Plateau (up to 350 m below ground surface)
- Aquifer consists primarily of weakly consolidated basin-fill sediments (Santa Fe Group rocks)

Hydrologic Conceptual Model

Regional Aquifer – Site Scale

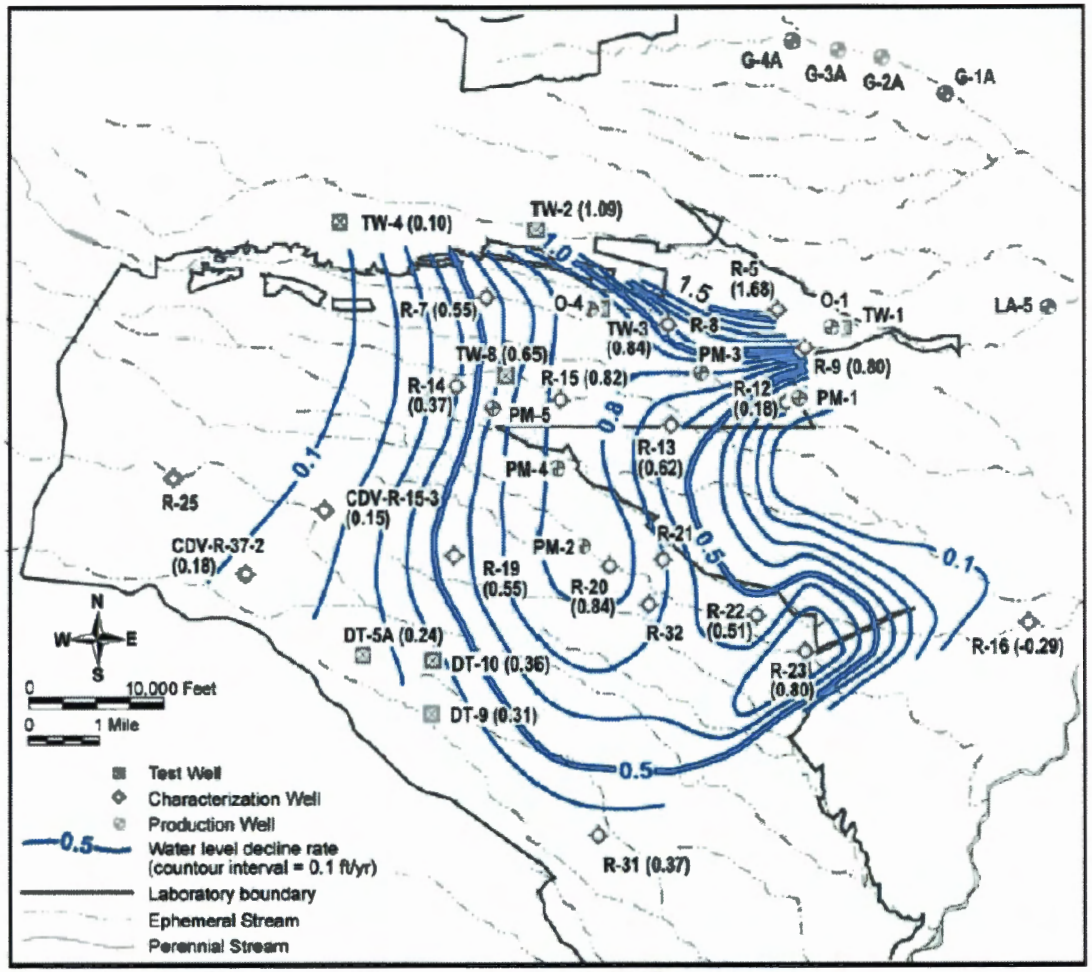
- Gradients are from west to east, toward the Rio Grande
- Steep gradients in the western portion of LANL are caused by the Pajarito Fault zone
- Municipal water supply well pumping has had an impact on the potentiometric surface



Hydrologic Conceptual Model

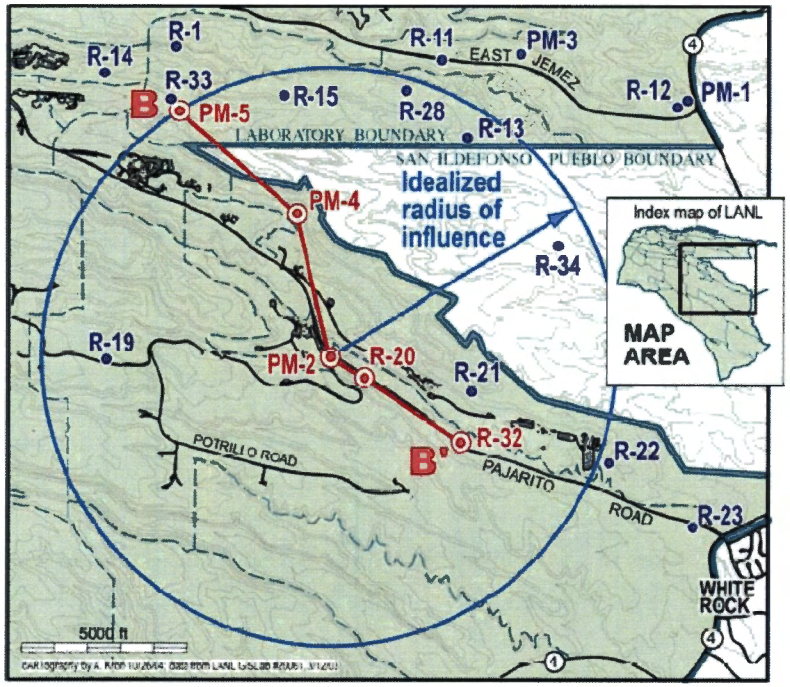
Regional Aquifer – Site Scale

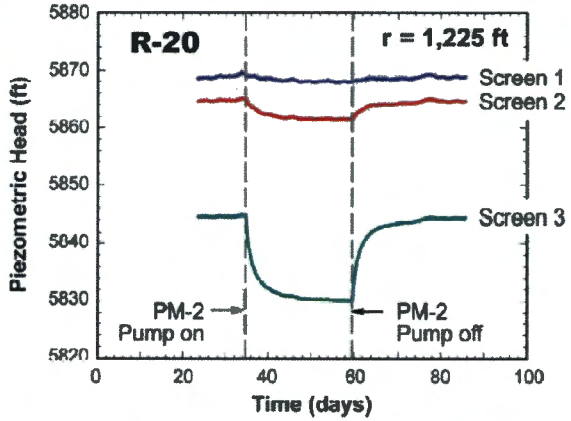
- Pumping of municipal water supply wells has led to measurable water level declines around LANL
- Declines at the depth of the pumping well screens are the largest
- Vertical anisotropy results in a more muted response at the water table

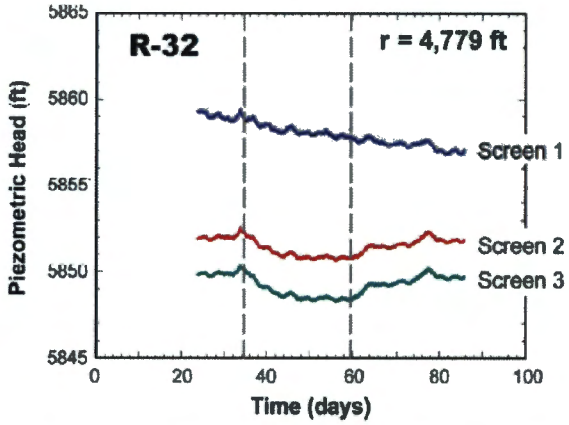


Hydrologic Conceptual Model

Regional Aquifer – Influence of Pumping





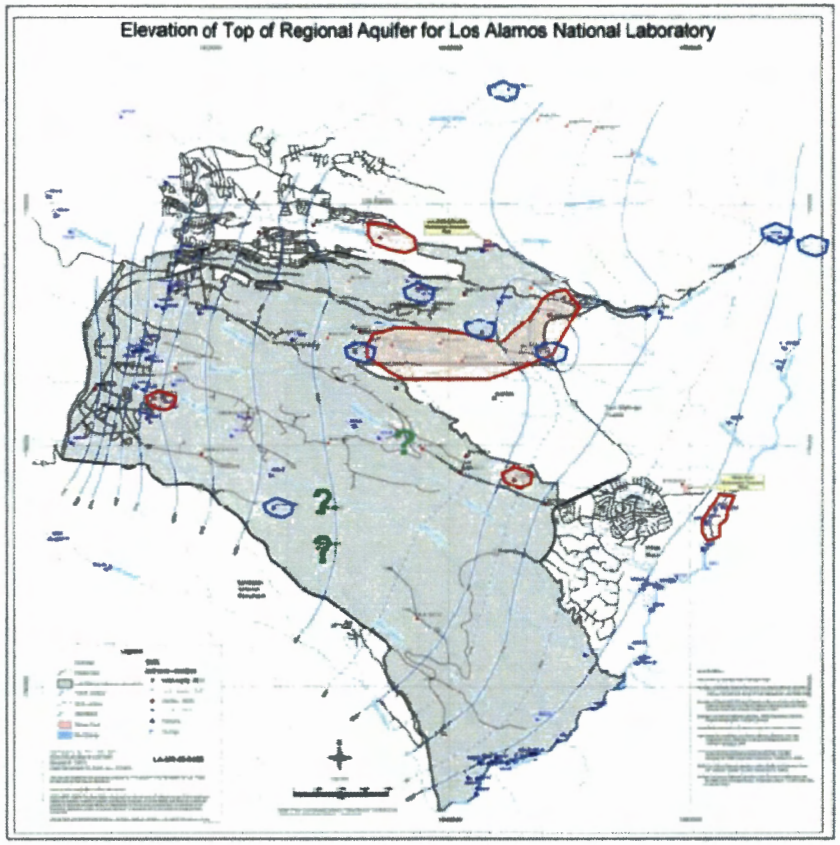


- Pumping tests show the large radius of influence for municipal water supply wells, and large vertical anisotropy in the regional aquifer (kv << kh)

Hydrologic Conceptual Model

Regional Aquifer – Hydrochemical information

- Different age indicators yield vastly different fluid ages in the regional aquifer
- Fluids are generally a mixture of very young and old waters
- Deep groundwater generally increases in age from west to east
- Groundwater from the greatest depths typically shows no indication of anthropogenic influence



Based on ^{14}C dating, groundwater has a component of very old water (> 1000 years)

Based on ^{3}H data, groundwater has a component of very young water (< 45 years)

Summary

- Alluvial groundwater represents a rapid lateral transport pathway for conservative contaminants
- Vadose zone transport is controlled by basic hydrogeolologic characteristics such as:
  - –Canyon vs. Mesa setting
  - –Bandelier Tuff vs. Basalt
  - –LANL and municipal water discharges
- Perched water is caused by a variety of complex, local hydrogeologic heterogeneities, and adds uncertainty to the characterization of subsurface pathways
- Regional aquifer pathways are well understood at the basin and Plateau scales, but predictions at the scale of individual contaminant sources is complicated by heterogeneities, anisotropy, and the influence of municipal water supply well pumping