General GW

COMMITTEE FOR THE TECHNICAL ASSESSMENT OF ENVIRONMENTAL PROGRAMS AT THE LOS ALAMOS NATIONAL LABORATORY

PUBLIC AGENDA

National Academy of Sciences
500 5th Street NW, Washington, DC

All times are approximate – Adjustments to schedule will be made as needs are identified

Tuesday, May 16, 2006

Hotel Santa Fe
1501 Paseo de Peralta
Santa Fe, New Mexico 87501

Open Session

11:00 AM – 11:05 AM	Welcome visitors – **Larry Lake, Chairman**
11:05 AM – 12:00 PM	Improving LANL's groundwater monitoring and analysis program – **Robert Gilkeson, Registered Geologist**
12:00 PM – 1:00 PM	**Adjourn for lunch**
1:00 PM – 1:30 PM	Overview of the LANL Consent Order – **James Bearzi, Chief, Hazardous Waste Bureau, NMED**
1:30 PM – 2:00 PM	Summary of LANL groundwater issues of regulatory importance – **James Bearzi, Chief, Hazardous Waste Bureau, NMED**
2:00 PM – 2:45 PM	A Brief History of Drilling for the Hydrogeologic Workplan at LANL – **Dave Broxton, LANL**
2:45 PM – 3:30 PM	Vadose-Zone Hydrology of the Pajarito Plateau – **Brent Newman and Kay Birdsell, LANL**
3:30 PM – 4:15 PM	Sources of Deep Groundwater Contamination – **Danny Katzman, LANL**
4:15 PM – 4:30 PM	Review of documents to be provided to the NAS panel – **DOE/LANL Staff**
4:30 PM – 4:45 PM	Comments from the Northern New Mexico Citizens Advisory Board – **J.D. Campbell, Chairman of NNMCAB**
4:45 PM – 5:00 PM	Comments from other attendees
5:00 PM	Adjourn open session

Please turn page over for the Agenda for Wednesday, May 17th.

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Wednesday, May 17, 2006

Hotel Santa Fe
1501 Paseo de Peralta
Santa Fe, New Mexico 87501

8:30 AM	Depart Hotel Santa Fe for Pueblo de San Ildefonso
9:00 AM	Tour Pueblo de San Ildefonso (Public are welcome to attend, but must register with Courtney Gibbs [cgibbs@nas.edu or 202-334-2743] before May 12, 2006.)
11:00 AM	Depart Pueblo de San Ildefonso
11:30 AM	Arrive at Los Alamos Inn
12:30 PM	Depart Los Alamos Inn for LANL site tour (Public are welcome to attend, but must register with Courtney Gibbs [cgibbs@nas.edu or 202-334-2743] before May 12, 2006.)
12:45PM – 1:30PM	Hilltop Overlook • Groundwater transport – **David Rogers** • Point to source areas • Canyons transport • Potential receptor areas • Plateau and canyon geology – **Dave Broxton & Dave Vaniman**
1:30 PM – 2:15 PM	Ground and Surface Water Monitoring Sandia Canyon: R-12 (or R-16, R-20) • Groundwater characterization – **Danny Katzman** • Groundwater monitoring plan – **Armand Groffman** • Groundwater sampling • Well quality • Well rehabilitation
2:30 PM – 2:45 PM	Radioactive Liquid Waste Treatment Facility TA-50 – **Pete Worland & Dave Moss** • Discharge improvements • Discharge quality • Sources
3:00 PM	Return to Los Alamos Inn via Diamond Drive
4:00 PM – 8:00 PM	Groundwater Forum poster session begins (Dwayne Smith Auditorium)

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Statement of Task

Los Alamos National Laboratory Groundwater Assessments

This study will focus on specific scientific and technical issues related to groundwater monitoring and contamination migration at LANL as follows:

1. General review of groundwater protection at LANL:

What is the state of the laboratory's understanding of the major sources of groundwater contamination originating from laboratory operations and have technically sound measures to control them been implemented?

Have potential sources of non-laboratory groundwater contamination been identified? Have the potential impacts of this contamination on corrective-action decision-making been assessed?

Does the laboratory's interim ground water monitoring plan follow good scientific practices? Is it adequate to provide for the early identification and response to potential environmental impacts from the laboratory?

Is the scope of groundwater monitoring at the laboratory sufficient to provide data needed for remediation decision-making? If not, what data gaps remain, and how can they be filled?

2. Specific data-quality issues:

Is the laboratory following established scientific practices in assessing the quality of its groundwater monitoring data?

Are the data (including qualifiers that describe data precision, accuracy, detection limits, and other items that aid correct interpretation and use of the data) being used appropriately in the laboratory's remediation decision making?

3. Recommendations to improve the future effectiveness of the laboratory's groundwater protection program with respect to:

Potential remedial actions for the groundwater contamination, especially for radionuclide contamination for which DOE is self-regulating; and

Monitoring for long-term stewardship.

A Review of Key Groundwater Contaminant Sources at Los Alamos

Danny Katzman, Presenter

LANL ENV-Environmental Remediation and Surveillance Program

May 16, 2006

Presentation topics

- Contaminant sources known to have impacted deep groundwater
- Material Disposal Areas as potential contaminant sources
- Other potential contaminant sources

Contaminant Sources Impacting Deep Groundwater

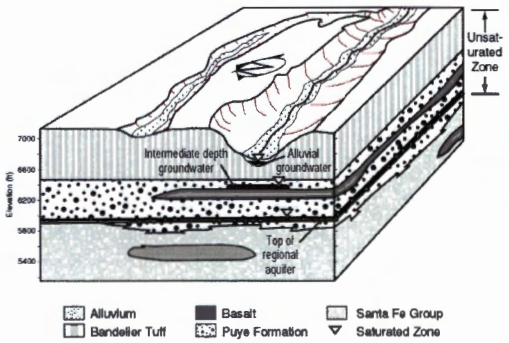
The potential for a contaminant source to impact deep groundwater is governed predominantly by the following:

- large inventory, typically with liquid discharge
- mobile form
- aqueous driver
  - natural or anthropogenic (e.g., facility effluent)
  - concurrent or subsequent to release
- subsurface stratigraphy
  - Important factor for spatial and temporal variability in infiltration

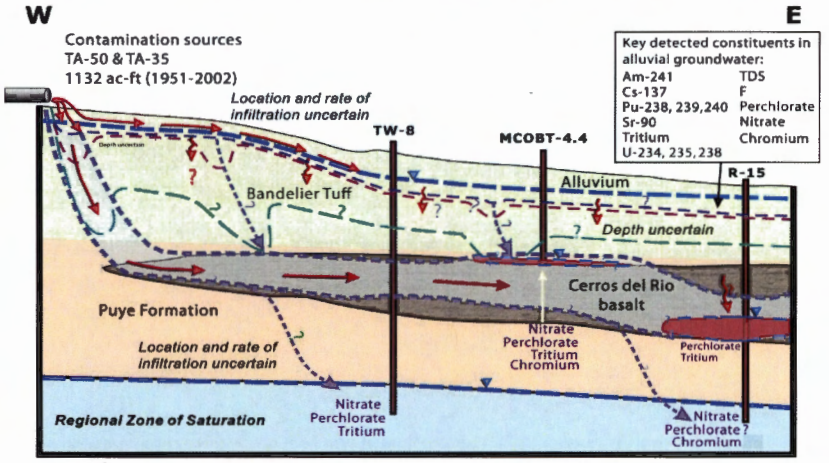
All factors must be present

Contaminants Observed in Deep Groundwater

- tritium
- perchlorate
- chromium
- nitrate
- high explosives
- volatile organic compounds (?)
- others (?)



Mortandad Canyon Hydrogeologic and Contaminant Conceptual Model



Legend

Not to Scale

- Perched zone
- Infiltration
- Adsorbing front for strongly-adsorbing contaminants (Cs, Pu, Am, Cr III)
- Adsorbing front for moderately-adsorbing contaminants (Sr-90)
- Infiltration front for non-adsorbing contaminants (Tritium, Perchlorate, Nitrate, Chromium VI)
- Possible contaminant transport pathways for non-adsorbing contaminants (Tritium, Perchlorate, Nitrate, Chromium VI)

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Current View of Key Sources of Deep Groundwater Contamination and Operational History

Source	Location Canyon (Watershed)	Operation	Period of Operation	Key Mobile Constituents Detected in Deep GW
TA-45 Outfall (SWMUs 45-001 and 01-002)	Acid Canyon (Pueblo)	Rad Waste Treatment	1944 - 1964	tritium, perchlorate
Omega West Reactor (SWMU 02-004[a])	upper Los Alamos Canyon	Research and Moly production	ca. 1970 - 1993	tritium
SWMU 21-011(k)	DP Canyon (Los Alamos)	Industrial wastewater outfall	1952 - 1986	tritium, perchlorate, nitrate
TA-3 Power Plant (SWMU 03-045[h]-00))	Sandia Canyon	Corrosion inhibitor	ca. 1950 - 1972	chromium
260 Outfall (SWMU 16-021[c]-99)	Canon de Valle (Water)	HE machining	1951 - 1996	high explosives (RDX), VOCs(?)
TA-50 Outfall (NPDES Outfall 051)	Effluent Canyon (Mortandad)	Radioactive Wastewater Treatment	1963 - present	tritium, nitrate, perchlorate
Los Alamos County Bayo Wastewater Treatment Plant	Pueblo Canyon	Sanitary wastewater treatment	1963 – present	nitrate, other (?)
Canyons sed and alluvial GW	Secondary sources	NA	variable	tritium, perchlorate, nitrate, chromium, high explosives, VOCs

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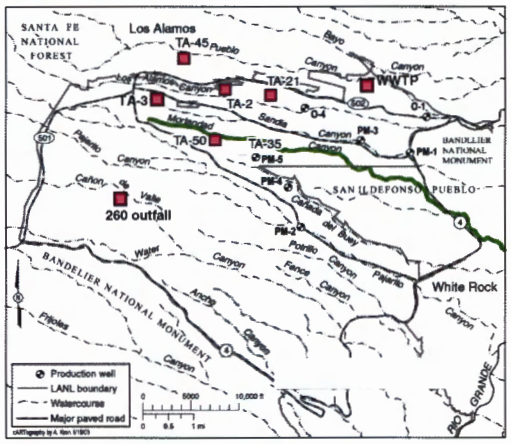
Primary Sources



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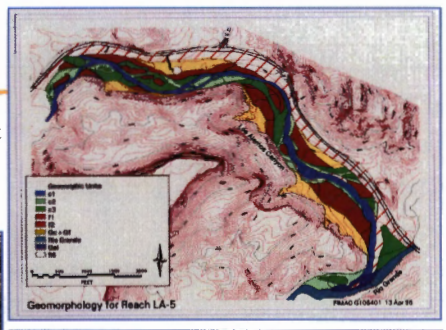
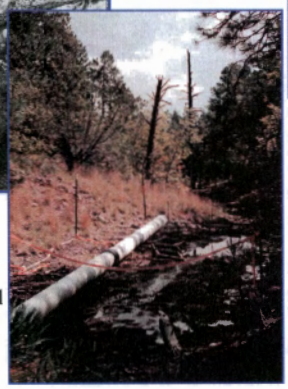
Examples of Sources

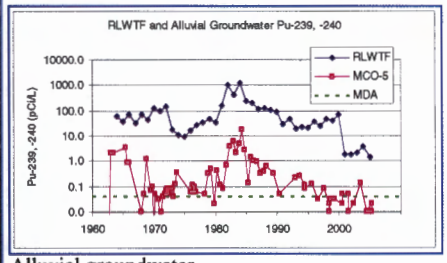
TA-45 outfall

Canyons sediment





260 outfall



Alluvial groundwater

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SWMU Report - Example

Consolidated Unit 45-001-00 --- Wastewater treatment plant - TA-45

Technical Area TA-45
Dates of Operation 1943-1964
Former Operable Unit OU 1079
Structure Number Various

Has ER Sampled the Site? Yes
ER Remedial Action Conducted? No
Other Remedial Action Conducted? Yes
Aggregate Area (Reporting) Pueblo Canyon

Unit Description:

Consolidated unit 45-001-00 consists of consolidated unit 01-002(b)-00, SWMUs 45-001, 45-002, 45-003, 45-004 and AOC C-45-001. These SWMUs and AOC consist of an untreated waste outfall, a wastewater treatment facility and outfall, a vehicle decontamination facility, waste lines, a sanitary sewer outfall, and the location of a past radioactive waste spill. These SWMUs and AOC were all associated with past wastewater treatment and disposal activities at TA-45.

Consolidated unit 01-002(b)-00 consists of a former industrial waste line outfall and its drainage into Acid Canyon. The outfall was located within the boundaries of former TA-45 at the head of a small branch of Acid Canyon known as the south fork of Acid Canyon. This outfall was used to discharge untreated RLW generated in laboratories and research facilities in former TA-01. These wastes were routed from TA-01 facilities to the outfall by a sewer system referred to as the industrial waste sewer system or acid waste sewer system. Most of this system was removed during decommissioning of TA-01 and associated contamination was investigated as part of the investigations for TA-01. Consolidated unit 01-002(b)-00 only includes the outfall and contamination in the drainage channel below the outfall. Discharges of untreated RLW from consolidated unit 01-002(b)-00 occurred from 1943 to 1951 and ceased when the TA-45 RLW treatment plant (SWMU 45-001) began operation. **During the period 1943 to 1951, approximately 4,800,000 gal. of untreated wastewater was discharged annually from SWMU 01-002(b)-00.** D&D of TA-45 began in October 1966 and included removal of the outlet pipe, an associated weir box, and tuff around the outfall and on the canyon wall below the outfall. Wastes generated during these activities were disposed of at TA-54. In September 1967, the TA-45 property was transferred to Los Alamos County. Several environmental investigations have been conducted at consolidated unit 01-002(b)-00. The earliest investigations were conducted from 1945 to 1947 and identified radioactivity near the outfall and downstream of the outfall. The TA-45 site, including consolidated unit 01-002(b)-00, was investigated by DOE during the period 1977-1981 as part of FUSRAP. This investigation included analysis of soil and sediment samples collected at and below outfalls. Based on the results of this sampling effort, additional soil and tuff were removed from consolidated unit 01-002(b)-00 along the drainage channel below the outfall.

Improved Water-Quality in Active Outfalls

RLWTF Annual Report for 2004 (LA-UR-05-4395)

A.6.2 Process Modifications

Discharge standards become more stringent each year. In 2001, for example, the NPDES permit for Outfall #051 was revised. Improvements to the process are also continually sought. There are economic and environmental benefits from changing process equipment and/or flows. A list of recent process modification projects is summarized in Table A-5 below, and a brief description of each appears in the text that follows.

Table A-5
Recent RLWTF Process Modifications

Completed	K$	Project
1996	800	1. Replace old PDP 1144 computer control system
1997	1,200	2. Install four above-ground storage tanks (Bldg 50-248)
1999	200	3. Electrochemical denitrification
1999	4,050	4. Membrane processes (TUF, CUF, RO)
1999	350	5. Electrodialysis reversal
2000	1,400	6. Interim evaporator
2001	300	7. TUF upgrades and valve replacement
2001	6	8. Use of gravity filter effluent for clarifier chemicals
2001	20	9. Permanganate pre-oxidation
2002	300	10. Ion exchange for perchlorate removal
2003	150	11. Replace old G2 computer control system

MDAs as Potential Sources of Deep Groundwater Contamination

25 Material Disposal Areas across the Laboratory

- Large, buried contaminant inventory
- Includes mobile constituents
- Located on dry mesa tops with little or no continuous aqueous driver
- Vapor phase migration from MDAs is known and currently being investigated (e.g., MDA L)
- MDAs are being investigated through 2010 w/corrective actions scheduled through 2015 under Consent Order

Significant Potential Sources of Contamination (cont.)

Watershed	MDAs
Los Alamos/Pueblo	B, V, T, A, U
Mortandad	C, W, X
Water/Canon de Valle	R, R, Z, S, N, AA
Pajarito	G, H, L, M, F, Q
Ancho	AB, Y
Chaquehui	D, E, K

Other Potential Deep Groundwater Contaminant Sources

Large number of mesa top and mesa slope SWMUs and AOCs

- Septic tanks and drain lines
- Surface spills
- Firing sites and mortar impact areas
- Many other types

These SWMU and AOC sources:

- include mobile constituents
- have relatively small inventories
- generally limited aqueous driver
- if liquid release was significant, then the affected canyons media became potentially important as a secondary source term and not the SWMU footprint

Summary

- The most important contaminant sources are high mass/high volume historical outfalls that are no longer in operation or are now releasing significantly reduced concentrations
- Improvements have been made in discharge quality and ongoing monitoring is being conducted
- Key documents for reviewing historical sources include the SWMU report, the General Facility Information report, and facility-specific treatment and monitoring reports (e.g., RLWTF Annual Report for 2004)
- Further discussion is anticipated at the August workshop

Vadose-Zone Hydrology of the Pajarito Plateau

Presenters: Brent D. Newman & Kay H. Birdsell

Earth & Environmental Sciences Division
Los Alamos National Laboratory
Los Alamos, NM

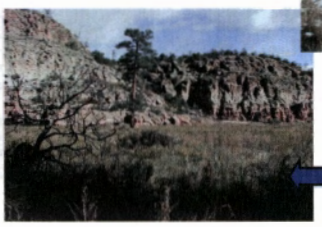
Part 2: Vadose-zone conceptual models and canyon hydrology

LANL Diverse Site: Described by 4 Conceptual Models

Dry and Disturbed Mesas

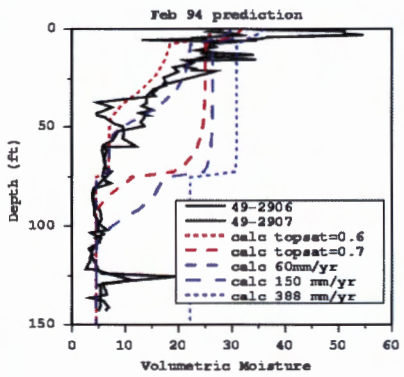
Mountain Front Mesas

*Wet Canyons



Dry Canyons

Dry and Disturbed Mesas



Site with Asphalt Pavement

Dry Mesa – Brent's examples
- Fingers mesa shed precipitation and runoff
- Thick nonwelded tuffs (matrix flow)
- Low water contents (generally <5%)
- Net infiltration rates on the order of 1 mm/yr
- Deep evaporation

Disturbed Mesa
- Liquid discharges, loss of vegetation, surface disturbance and open pits
- Temporarily higher infiltration rates
- Elevated water contents

Example
Site paved from 1961 through 1999
- Limited evapotranspiration
- Dammed surface water
- Infiltration through cracks
- Matrix properties
- Rate increased from ~0.1 mm/yr to ≥ 60 mm/yr
- Slow drying since 1999 (Levitt et al., 2005)

Mountain Front Mesas

- Greater precipitation
- Naturally wetter and greater recharge than dry mesas
- Broader mesas shed less precipitation and runoff, less deep evaporation
- Thick welded tuffs (fracture flow observed)
- Greater variation in infiltration rates with some rapid flow
- Springs are common

Dry Canyons

- Head on plateau
- Small catchment areas
- Limited surface and near-surface alluvial water
- Not highly eroded - nonwelded tuff bedrock
- Infiltration rates not much higher than dry mesas, a few mm/yr

Wet Canyons

TA-50 outfall

Wet Canyons – Anthropogenic Sources

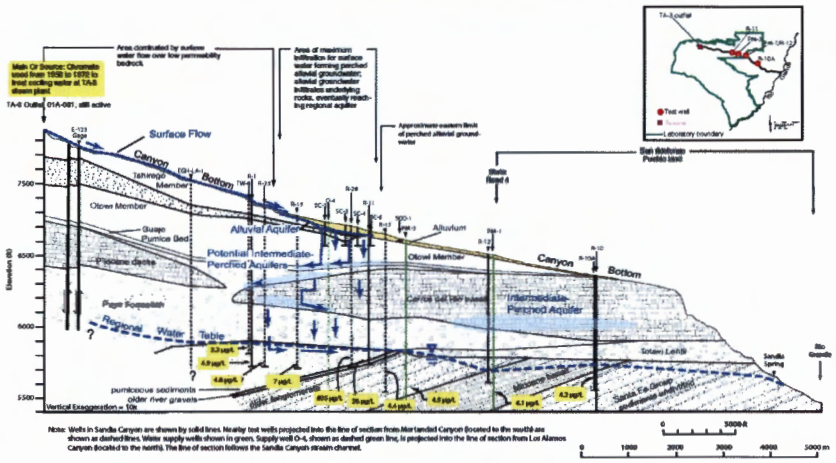
- Effluent generates wet canyon conditions

Naturally Wet Canyons

- Head in mountains
- Large catchment areas
- Collect and channel precipitation and runoff
- Surface and near-surface alluvial water
- Deep erosion – thinner tuff units, basalts exposed
- Intermediate perched zones common
- Infiltration rates up to 1 m/yr

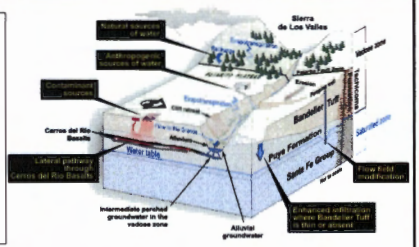
Wet Canyon Flow and Transport

Schematic Geologic Cross Section Showing Potential Chromium Transport Pathways and Hexavalent Chromium Values for Monitoring Wells and Water Supply Wells in the Vicinity of Sandia Canyon



Alluvial Groundwater

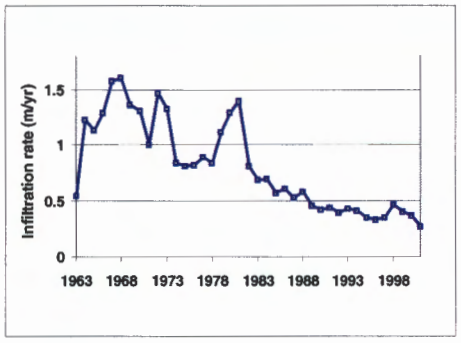
- Alluvial groundwater is a significant lateral fast pathway
- Conservative contaminants are rapidly flushed from the alluvial groundwater into the deeper vadose zone
- Sorbing contaminants tend to remain close to the source in the alluvial system

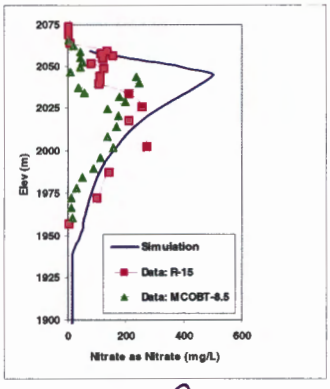


Tritium and Chloride Tracer Test in Mortandad Canyon
Purtymun, 1974, LA-5716-MS

	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

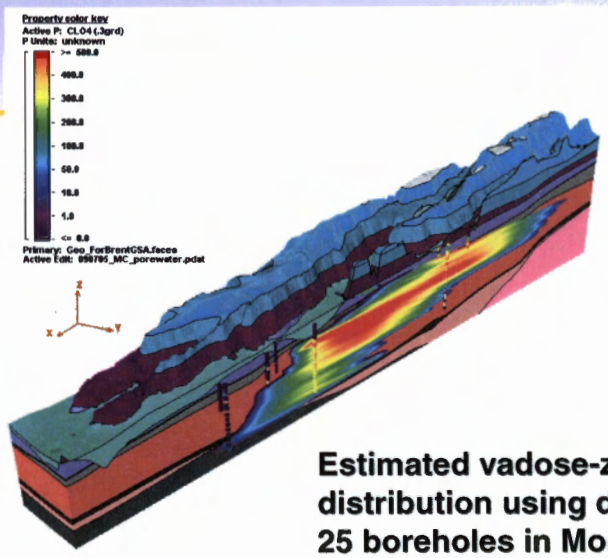
Effluent Volumes vs. Deep Infiltration





For Mortandad Canyon

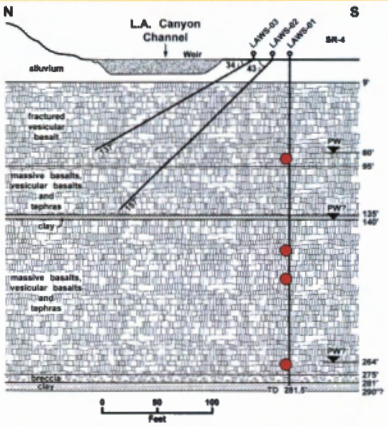
- Infiltration rate linked to effluent volumes
- Simulated nitrate profile (with depth) agrees with data



Estimated vadose-zone perchlorate distribution using data from 25 boreholes in Mortandad Canyon
(preliminary result)

Wet Canyon Flow and Transport

Vadose Zone – Transport through basalts



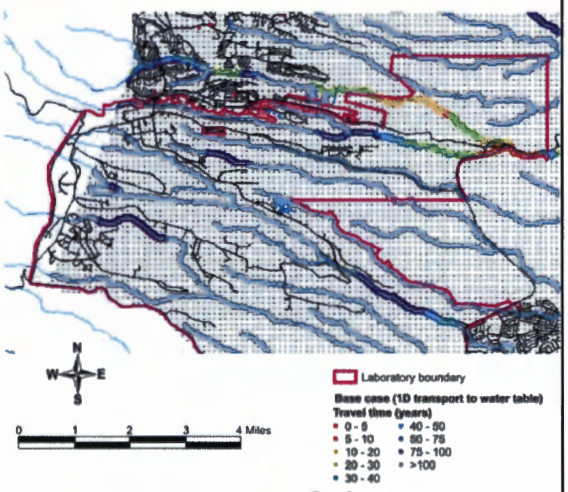
- For basalts, the measured transport times from the surface to significant depths are on the order of days to months
- Flow and transport occurs exclusively through fast paths

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



Summary
Implications for Transport Rates

Beneath wet canyons with liquid drivers
Laterally in alluvium (and perhaps perched zones)
Through fractured basalts

Beneath canyons with a significant thickness of Bandelier tuff
Beneath disturbed mesa top sites
Beneath dry canyons

From stabilized or undisturbed dry mesa top sites

Agrees with contaminant distributions observed in alluvial, intermediate perched and regional aquifer waters

Vadose-Zone Hydrology of the Pajarito Plateau

Presenters: Brent D. Newman & Kay H. Birdsell

Earth & Environmental Sciences Division
Los Alamos National Laboratory
Los Alamos, NM

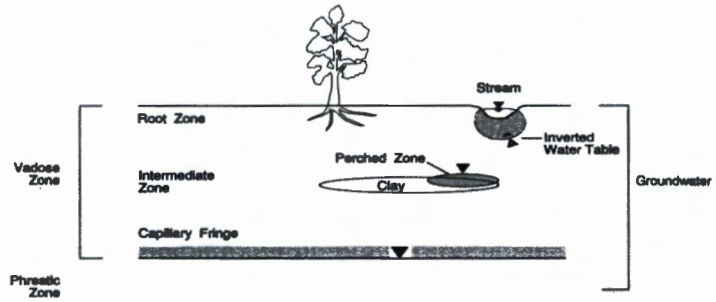
Overview of Talk

Part 1: Regional Observations of Mesa and Canyon Vadose-Zone Hydrology under "Natural" Conditions

Part 2: LANL-Specific Vadose-Zone Conceptual Models and Canyon Hydrology

Part 1. Mesa & Canyon Vadose Hydrology Under "Natural" Conditions

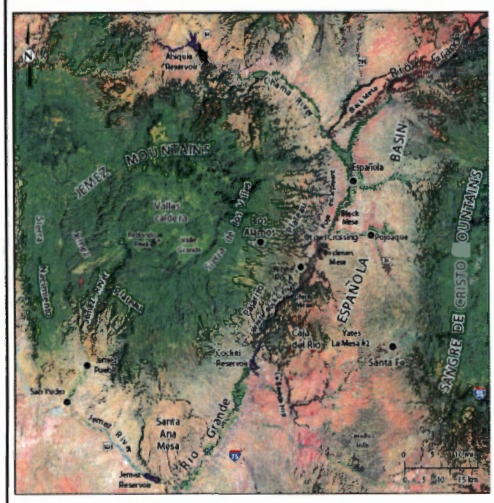
The vadose zone is the region between the land surface and the regional water table



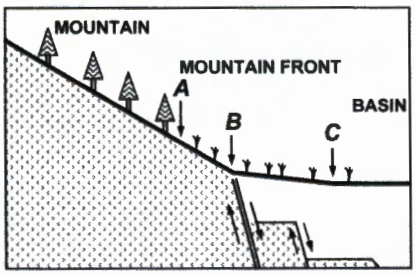
From: D.B. Stephens, 1996

- **Has a major impact on groundwater recharge and water quality**

Focus on the vadose zone within the Española basin



Exclude the mountain block & front, & the riparian zone around the Rio Grande & Chama



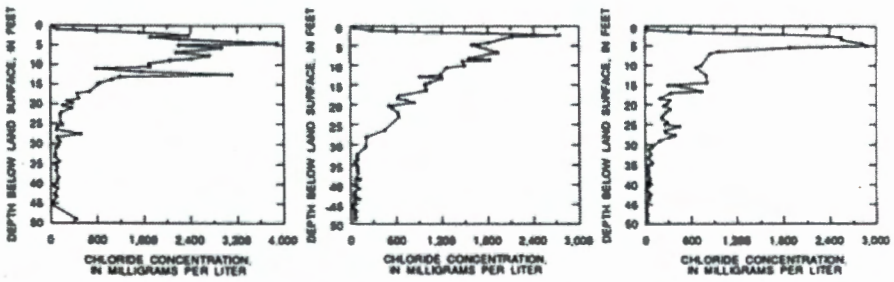
From Wilson and Guan, 2004

Chloride Mass Balance

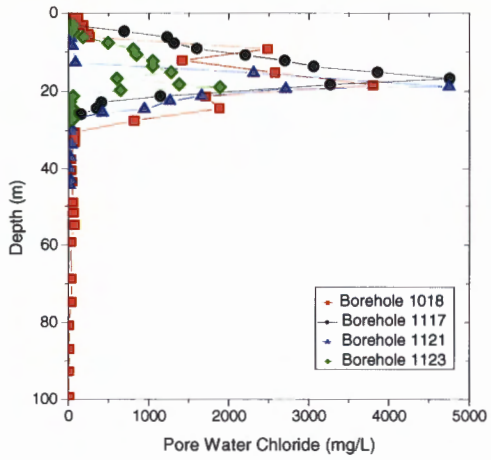
- Downward flux is inversely proportional to chloride content in the rock or sediment.
- Vadose residence time is proportional to chloride content in the rock or sediment.

1. Flux (m/yr) = $(Cl_p P)/Cl_{sw}$
2. Residence Time = $Cl_{cum}/(Cl_p P)$
   - P is ave. annual precip. (m/yr); Clp is ave. chloride concentration in precip. (g/m3); Clsw is ave. pore water chloride concentration (g/m3); and Clcum is ave. pore water chloride concentration over a depth interval (g/m3)

Santa Fe area chloride profiles from mesa sites (Anderholm, 1994, USGS WRIR 94-4078)



- Vadose zone residence times are 6,700 to 8,800 years

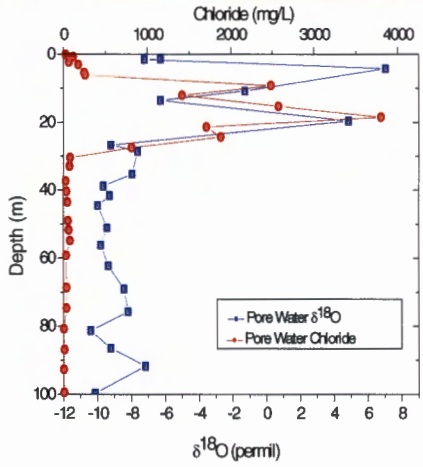


Chloride Profiles from Mesita del Buey Boreholes at Los Alamos

Los Alamos Chloride Mass Balance Results

- Downward fluxes < 1 mm/yr
- Residence times 1,300 to 18,000 years

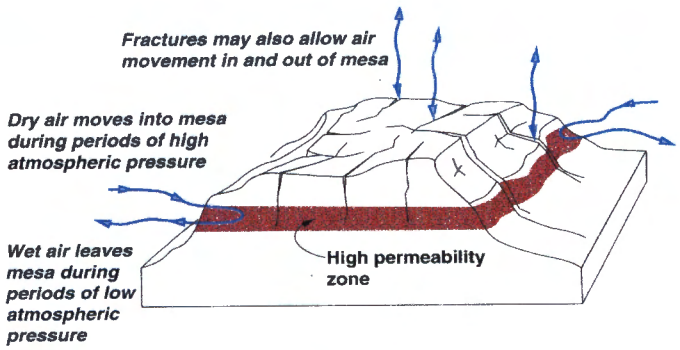
Why are mesa fluxes so low?



- Heavy stable isotope values suggest deep evaporation may restrict downward flow in mesas

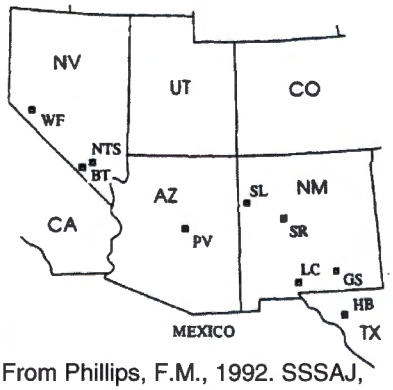
Borehole 1018, Los Alamos, Pore Water Chloride and $\delta^{18}O$

Conceptual Model of the Deep Evaporation Process



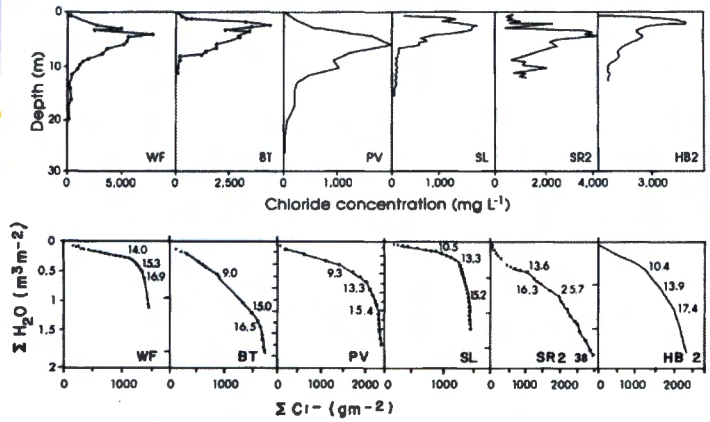
Even though water contents are low, air in pore spaces will be at or near saturation (~95-100% relative humidity)

The Southwest Regional Context



From Phillips, F.M., 1992. SSSAJ, 58:15-24

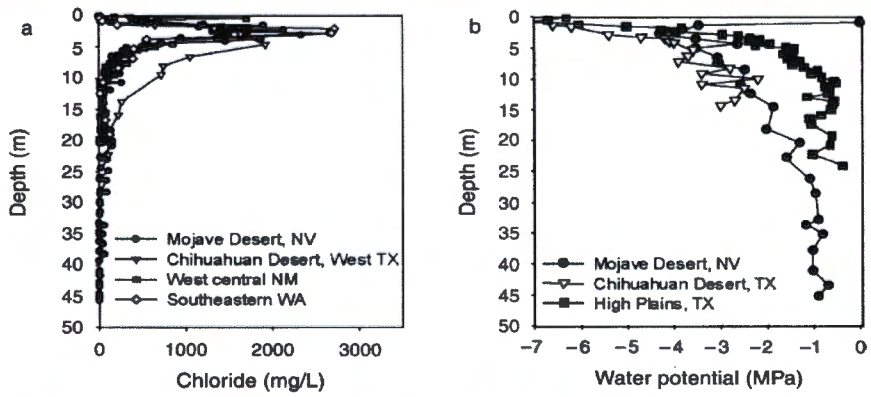
Phillips, 1992 examined multiple chloride, tritium, and ^{36}Cl profiles across the Southwest



From Phillips, F.M., 1992. SSSAJ, 58:15-24

- Chloride based fluxes and residence times are similar
- Indicates no recharge in interdrainage areas across the Southwest since the Pleistocene (>10,000 years)
- Subsequent studies have continued to support these results

Chloride & Potential Profiles from NM, NV, & TX (Walvoord et al., 2002, WRR, 38:1308)



- Potential data indicate upward not downward fluxes
- This behavior certainly occurs in the Española Basin
- It is another reason why mesa fluxes are so low

Pajarito Plateau (Los Alamos) Canyon/Mesa Comparison

	Max Cl^-	Ave Cl^-	Max PO_4^{3-}	Ave PO_4^{3-}	Max SO_4^{2-}	Ave SO_4^{2-}	Max $\delta^{18}O$	Ave $\delta^{18}O$	Max θ_v	Ave θ_v
Canyons	172	30	54	10	641	78	-7	-10	52	20
Mesas	1761	398	99	19	8913	766	-1	-8	18	7
Delta	1589	368	45	9	8272	688	6	2	-33	-13

From Birdsell et al., 2005, VZJ, 4:620-636

- Examined 9 Canyon Boreholes & 13 Mesa Boreholes
- Mann-Whitney U Tests indicate significant differences for all parameters except for phosphate

Comparison of Canyon and Mesa Water Contents and Chloride

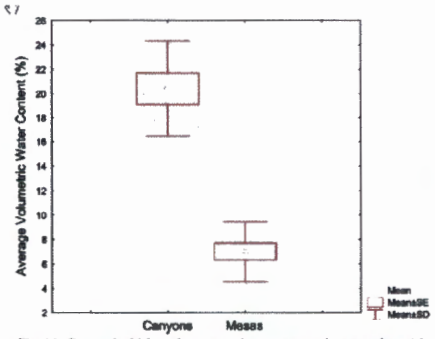


Fig. 14. Box and whisker plot comparing canyon and mesa volumetric water contents.

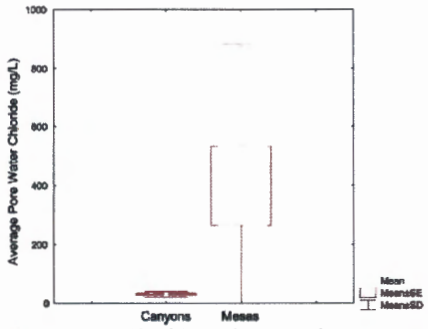
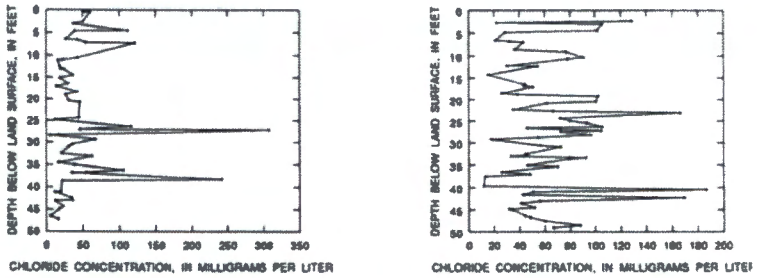


Fig. 15. Box and whisker plot comparing canyon and mesa pore water chloride concentrations.

From Birdsell et al., 2005, VZJ, 4:620-636

- Borehole profiles from the Santa Fe area (Anderholm, 1994, WRIR 94-4078) also show higher fluxes (and recent recharge) at arroyo locations



- Minimum downward fluxes are about 2 mm/yr
- Also observe higher water contents than in mesas

Summary (Part 1)

- Little to no recent recharge over much of the mesa (interdrainage) area in the Española Basin because of the thick, dry vadose zone.
  - Chloride profiles from the areas around Los Alamos and Santa Fe suggest vadose zone residence times of 1000+ years (sometimes >10,000 years).
  - These results are consistent with other studies in the Southwest
- However, drainages within the basin do indicate recent recharge
  - Lower amounts of chloride and higher fluxes

A Brief History of Drilling for the Hydrogeologic Workplan at LANL

David Broxton

May 16, 2006

NAS Meeting

Need for Hydrogeologic Characterization

- **1989 EPA/NMED RCRA Operating Permit:** Monitoring for RCRA-regulated units
- **1990 HSWA Permit issued:** Task III, Section A.1 requires evaluations of hydrogeologic conditions
- **1991 LANL Self Assessment:** Groundwater monitoring at 22 unevenly distributed wells not adequate
- **1991 Tiger Team Findings:** Monitoring network not extensive enough
- **1995 Groundwater Protection Management Plan**: recognize groundwater issues due to inadequate characterization
- **1995 NMED letters**: inadequate characterization and denial of groundwater monitoring waiver
- **1998 Hydrogeologic Workplan Approval:** NMED approval of Laboratory plan to characterize LANL's hydrogeologic setting

NMED 1995 Letters

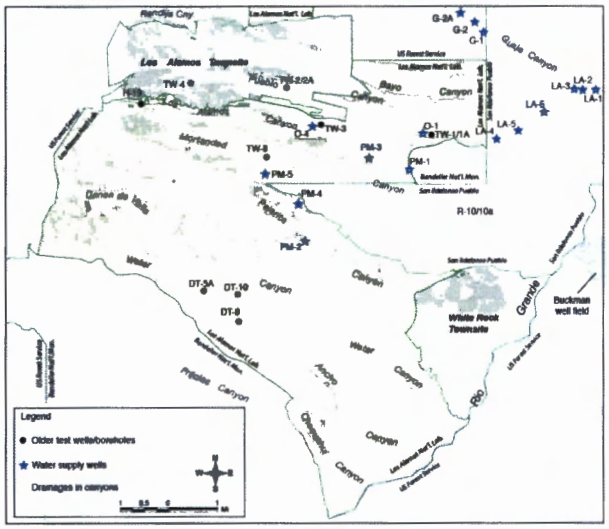
- Individual zones of saturation have not been adequately delineated and the hydraulic interconnection between these is not understood.
- Recharge areas for regional and intermediate aquifers and any associated effects of fracture/fault zones with regards to contaminant transport and hydrology are not identified
- Groundwater flow directions in perched and regional aquifer, as influenced by pumping production wells, are not known
- Aquifer characteristics cannot be determined without additional monitoring wells installed in specific intervals of the various aquifers beneath the facility

Hydrogeologic Workplan (HWP)

- Primary purpose: hydrogeologic characterization to develop a refined understanding of the hydrogeologic setting in order to design an effective monitoring network
- Submitted to NMED in December 1997; approved March, 1998
- Developed using EPA's Data Quality Objective (DQO) Process
- Data collection focused by consideration of contaminant sources, release mechanisms, and transport

Circa 1997...

- 7 regional aquifer test wells and 2 deep borings
- 2 intermediate depth wells
- 14 regional aquifer water supply wells



Los Alamos NATIONAL LABORATORY EST. 1943

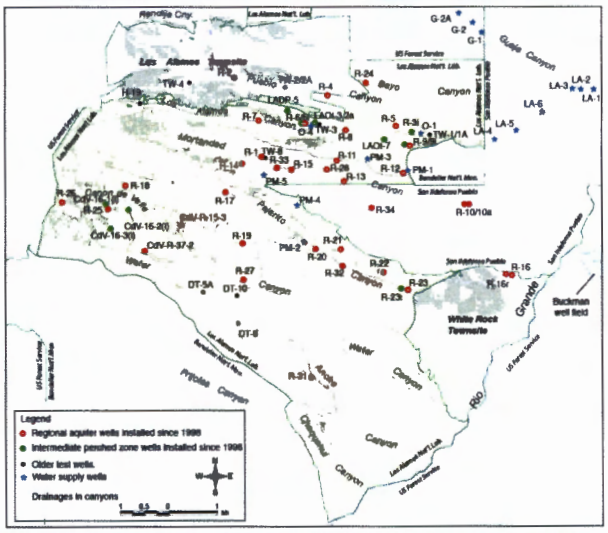
The World's Greatest Science Protecting America

LA-UR-06-3516

NNSA

Now...

- 35 new regional aquifer wells with 84 well screens (71 functional)
- Approximately 22 new intermediate-depth boreholes and wells since 1998



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NNSA

Develop DQOs for Each Characterization Well

- Conceptual model for watershed used to identify potential release sites, how contaminants would move, and where they were likely be detected
- Gave special consideration given to issues previously identified in the 1995 NMED letters
- Identifed and prioritized site-specific characterization goals (e.g. determine if contaminants are present in groundwater at the Laboratory boundary, determine whether springs in White Rock Canyon represent perched or regional groundwater)

DQOs cont.

- Specified Data to be Collected:
  - Hydrogeology - e.g. water-bearing zones, water levels, gradients, aquifer properties, stratigraphy, lithology, structure
  - Geochemistry - e.g. general water quality, contaminant distribution, geochemical controls on groundwater compositions
- Identified methods for data collection (e.g. core/cuttings, water samples and analyte suites, borehole geophysics, water level measurements, in-situ hydraulic tests, other laboratory measurements)
- Selected well locations, target depths, and conceptual well designs to satisfy DQOs

From DQOs to Drilling Methods

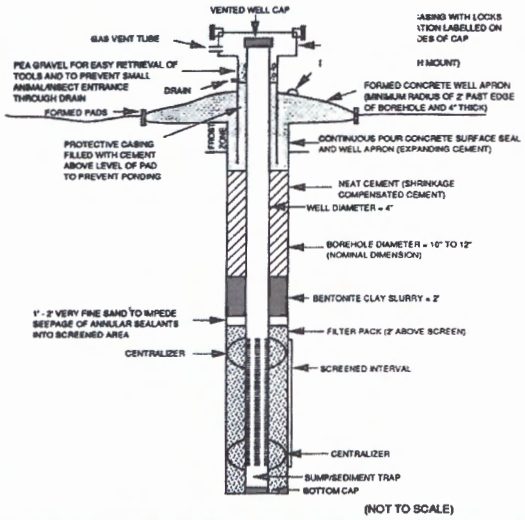
- Drilling methodology tailored to meet the data requirements identified by the DQO process
- When selecting drilling methods, considered:
  - What drilling methods are capable of reaching the desired depths?
  - What diameter does the borehole need to be in order to accommodate the conceptual well design and/or instrumentation?
  - How does the predicted geology influence drilling choices?
  - How many perched zones will be encountered? (do any of these need to be isolated from the regional aquifer?)
  - How deep into the regional aquifer is the target depth?
  - How do the various drilling approaches impact the DQOs?

Well Types

In the approved work plan:

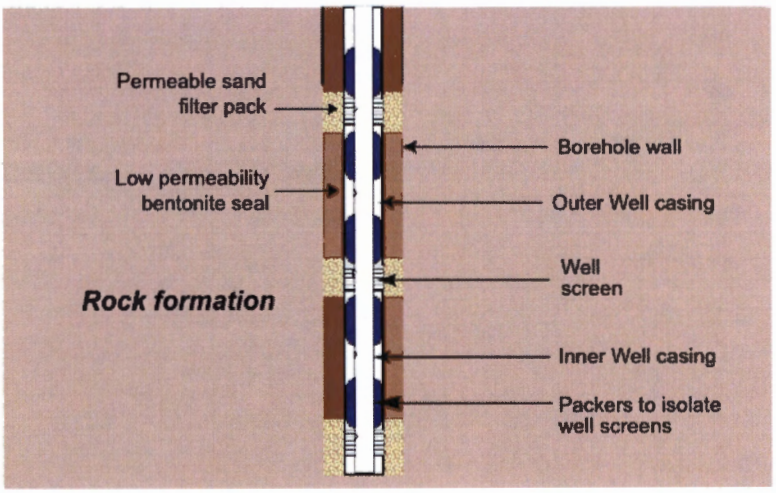
- 32 regional aquifer wells
- Originally planned with single screens straddling the regional water table (with boreholes extending several hundred feet into the upper part of the regional system for characterization)
- Multiple screen wells added during early stages of program implementation

Single Screen Well Completion



EPA, 1991

Multiple Screen Well Completion

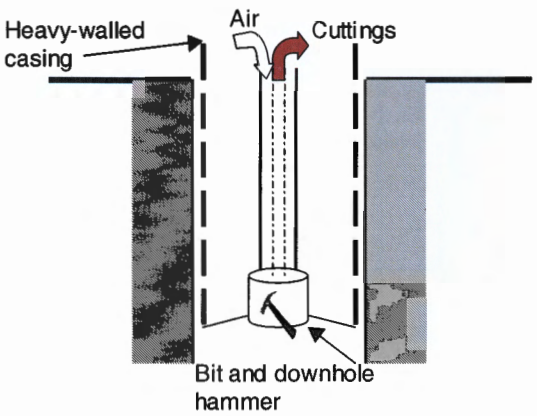


R-9 - An Example of a Characterization Well's History (initial borehole installed in late 1997)

Primary Goals:

- Collect water quality data down gradient of contaminant release sites in Los Alamos Canyon (e.g. TA-21, TA-41)
- Monitor water quality at the top of regional saturation near the eastern Laboratory boundary
- Identify zones of intermediate-depth perched groundwater and determine their water quality
- Determine geologic controls on regional and perched zone hydrology in a relatively poorly characterized part of the Laboratory

Down-Hole Bit/Hammer Casing Advance



Use of drill casing:

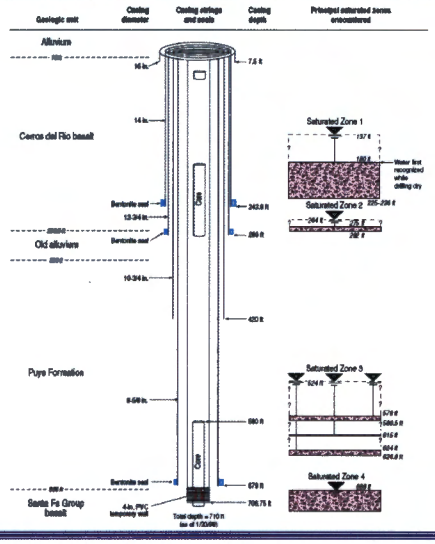
Stabilize borehole in unstable geologic formations (e.g. Otowi Member, basalt, Totavi)

Cover loss-circulation zones

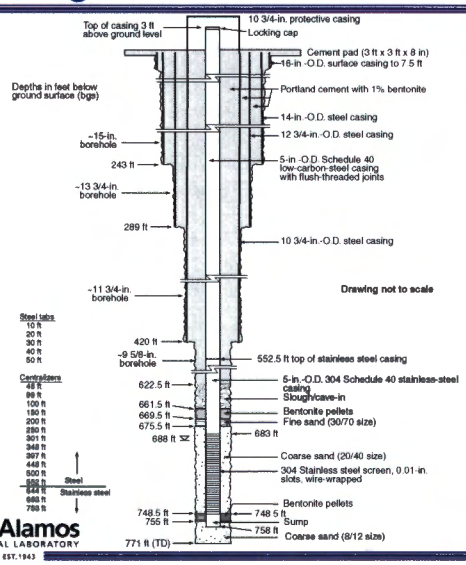
Seal off intermediate perched groundwater when drilling to the regional aquifer

R-9 Example Cont.

R-9



Well Completion and Problems Extracting Drill Casing



Other wells with abandoned drill casing:

R-7 13.375" from 60-290 ft

R-8 11.75" from 184-684 ft

R-9 14" from 0-230 ft

R-9 12.75" from 0-289 ft

R-9 10.75" from 0-420 ft

R-12 14" from 0-449 ft

R-16 11.75" from 0-729 ft

R-19 13.625" from 113-205 ft

R-31 9.625" from 52-124 ft

R-25 13.375" from 508-578 ft

Total 2632 ft

Well Screen Placement

- Typical targets:
  - Perched water zone(s)
  - Regional water table
  - High permeability zones (potential contaminant pathways)
  - Major hydrostratigraphic units (modeling)
  - Vertical distribution for vertical pressure and geochemical gradients
  - Zones that were considered to have "representative hydraulic properties" for some rock units
- Examples of Data Considered:
  - Water levels
  - Geologic information from cuttings/core
  - Geologic and hydrologic information from borehole geophysics
  - Driller's observations about water production and drilling behavior
  - Long-term decline in water levels from pumping of nearby supply wells

Concern About Well Costs

- Well and characterization costs for first wells were strongly criticized
- There were concerns that the drilling was too expensive for the program goals to be achieved
- The inspector general's office opened an investigation into drilling costs

Lab Water-Testing Well Costs Rising

Journal Arch 4/11/98

from PAGE 1

ical makeup. Only three aquifers were expected.

One aquifer also was under pressure, making it hard to seal off so drillers could press on to the deep aquifer at about 720 feet. These unexpected factors, said lab and DOE officials, doubled the work at R-9 to 80 days and so boosted the well's cost significantly.

"You can't see what's below the surface of the Earth until you take a look at it," Koch said. "We consider this to be a valid addition of scope, and so DOE is not concerned."

R-9 is to yield the first unambiguous answers to crucial questions: Has LANL's weapons research sent radioactive and hazardous pollutants through 700 feet of rock into the deep, regional aquifer? If so, will more dangerous lab wastes — now suspended in the canyon bottom — be far behind?

The answers lie in the complex volcanic rock and layers of water under Los Alamos. So while drilling R-9, scientists also took rock samples and ran sophisticated geophysical tests to look for fractures in surrounding rock — all designed to see how fast contamination might move down toward the deep aquifer.

"This is really the first time a hole of this kind has been drilled at Los Alamos," said Allyn Pratt, head of the lab's project to measure the risk of contamination in Los Alamos' canyons.

A preliminary breakdown of costs at R-9 shows the lab itself contributed to the overruns. During the drilling, a number of scientists, engineers, technicians and consultants from nine different lab management groups billed the well's account for their time on site. These included radiation-safety technicians, geologists, hydrologists, chemists, facility managers and occupational-safety inspectors.

In all, payment of lab personnel on site amounted to over $320,000. More than $180,000 of this was not in R-9's original budget.

"The whole thing sounds like a money tree, and they're shaking it real hard," said Jay Coghlan, an activist who studies the lab's environmental cleanup for the Santa Fe watchdog group Concerned Citizens for Nuclear Safety.

"This gold-plated hole aligns perfectly with the lab's primary mission, which is to burn up money," he said. "It shows the lab's inability to be competitive in a business sense."

At times during the drilling, lab employees were taking rock and water samples while the drill crew and rig stood by, at a cost of hundreds of dollars an hour.

"We're very aware of trying to be good stewards with the public funds. We try to keep the drill crews off the site as much as we can," said LANL's Pratt. "I pay taxes, too."

Lab and DOE officials say they are looking at ways to curb the costs of future wells, for example, with less expensive drilling techniques.

Oversight and Review of Drilling Program

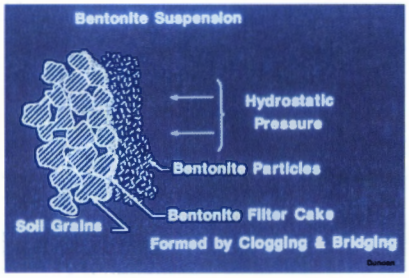
- External Advisory Group semi-annual review (1998-2002)
- DOE Value Engineering Review (2001)
- Inspector General Audits/Investigations (1999, 2001, 2004)
- NMED/AIP (1998 to present)
- Northern New Mexico Citizens Advisory Board (1998 to present)

Evolution of Drilling Methods and Well Design

- This was an ongoing process throughout the project
- Fluids progressively introduced over time to address borehole stability and casing friction problems
- Additional drilling methods introduced into the drilling toolbox to provide more options for dealing with drilling problems
- Simpler regional wells installed - more single screen wells and fewer screens placed in multiple screen wells
- Perched zones identified while drilling regional wells, but installation of perched-zone wells deferred until later
- In addition to passive-flow sampling systems, low-flow sampling systems and to two-screen high-flow sampling systems in multiple screen wells introduced

Fluids Introduced to Facilitate Drilling

- Drilling fluid function:
  - cools the drill bit
  - circulates cuttings out of borehole
  - provides structural stability to the borehole
  - Lubricates casing
- LANL-utilized fluids:
  - air
  - water
  - air-foam and water-foam
  - polymers (e.g. EZ-Mud)
  - bentonite clay
- Drilling conditions dictated the initial drilling fluid selection. Fluids were adapted as changing drilling conditions were encountered.



Drilling Fluid Characteristics

- Small quantities of polymer additives, or polymer-based drilling fluids, are used as "binding agents" along with the bentonite clay drilling fluid
  - Used to decrease fluid loss to the formation
  - provides greater viscosity to aid circulating cuttings to the surface
- Bentonite clay-based drilling fluid
  - Used to provide stability to the borehole wall
  - Typically develops a "filter cake" on the borehole wall approximately 2/32-inch thick
  - Filter cake reduces fluid loss to the rock formations

Evolution of Drilling Methods

Drilling Method	Example Wells (total depth)	# Screens	Comments
Casing advance, dry	R-9 (771 ft) R-12 (886 ft)	R-9: 1 R12: 3	Good data collected during drilling and fewer complications during well development. Casing frequently stuck. Very expensive and slow
Casing advance, additives	R-25 (1942 ft) R-15 (1107 ft)	R-25: 9 R-15: 1	Decreased but did not eliminate instances of stuck casing; More time needed for well development to remove drilling fluid; Drilling continues to be expensive and slow
Fluid-assisted air rotary, open hole, additives, limited casing advance	R-7 (1097 ft) CdV-15-3 (1722 ft)	R-7: 3 CdV-15-3: 6	More time needed for well development to remove drilling fluid; but less expensive and faster than using casing throughout the hole
Fluid-assisted air rotary, open hole in vadose zone; seal vadose zone with casing; then complete hole in saturated zone with air or mud rotary as conditions dictate	R-2 (943 ft) R-16 (1287 ft)	R-2: 1 R-16: 4	Most flexible for different geologic conditions encountered; more time needed for well to clean up; least expensive and fastest drilling

Well Development

- The process used to repair damage done to the borehole wall during well drilling
- Aims to restore or improve the original porosity and permeability of the formation
- Involves removal of drilling mud and solids and formation fines near the borehole face
- Goals are to produce higher flow rates to the well and to stabilize formation fines so that produced water will be sediment free

Early Well Development Efforts

- Bailing used to remove drilling fluids and other suspended materials from the well
- Airlifting of fluids from the well casing
- Pumping fluids adjacent to the well screen(s)
- Surging water in and out of well screen
- Repeat as necessary

- Development progress was monitored using field parameters. The goal was to produce water with turbidity less than 5 NTU and/or achieving stable water quality parameters (including, pH, temperature, conductivity)

Assessment of Well Development Techniques at LANL by the EAG (Feb. 8, 2002)

- The development procedures used are standard, and they are appropriate, consistent with ASTM standards and accepted groundwater industry standards
- Nonetheless, water samples from completed wells show the presence of drilling additives that have not been completely removed - so further work is needed on well development
- Key physical parameters affecting development:
  1. The wells are deep
  2. The wells are small in diameter
  3. The static water levels are deep
  4. Some of the aquifer materials are tight and low yielding
  5. Multiple zones have substantially different piezometric heads

EAG - Recommendations

- Isolate screens in all multiple completion wells during development
- Pumping, bailing, and air lift to remove drilling fluids and to ensure that fine particles dislodged during development are not re-introduced into the formation
- Induce flow reversal periodically during development so that water is forced into the formation, breaking sand and silt bridges, allowing more fines to be introduced during the next pumping cycle (backwashing, surging, water jetting, introducing compressed air)

Improvements in Development Procedures in Response to EAG Recommendations

- In addition to methods already in use:
  - Employ packers to isolate screens
  - Use of chemicals to break down drilling additives
  - Jet the well screens with water to dislodge fine particulates so they can be pumped from the well
  - During development, remove substantially more water than the volume of fluids introduced during drilling
  - Improve the monitoring of development progress by using quick turn-around laboratory analyses for indicators such as TOC

Final Thoughts in the EAG Report

"There is not one single approach that is guaranteed to produce ideal results"

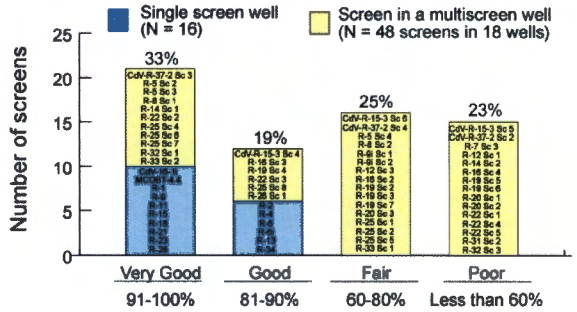
"Even when more extensive development procedures are employed, challenges caused by the physical constraints of the hydrogeologic setting at LANL may tend to neutralize these efforts to some extent"

"… it likely will not be feasible to develop individual screen zones to 'near perfect' conditions, as it might be possible in a large diameter, shallow well in a permeable aquifer with a high static water level.

"However, …it should be possible to obtain acceptable well development and reasonable results"

Well Screen Analysis Report - Nov. 2005

- Analyzed impacts of residual drilling fluids on the ability of the groundwater wells in the regional aquifer to provide representative measurements of contaminants
- Concluded that many screens in multiple-screen characterization wells are impacted



Actions Based on the Well Screen Analysis Report

- Since November 2005 LANL has been developing a groundwater data adequacy project to ensure that the Laboratory is capable of providing reliable monitoring data.
- The project includes:
  - Pilot well-screen redevelopment
  - In response to a request by NMED, LANL is preparing a well rehabilitation and/or replacement plan
  - Work to complete the data qualification process
  - Chemical and hydrology testing and modeling are either underway or planned to address issues raised by EPA

Future Actions

Well Rehabilitation

- Additional development of those screens that yield fair to poor water quality data
- Isolation of individual screens during development
- Use of a new method for jetting (hydropulse)
- To measure effectiveness, use real-time field data and quick-turnaround lab analysis during well rehabilitation

Future Actions Cont.

Sampling system reinstallation options:

- Reinstall passive multi-port sampling systems
- Install low- or high-flow multi-port sampling systems
- Where viable, reduce the number of screens used for monitoring in multiple screen wells. Consider converting multiple screen wells to a single or dual-screen systems that are fully purgeable.
- Continue to refine monitoring objectives. Use the method developed for the Well Screen Assessment Report to measure well performance in meeting monitoring objectives

Future Actions Cont.

New regional aquifer wells:

- Continue to improve drilling toolbox from lessons learned (consider all drilling technologies including the return to dry drilling where possible)
- Focus on specific monitoring objectives that allow for single-screen or dual screen target depths (keep the wells as simple as possible)
- Apply lessons learned during well rehabilitation effort to improve development of new wells.

Final Thoughts

- The Hydrogeologic Workplan wells led to a better understanding of the hydrogeologic setting of LANL
- Data from these characterization wells forms the basis optimizing a long-term effective groundwater monitoring network
- Further work with NMED is needed to refine the monitoring objectives in the Site-Wide Monitoring Plan
- Need to identify which of the HWP characterization wells (or individual well screens) satisfy monitoring objectives
- The monitoring network can be augmented as necessary with new wells whose sole purpose is to provide water quality data