OCTOBER 1999

Los Alamos National Laboratory

EAG SEMI-ANNUAL MEETING AND HYDROGEOLOGIC CHARACTERIZATION PROGRAM QUARTERLY MEETING

October 13-15, 1999

John Kieling

LOS ALAMOS NATIONAL LABORATORY
HYDROGEOLOGIC CHARACTERIZATION PROGRAM QUARTERLY
AND EXTERNAL ADVISORY GROUP (EAG)
COMBINED MEETING

AGENDA

October 13
EAG Meeting
LATA Conference Room, 4th Floor Los Alamos National Bank Building

9:00 Welcome and Overview of the Agenda (C. Nylander)
9:15 Action Plan for EAG March Report

10:15 Break

10:30 Performance Review for Hydrogeologic Workplan activities

12:00 Lunch

1:30 Topical Presentations
- Modeling
- DQO re-visitation results

4:30 Adjourn

LOS ALAMOS NATIONAL LABORATORY
HYDROGEOLOGIC CHARACTERIZATION PROGRAM QUARTERLY AND EXTERNAL ADVISORY GROUP (EAG) COMBINED MEETING

October 14
GIT Quarterly Meeting
Los Alamos Inn, Los Alamos

8:00 Welcome and Introduction (C. Nylander)
8:15 GIT Subcommittee Status Reports

- Information Management (K. Mullen)
- Hydrology (D. Rogers)
- Geochemistry (P. Longmire)
- Modeling (B. Robinson)
- Well Construction (D. Broxton)

10:15 Break

10:30 Status of Field Activities (D. Broxton)

- R-25
- R-15
- R-9
- R-12

LOS ALAMOS NATIONAL LABORATORY
HYDROGEOLOGIC CHARACTERIZATION PROGRAM QUARTERLY
AND EXTERNAL ADVISORY GROUP (EAG)
COMBINED MEETING

11:00 Issues (C. Nylander)

- Response to contaminations
- Drilling schedule

12:00 Lunch

1:30 Stakeholders meet with EAG
3:30 EAG facilitate discussion of stakeholder concerns

5:00 Adjourn

LOS ALAMOS NATIONAL LABORATORY
HYDROGEOLOGIC CHARACTERIZATION PROGRAM QUARTERLY AND EXTERNAL ADVISORY GROUP (EAG) COMBINED MEETING

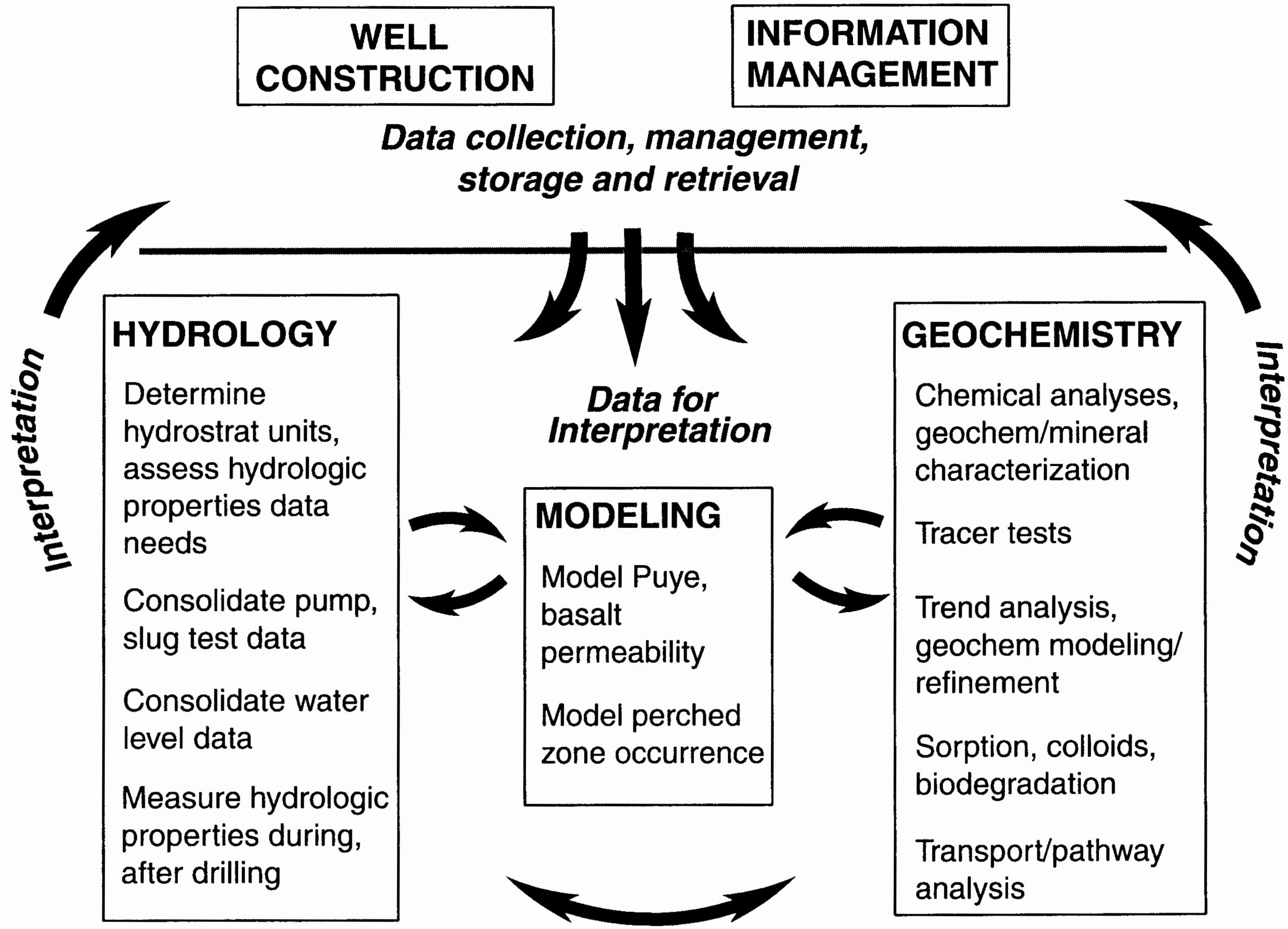
October 15
EAG Meeting
LATA Conference Room, 4th Floor Los Alamos National Bank Building

9:00 EAG meeting with DOE, LANL, and NMED Managers
11:00 EAG facilitate discussion of management concerns

12:00 Lunch

1:30 EAG report preparation

GIT SUBCOMMITTEE INTERPRETIVE TASKS



LANL-GIT Action Plan
for
EAG November 1998 Recommendations

COMPLETED ACTIONS

RECOMMENDATION	ACTIONS
11-98-3: Have NMED representatives present during some portion of the next EEG meeting.	Arrangements have been made with NMED to attend appropriate portions of the next EAG meeting. Invitations will continue.
11-98-6: The proper sequence of priorities should be consistent in Tables 4.1 and 4.2.	The tables have been updated in the Annual Report for FY98 and will be updated in every annual report.
11-98-9: Core should be logged and evaluated as soon as possible after retrieval. Core that will be used for parameter testing or sorptive potential should be stored intact and tested as soon as possible.	Adherence to the Standard Operating Procedures for handling core and other samples will continue.
11-98-11: Review data needs on a continual basis and review the scope of the characterization program on an annual basis in light of what the regulators require.	Continual re-evaluation of the data needs will occur annually, quarterly, and informally in conjunction with stakeholder and EAG input.

LANL-GIT Action Plan
for
EAG November 1998 Recommendations

COMPLETED ACTIONS

RECOMMENDATION	ACTIONS
11-98-13: WESTBAY systems should be demonstrated and well-understood before used.	The use of WESTBAY systems will be evaluated on a well-by-well basis and will incorporate stakeholder and EAG input.
11-98-17: Place filter packs greater than 2 feet (10 to 20 feet) above the top of the screens to account for settling of the filter material in wells that may be used for monitoring.	Adherence to Standard Operating Procedures for well construction and evaluation of current knowledge and experience will continue.
11-98-22: Consider periodic re-bid of drilling work on a combination of per-foot basis for drilling and coring and per-hour basis for other activities.	The development of drilling procurement documents has focused on how to structure the compensation framework.

LANL-GIT Action Plan
for
EAG November 1998 Recommendations

ACTIONS IN PROCESS

RECOMMENDATION	ACTIONS
11-98-1: Continue frequent, detailed and exhaustive communication efforts to keep relationships on the upswing with regulators and the community as well as funding organizations.	Communication will be maintained at a similar level as the past 2 years. Additionally, a web interface will be operational in approximately one year.
11-98-2: Reach agreement with NMED on MCL's (and ACL's).	Initial discussions occurred at January 1999 Quarterly Meeting, and the proposed approach was discussed at the Annual Meeting in March 1999.
11-98-7: Develop contingency for examination of intermediate zones, particularly working with stakeholders to evaluate tradeoff between deep wells and shallower wells.	A proposed approach will be discussed with NMED at the Annual Meeting. When finalized, it will be formalized by inclusion in the reauthorized RCRA permit.
11-98-14: FIMAD should more rapidly incorporate legacy data and the system should be available for timely use by stakeholders	The Groundwater Database is in development.

LANL-GIT Action Plan
for
EAG November 1998 Recommendations

ACTIONS IN PROCESS

RECOMMENDATION	ACTIONS
11-98-15: The three-person drilling crew should have backups in case of fatigue, illness, or other reasons.	The staffing provided under the drilling contract is under close scrutiny. Procurement for continued drilling services to be released fall 1999 should specify staffing levels.
11-98-20: Revise budget and update projections on a continual basis to reflect iterative nature of the program.	This recommendation will be fully implemented at the annual project review scheduled for October, 1999.
11-98-21: Have an annual project review to identify mid-course corrections and ensure cost-effective management and execution. Review should include performance reviews, costs to date, next year's tasks, and proposed budget.	An annual project review including a technical and management performance review, previous year costs, and the next year tasks and budget is scheduled for October, 1999.
11-98-23: Use modeling as a tool to evaluate the need for and location of future wells and as a communication tool with stakeholders.	Planned modeling activities for FY99 should produce a working model that can be used for this purpose. The model will also be used to communicate with stakeholders.

LANL-GIT Action Plan
for
EAG November 1998 Recommendations

ACTIONS PENDING

RECOMMENDATION	ACTIONS
11-98-4: Have a better description of the relationship and support within LANL for the activity, including how the management of ESH, ER, NWT, etc regards the activity with respect to other priorities.	A description of how the Hydrogeologic Workplan activities fit within the LANL structure will be prepared for the next meeting of the EAG.
11-98-5: Have a more detailed stakeholder's identification map defining relationships other than the three to five major stakeholders.	A stakeholder identification map will be prepared for the next meeting of the EAG.
11-98-8: Use low-flow purging and sampling techniques for water-yielding wells and passive sampling for poorly-yielding wells.	This issue will have increased importance when a well is completed and quarterly sampling begins. Consensus with stakeholders on the use of these sampling techniques must be reached before sampling begins.

LANL-GIT Action Plan
for
EAG November 1998 Recommendations

ACTIONS PENDING

RECOMMENDATION	ACTIONS
11-98-10: Consider using cement seals if the bentonite grout seals fail under certain circumstances.	If other seals are necessary, the EAG will be asked to provide input on options. Options will be presented to NMED before changing well completion specifications.
11-98-12: Avoid mud-rotary drilling in order to preserve the pristine nature of subsequent samples.	If other drilling methods are considered, the EAG will be asked to provide input on the options. Options will be presented to NMED before changing well drilling methods.
11-98-16: Complete the wells with metal fittings rather than PVC.	Currently, completions of all deep wells are planned with metal fittings. Decisions otherwise would not be made without seeking input from the stakeholders and technical experts.
11-98-18: Benchmark the costs-to-date against similar activities.	A benchmarking study will be initiated in early 1999 with the goal of having preliminary results for the next EEG meeting.

LANL-GIT Action Plan
for
EAG November 1998 Recommendations

ACTIONS PENDING

RECOMMENDATION	ACTIONS
11-98-19: Develop a more detailed GANTT chart with scheduled deliverables that indicates how the results of the hydrologic investigations will be incorporated into the RFIs and CMSs.	A description of how findings from hydrogeologic characterization will be incorporated into other programs will be given at the October 1999 meeting of the EAG.

LANL-GIT Action Plan
for
EAG June 1999 Recommendations

Recommendation	Action
6-99-1: Develop an understanding the relationships (of) upper management among the stakeholders.	LANL, DOE, and NMED upper management will be invited to quarterly meetings, annual meetings, and the EAG October 1999 meeting.
6-99-2: Pursue some aspects of benchmarking.	The benchmarking study is important to the GIT and some progress has been made toward implementing this study.
6-99-3: Continue meetings between external stakeholders and the EAG.	This recommendation will continue to be implemented at all future meetings of the EAG.
6-99-4: Continue extensive communication efforts, including the expansion of Internet utilization.	In addition to the formal and informal meetings with stakeholders, the GIT plans to make information accessible via the internet.
6-99-5: Continue preparation and implementation of action plans responding to the EAG's recommendations.	This recommendation will continue to be implemented.
6-99-6: Continue providing meeting locations that enhance focus.	The meeting locations will be off-LANL to enhance focus.
6-99-7: Prepare hard copies of presenter's more technical transparencies.	The overheads will be compiled into a meeting booklet to facilitate EAG program reviews.

LANL-GIT Action Plan
for
EAG June 1999 Recommendations

Recommendation	Action
6-99-8: Add some technical sessions.	There will be increased time allotted for technical presentations. Concurrent sessions may be appropriate if the participants at meetings have clearly defined and distinct interests that can be addressed in separate sessions.
6-99-9: Add EAG members for geoscience and economics expertise and, possibly temporary members in other areas.	The EAG is requested to identify potential new members and invite their commitment to join the EAG.
6-99-10: Develop a risk-based conceptual plan in three categories: Chemicals of Concern, Source, Transport and Fate, and Exposure to Receptors.	A plan to address contamination found while implementing Hydrogeologic Workplan activities will be presented to NMED and EAG during the October 1999 meeting.
6-99-11: Have EAG review LANL's risk assessment team results and future plans.	The EAG will be asked to review the LANL's draft contaminant response strategy at the October meeting

LANL-GIT Action Plan
for
EAG June 1999 Recommendations

Recommendation	Action
6-99-12: Develop a risk-based approach for interpreting the significance of finding on-site well contamination; as the site-specific, alternate contaminant level (ACL) approach has proven most useful for complex sites such as LANL.	The ACL criteria have been incorporated into the contaminant response strategy.
6-99-13: Compare such plans to those used by other regulatory agencies (e.g. EPA) and other states.	Those resources will be used in the development of the contaminant response plan.
6-99-14: Establish acceptance of site-specific ACLs.	The ACL criteria have been incorporated into the contaminant response strategy.
6-99-15: Reconsider the Hydrogeologic Workplan DQO scenarios when updating the hydrogeologic conceptual models.	The conceptual models will be refined based on new data collected in this program. The DQO scenarios, which are based on the conceptual models, will likewise be refined as appropriate.

LANL-GIT Action Plan
for
EAG June 1999 Recommendations

Recommendation	Action
6-99-16: Develop DQOs for processes subordinate, but essential to, the hydrogeologic characterization such as well completion, sample collection, data validation, database development, and model development.	The GIT subcommittees have been encouraged to use the DQO process (or a DQO-like process) in the areas mentioned and in all of their planning activities.
6-99-17: Data gathering efforts should utilize DQO processes and a special session discussing these efforts should be held.	The GIT subcommittees have been encouraged to use the DQO process (or a DQO-like process) to develop comprehensive Standard Operating Procedures for data collection.
6-99-18: Database issues should be clarified and funding issues for database development should be given a high priority	The Information Management Subcommittee is developing a resource-loaded schedule to support a request for adequate funding for database development and maintenance.
6-99-19: The geologic model should be used for preliminary predictions of stratigraphic boundaries.	Predictions on stratigraphic contacts will continue to be made from the model. As more data are incorporated, predictions will be become more certain.

LANL-GIT Action Plan
for
EAG June 1999 Recommendations

Recommendation	Action
6-99-20: An overall geochemical model should be developed.	The Geochemistry Subcommittee is developing an overall geochemical model.
6-99-21: Present more geochemical calculations and carry out sorption isotherm experiments.	Sorption studies are planned for when contamination is encountered so that remedial options can be developed.
6-99-22: Additional hydrogeologic modeling results should be presented.	Modeling presentations for the October 1999 EAG meeting will focus on technical details of modeling accomplished thus far.
6-99-23: The segmented approach to site modeling should be continued.	The current approach to presenting modeling results at three different scales seems effective and will be continued.
6-99-24: Review of hydrologic modeling reports is requested by the EAG.	The EAG will be requested to review the hydrologic modeling reports.
6-99-25: The locations and rates of recharge should continue to be defined.	Results of modeling efforts will be presented at the October meeting.
6-99-26: Improvement of drilling cost analyses as part of benchmarking should continue.	The benchmarking study is important to the GIT and some progress has been made toward implementing this study.

LANL-GIT Action Plan
for
EAG June 1999 Recommendations

Recommendation	Action
6-99-27: Review of the design of stainless steel screens installed in the deep monitoring wells is requested by the EAG.	The EAG will be requested to review the well design for each well.
6-99-28: Evaluate drilling method after 5 or 6 wells have been drilled using the current method.	The new drilling procurement will allow the flexibility to try different drilling methods if the drilling costs remain high after five or six holes.
6-99-29: Geophysical logging of boreholes should use modern and accurate technologies.	The GIT will seek new, more appropriate methods rather than defaulting to familiar methods.

Review of LANL Hydrogeologic Characterization Program FY99

Charles Nylander, Program Manager
ESH-18

Performance Review Outline

- Program Description
- Regulatory Framework
- FY99 Accomplishments and Issues
- FY99 Budget Performance
- FY00 Proposed Budget

Program Description

- Goal: Develop a refined understanding of the hydrogeologic setting
- Scope of the program described in the Hydrogeologic Workplan:
  - 32 regional aquifer wells; 51 alluvial wells
  - Data management/stakeholder data access
  - Hydrologic modeling

Regulatory Framework

- 1995 GWPMP: recognize groundwater issues due to inadequate characterization
- 1995 NMED letters: inadequate characterization and denial of groundwater monitoring waiver
- 1990 EPA/NMED RCRA Operating Permit: Task III, Section A.1 requires evaluations of hydrogeologic conditions

FY99 Accomplishments

- Drilled and constructed two wells (R-25 and R-15); completed drilling a third well (R-9); started drilling a fourth well (R-31)
- External Advisory Group produced 2 reports and Groundwater Integration Team (GIT) responded with two action plans
- Increased stakeholder participation at Annual Meeting and 2 Quarterly Meetings

FY99 Accomplishments (cont.)

- Produced the FY98 Groundwater Protection Program Annual Status Report, published as a LANL Status Report (LA-13598-SR)
- GIT participated in 3 Division Review Committee Program Reviews (ESH, EES, CST) and the program presentation was rated as "outstanding"

FY99 Accomplishments (cont.)

- Improved steady-state regional-scale flow model (pre-development conditions) and developed and calibrated transient flow model (water level responses over a 50 year period)
- Comprehensively evaluated aquifer recharge model and prepared preliminary water budget calculations for plateau

FY99 Accomplishments (cont)

- Imbedded high-resolution Pajarito Plateau grid within coarser regional-scale model
- Canyon- and MDA-scale models calibrated
- GIT Geochemistry Subcommittee formed
- Reprioritized wells in response to HE found in R-25

FY99 Accomplishments (cont)

- Developed refined understanding of resources required to complete interpretive tasks
- Information management system conceptualized and initiated with web interface for stakeholder access

Issues

- R-25 Repairs
- Drilling Method - Schedule and Cost
- Drilling Cost Comparisons
- Response to Contamination

Issue: R-25 Repairs

- Two Major incidents required repairs:
  - Dropped tremie lines
  - Collapse of Screen 3
- Actions have been taken to prevent similar incidents
- Schedule impacts of 7+ months and cost increase of about $1 million

R-25 Dropped Tremie Lines

- Tremie lines are pipes used to place backfill
- Sling holding the tremie lines broke, the pipes fell downhole and penetrated backfill
- Repair required extensive geophysical logging, "fishing" for tremies lines, and extracting tremies while backfilling
- Costs of 1.5 months and $300,000; cost sharing with driller

R-25 Screen 3 Collapse

- Screen 3 collapsed because:
  - It was compressed and torqued during retraction of heavy wall casing (design assumed casing would remain solely under tensile stress)
  - The screen gage was of inadequate tensile and compressive strength
  - The screen 3 section was unthreaded from the casing section below it after installation

R-25 Screen 3 Collapse (cont)

- Resulting aperture in the screen was too small for WESTBAY equipment
- Repair required cementing the collapsed interval and coring through the cement
- Problems with cement mix, curing, and drilling
- Repair costs: 5+ months and $700,000

R-25 Repair Issue Resolutions

- More frequent drilling equipment inspections by ESH-5 to ensure industry standards are met
- Increased awareness to minimize dropping items down the borehole
- Use heavy gage screen in all wells
- Have well construction design reviewed by EAG

R-25 Issue Resolution (cont.)

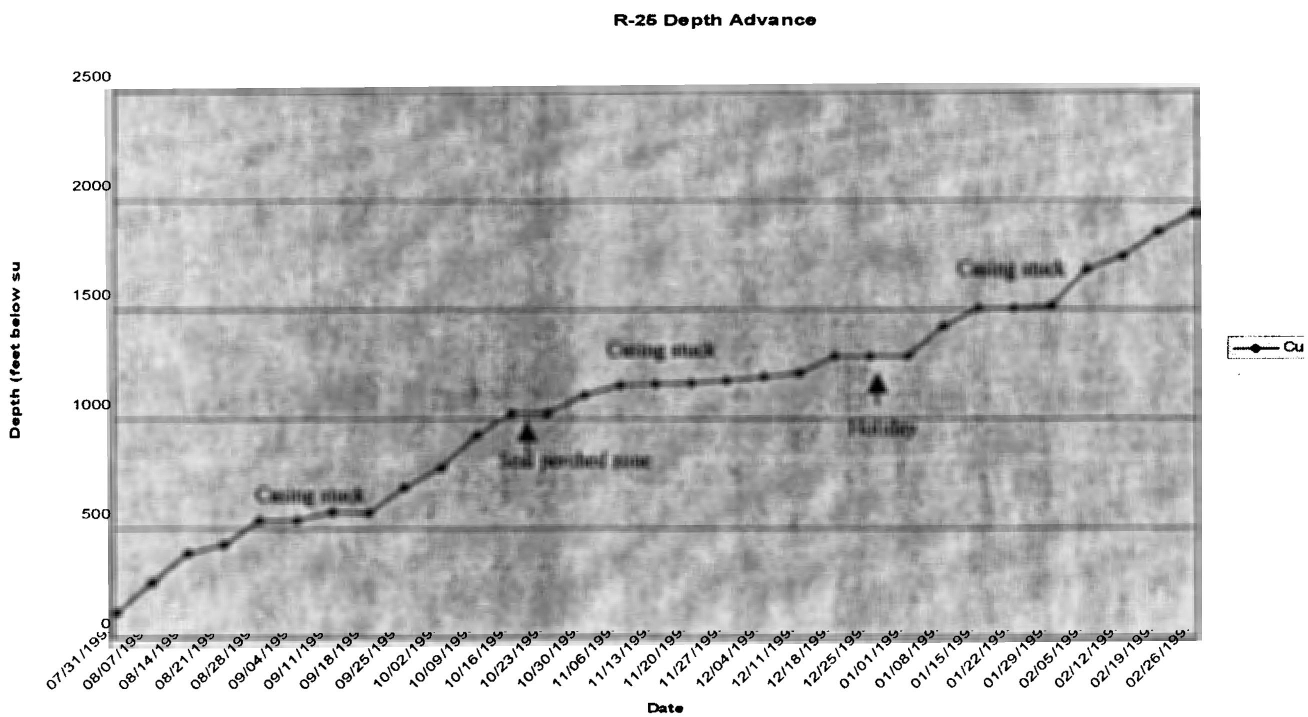
- Minimize the number of tremie lines downhole while retracting the heavy-wall casing
- Video film all well screens and casing joints before and after backfilling
- Pursue subcontract re-performance and claim enforcement expeditiously in the event of subcontractor errors and omissions

Issue: Drilling Method

- Geologic conditions require a drilling method that maintains an open borehole
- Borehole Data Quality Objectives influence selection of drilling method; NMED has signaled flexibility in DQOs
- Current method is simultaneous air rotary drilling and casing driven by hammer

Issue: Drilling Method (cont)

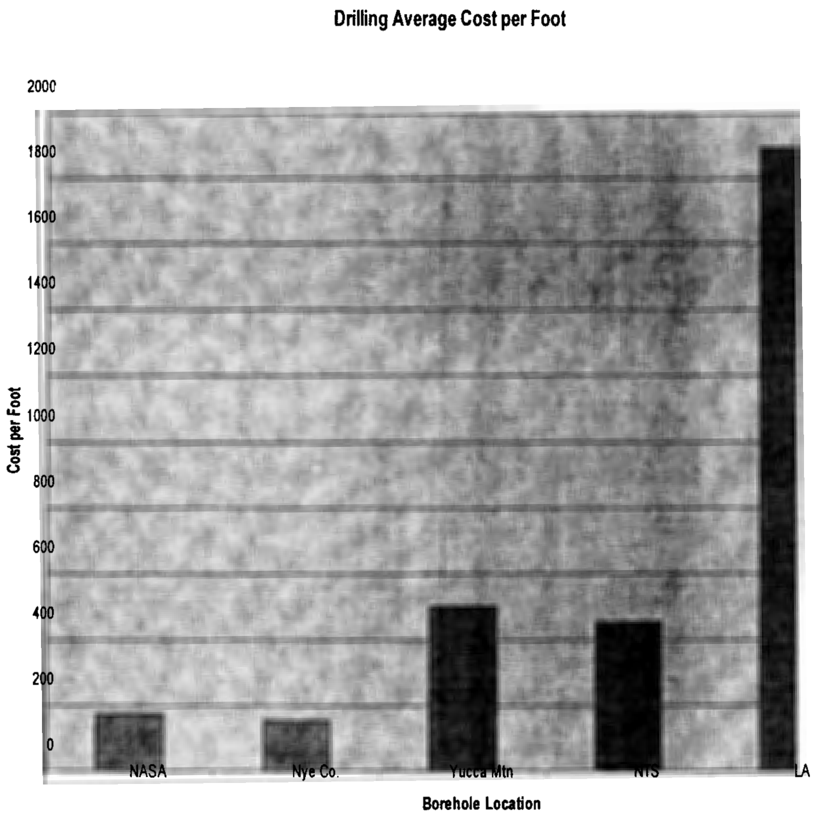
At R-25, stuck casing accounted for 75% of the drilling time



Drilling Method Issue Resolution

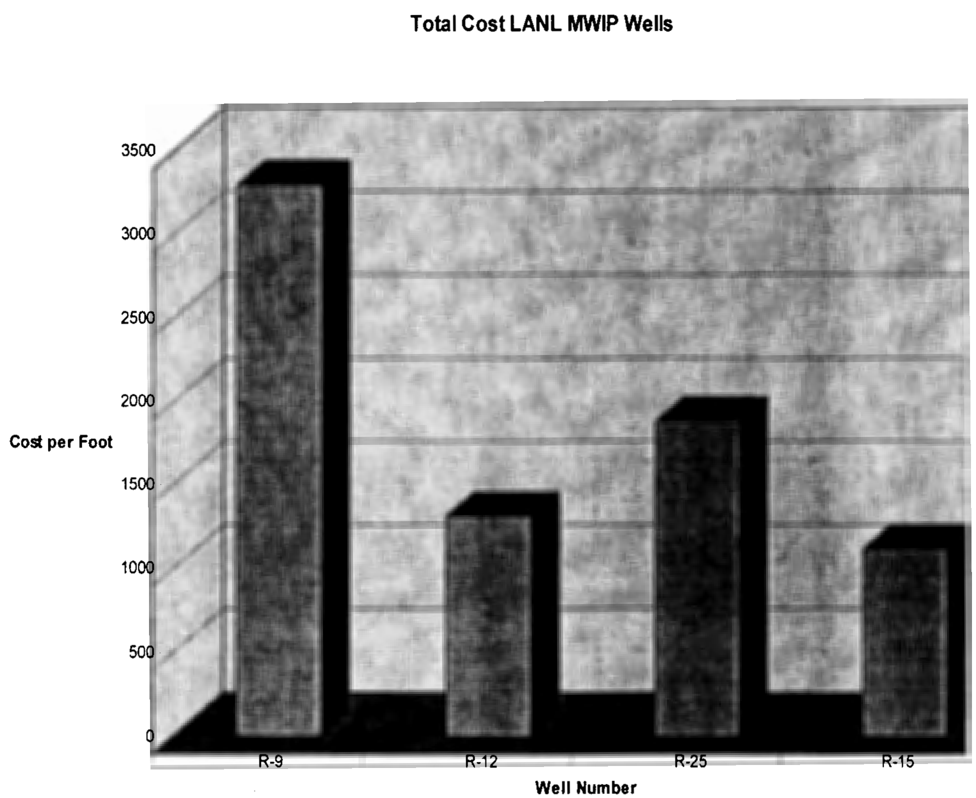
- Data Collection DQO Review held Sept. 13 with NMED and GIT
- Consensus was reached that either mud rotary or casing advance methods could be used to collect most of the types of data that might be required
- Drilling method will be selected on a well-by-well basis and documented in the FIP

Issue: Drilling Cost Comparison



- Mature programs have worked out the “bugs”
- Borehole stability not an issue at other locations
- Costs do not reflect data collection during drilling

Drilling Cost Issue Resolution



- Continuous decrease in the total cost per foot (excluding R-25)
- Refining the drilling technology to match geologic conditions
- Increased flexibility to use other drilling methods

Issue: Response to Contamination

- NMED has repeatedly asked what actions will be taken when contamination is encountered
- Responses to date have varied:
  - R-9 and R-12: no further investigation to date
  - R-25: Plume definition plan developed and implementation begun
- Consistent approach for responding is important

Response to Contamination Issue Resolution

- Present proposed response to NMED at Quarterly Meeting on 10/14
- Response includes:
  - Triggered by confirmed detection above regulatory standard
  - Review of analytical results from nearest water wells, with immediate action to define plume if detected in water supply above regulatory standard

Response to Contamination Issue Resolution (cont.)

– Joint GIT/NMED prioritization of plume using 15 Contaminant Response Criteria

– Action (plan and characterization) will be in these priority levels:

  - **High** - Within 6 months using current year contingency funds
  - **Moderate** - Within 1 year using funds requested at time of detection
  - **Low** - within 3-5 years using funds requested in 5-year planning

Response to Contamination Issue Resolution (cont)

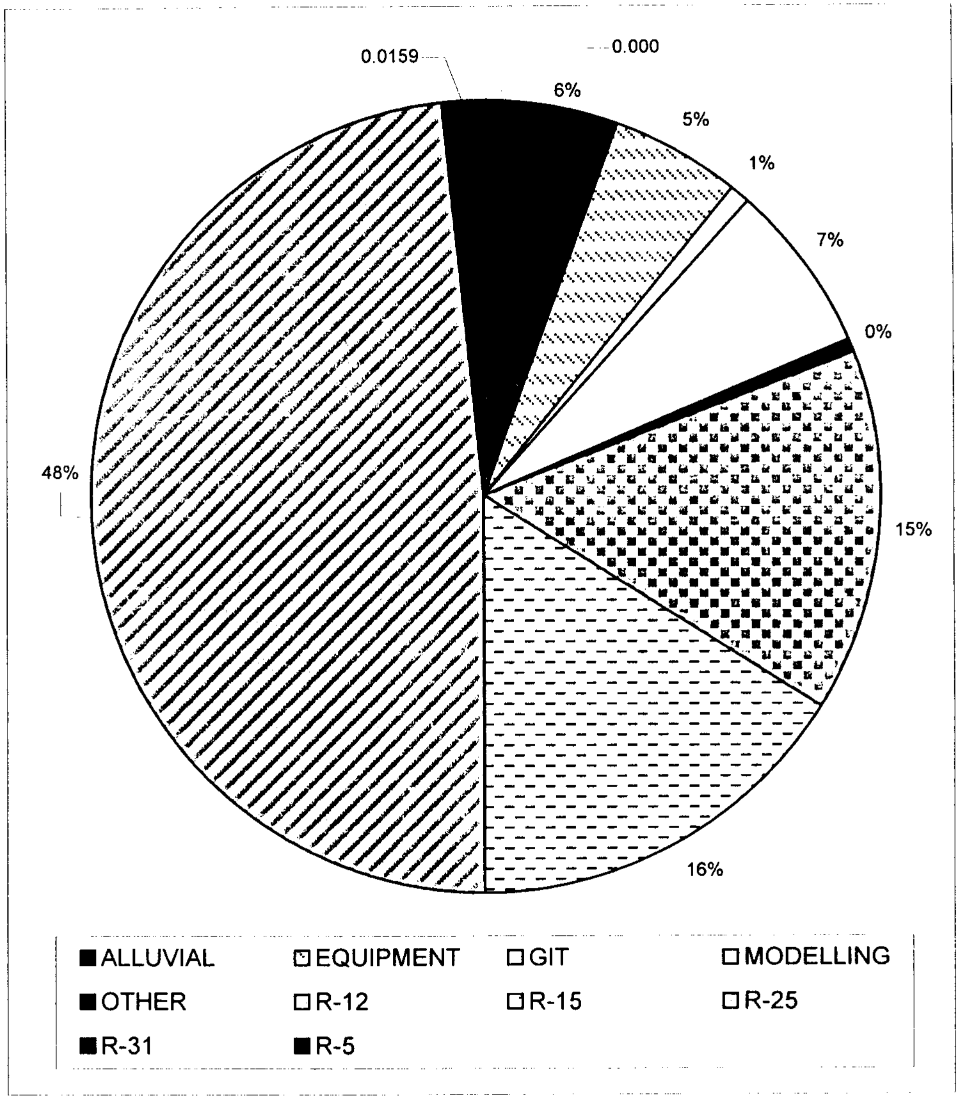
Contaminant Response Criteria

1. Physical and chemical characteristics of the constituent(s)
2. Hydrogeologic characteristics of the immediate area
3. Quantity of groundwater and direction of groundwater flow
4. Proximity and withdrawal rates of water-supply wells
5. Current and future uses of the water
6. Existing quality of the groundwater, including other sources of contamination and their cumulative impact on the ground-water quality
7. Potential for health risks caused by human exposure to the constituent(s) of concern
8. Potential to damage wildlife, vegetation or physical structures caused by exposure to the constituents
9. Persistence and permanence of adverse impacts from exposure to the constituents
10. Location with respect to the Lab boundary
11. Well construction issues (intermediate perched zones require special construction)
12. Schedule for drilling nearby wells
13. Facilitate finishing an RFI Report
14. Programmatic consistency
15. Budget/Priorities

FY 99 Budget Performance

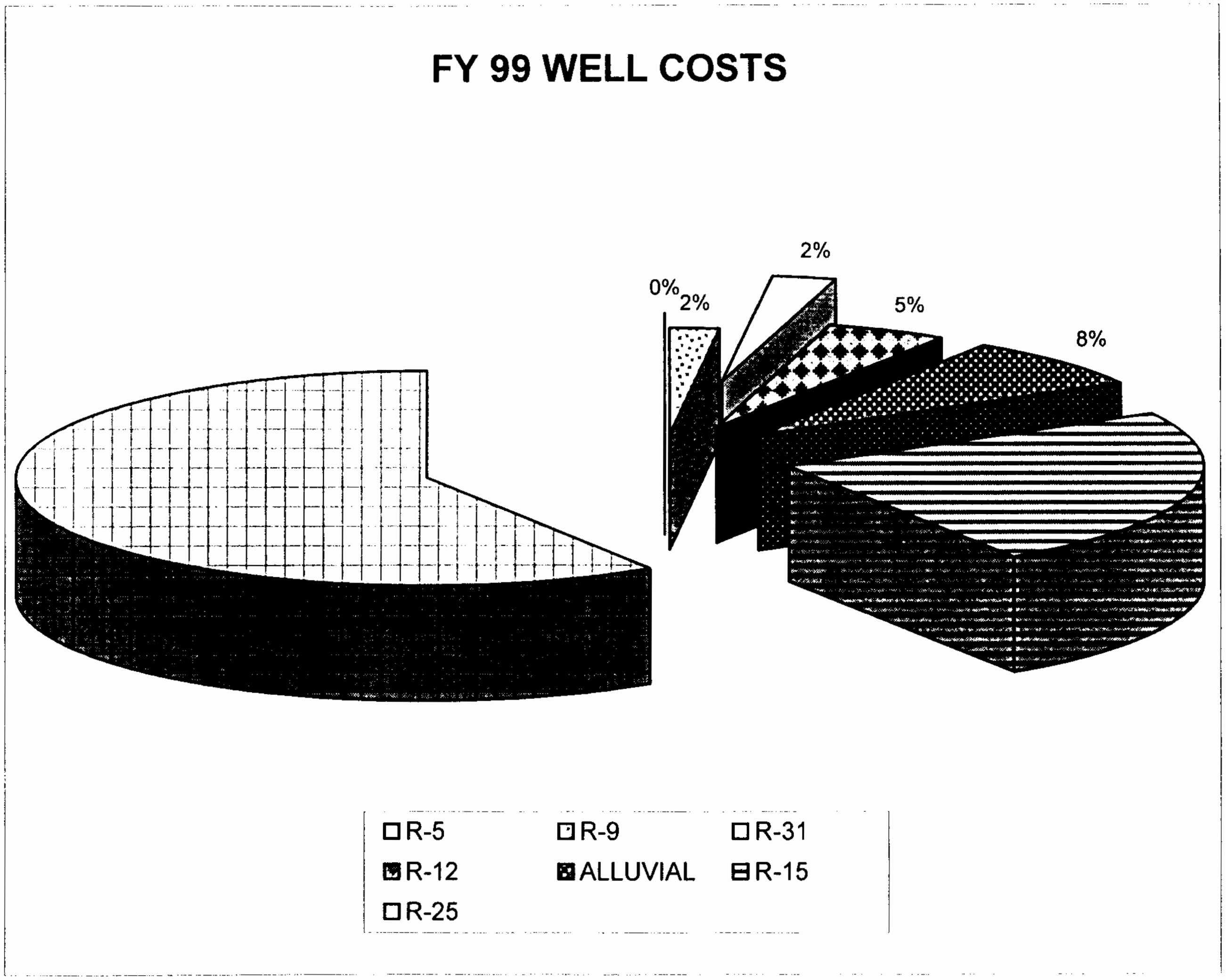
TOTAL PROGRAM COSTS

WELL/ACTIVITY	FY 97/98	FY 99	Grand Total
ALLUVIAL	59,000	369,388	428,388
EQUIPMENT	389,591		389,591
GIT	38,825	26,507	65,332
MODELLING	254,923	268,017	522,940
OTHER	8,185	23,478	31,664
R-12	868,000	236,496	1,104,496
R-15	73,000	1,142,953	1,215,953
R-25	792,316	2,851,942	3,644,258
R-31		119,612	119,612
R-5		3,635	3,635
R-9	2,252,000	85,033	2,337,033
Grand Total	4,735,840	5,127,062	9,862,902



FY 99 DP and ER FUNDED WELL COSTS

WELL	COST
R-5	3,635
R-9	85,033
R-31	119,612
R-12	236,496
ALLUVIAL	369,388
R-15	1,142,953
R-25	2,851,942
TOTAL	4,809,058

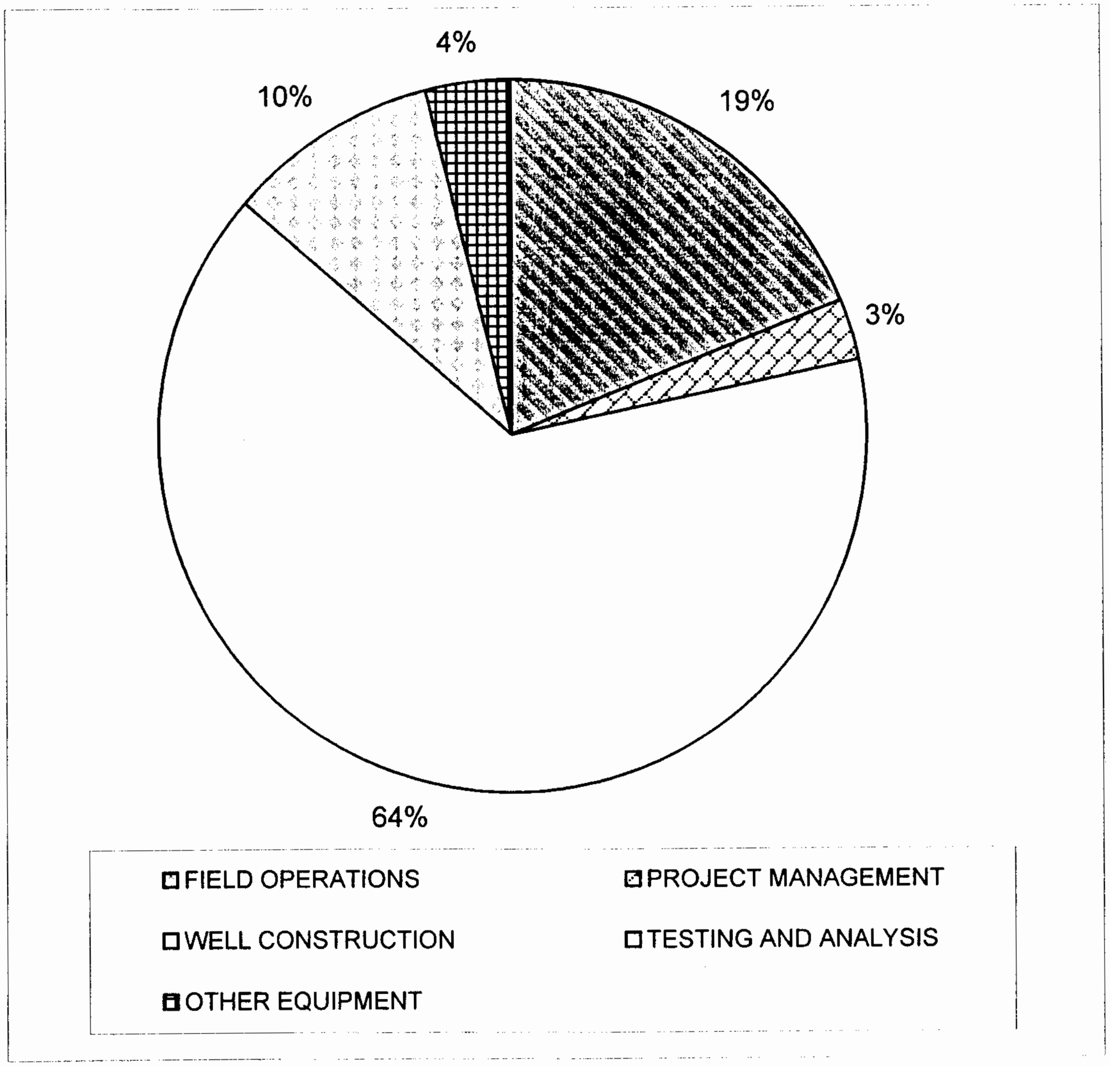


FY 99 COST SUMMARY

FY 99 COST	FUNDING		
ACTIVITY	ER FUNDED	DP FUNDED	Grand Total
ALLUVIAL WELLS GENERAL	369,388		369,388
EQUIPMENT - ALL WELLS		27,409	27,409
FIELD OPERATIONS	321,021	571,144	892,165
GIT ACTIVITIES		26,507	26,507
MODELLING		268,017	268,017
MONITORING WELLS - GENERAL		(3,931)	(3,931)
PROJECT MANAGEMENT		111,739	111,739
WELL CONSTRUCTION	391,861	2,012,325	2,404,186
TESTING AND ANALYSIS	160,758	271,932	432,690
OTHER EQUIPMENT		112,887	112,887
MWIP		33,717	33,717
GENERAL MANAGEMENT	17,828		17,828
CENTRALIZED DATA MGMT - WATER	1,522		1,522
GENERAL	321,529		321,529
WELL COMPLETION	42,991		42,991
PLANNING	27,930		27,930
EQUIPMENT	22,439		22,439
GENERAL INTERPRETATION	5,369		5,369
QUARTERLY SAMPLING	12,678		12,678
Grand Total	1,695,315	3,431,747	5,127,062

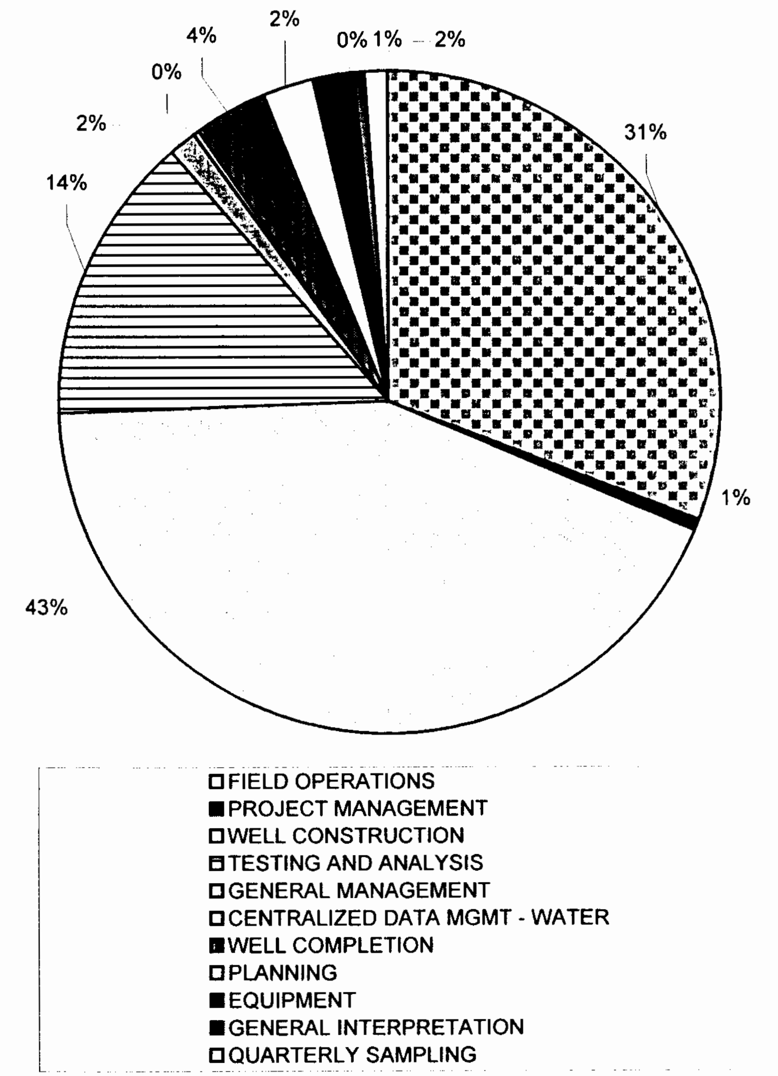
R25 FY 99 COST SUMMARY BY ACTIVITY

FIELD OPERATIONS	537,318
PROJECT MANAGEMENT	79,701
WELL CONSTRUCTION	1,850,103
TESTING AND ANALYSIS	271,932
OTHER EQUIPMENT	112,887
Grand Total	2,851,942



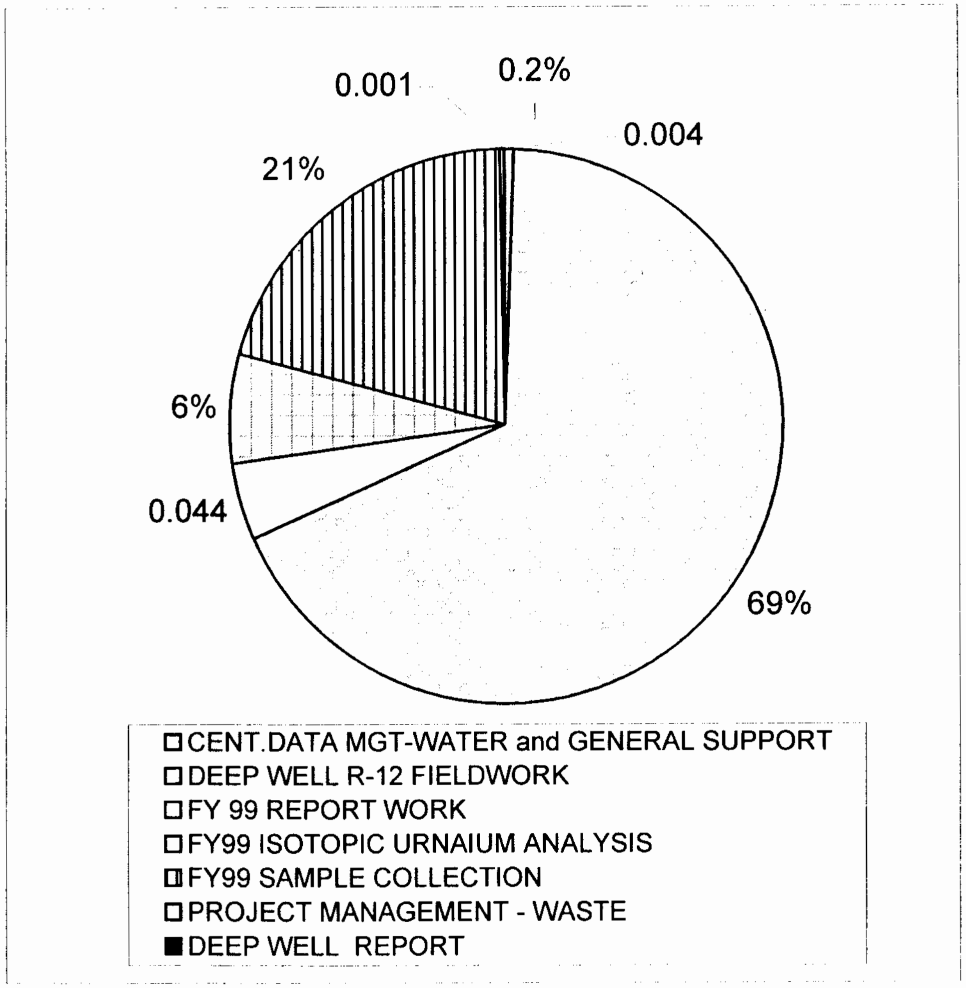
R15 FY 99 COST SUMMARY BY ACTIVITY

ACTIVITY	ER FUNDED	DP FUNDED	Grand Total
FIELD OPERATIONS	321,021	31,700	352,721
PROJECT MANAGEMENT		6,244	6,244
WELL CONSTRUCTION	391,861	100,611	492,472
TESTING AND ANALYSIS	160,758		160,758
GENERAL MANAGEMENT	17,828		17,828
CENTRALIZED DATA MGMT - WATER	1,522		1,522
WELL COMPLETION	42,991		42,991
PLANNING	27,930		27,930
EQUIPMENT	22,439		22,439
GENERAL INTERPRETATION	5,369		5,369
QUARTERLY SAMPLING	12,678		12,678
Grand Total	1,004,398	138,555	1,142,953



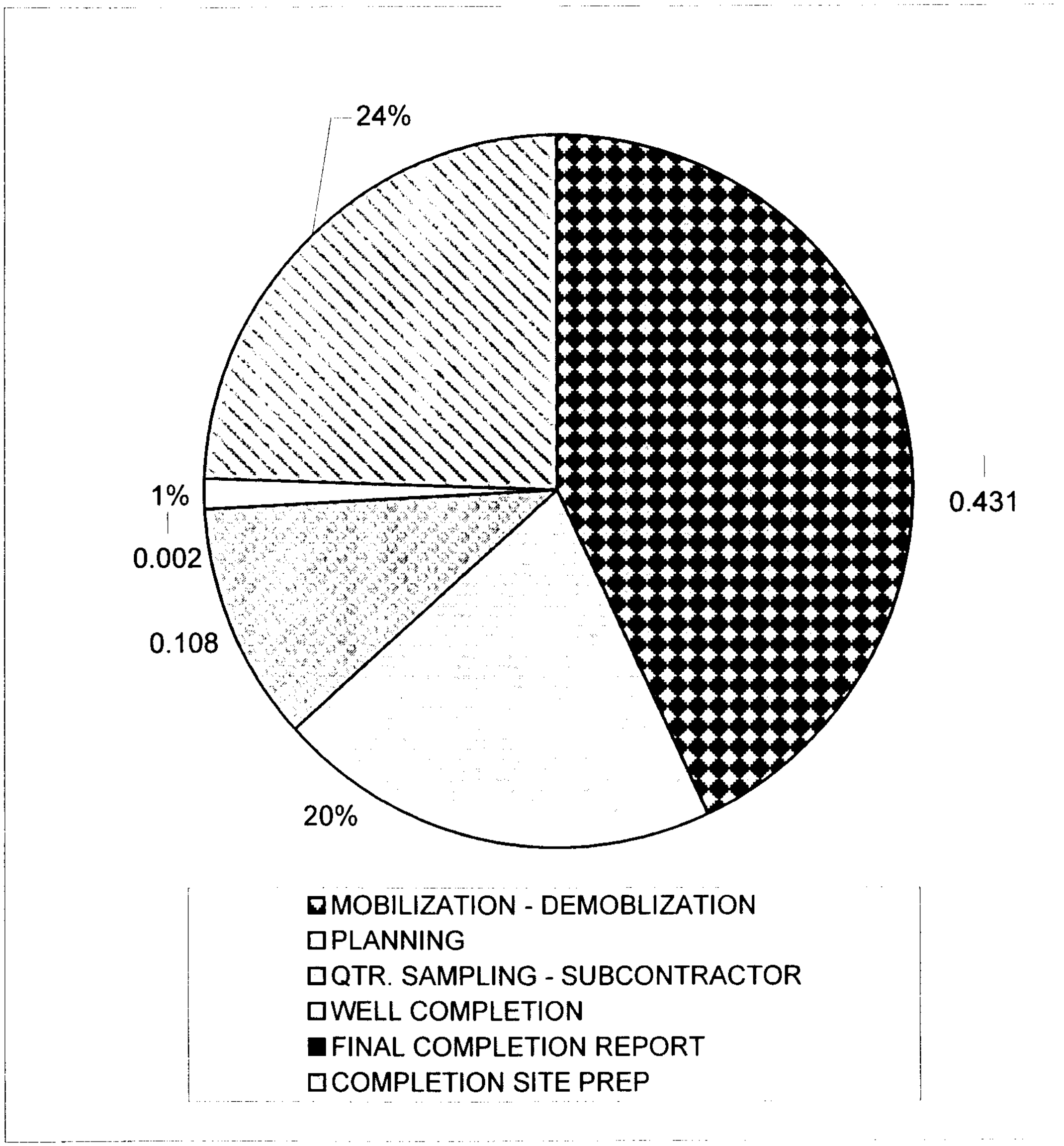
R12 FY 99 COST SUMMARY BY ACTIVITY

FY 99 COST	
ACTIVITY	Total
CENT.DATA MGT-WATER and GENERAL SUPPORT	1,019
DEEP WELL R-12 FIELDWORK	160,839
FY 99 REPORT WORK	10,500
FY99 ISOTOPIC URNAIUM ANALYSIS	14,734
FY99 SAMPLE COLLECTION	48,587
PROJECT MANAGEMENT - WASTE	557
DEEP WELL REPORT	260
Grand Total	236,496



R9 FY 99 COST SUMMARY BY ACTIVITY

ACTIVITY	Total
MOBILIZATION - DEMOBLIZATION	36,690
PLANNING	17,257
QTR. SAMPLING - SUBCONTRACTOR	9,177
WELL COMPLETION	1,016
FINAL COMPLETION REPORT	176
COMPLETION SITE PREP	20,717
Grand Total	85,033



MAJOR ACTIVITIES

TOTAL COST	FY		
WELL CONSTRUCTION	FY 97/98	FY 99	Grand Total
ACCESS ROAD, DRILL PAD, SITE CONSTRUCTIO		24,386	24,386
DRILLING SERVICES SUBCONTRACT		94,416	94,416
EQUIPMENT		22,439	22,439
EQUIPMENT - ALL WELLS	389,591	27,409	417,000
OTHER EQUIPMENT	93,253	112,887	206,141
TONTO DRILLING SERVICES SUBCONTRACT		365,860	365,860
WELL COMPLETION		8,750	8,750
WELL CONSTRUCTION	418,143	2,012,325	2,430,468
Grand Total	900,988	2,668,472	3,569,460

TOTAL COST	FY		
GIT/MODELLING	FY 97/98	FY 99	Grand Total
GIT ACTIVITIES	38,825	26,507	65,332
MODELLING	254,923	268,017	522,940
Grand Total	293,748	294,525	588,272

TOTAL COST	FY		
SAMPLING and ANALYSIS	FY 97/98	FY 99	Grand Total
ANALYTICAL MEDIA SAMPLES		160,758	160,758
CORE SAMPLE ANALYSIS		8,223	8,223
FY99 ISOTOPIC URNAIUM ANALYSIS		14,734	14,734
FY99 SAMPLE COLLECTION		48,587	48,587
GIT ACTIVITIES	38,825	26,507	65,332
GROUND WATER SAMPLING ANALYSES		17,052	17,052
INTERPRETATION OF DATA AND TEST RESULTS		5,369	5,369
QTR. SAMPLING - SUBCONTRACTOR		9,177	9,177
QUARTERLY SAMPLING		12,678	12,678
QUARTERLY SAMPLING			
SAMPLE ANALYSIS		22,281	22,281
TESTING AND ANALYSIS	31,975	271,932	303,907
Grand Total	70,800	597,298	668,099

TOTAL COST	FY		
FIELDWORK	FY 97/98	FY 99	Grand Total
ALLVUIAL WELLS FIELDWORK		1,345	1,345
DEEP WELL R-12 FIELDWORK		160,839	160,839
FIELD OPERATIONS	121,062	571,144	692,205
FIELD TEAM LEADER SITE GEOLOGIST		13,827	13,827
FIELD WORK		38,814	38,814
GROUND WATER SAMPLING FIELD EFFORT		15,528	15,528
Grand Total	121,062	801,497	922,558

FY 00 BUDGET FOR DP FUNDED WELLS

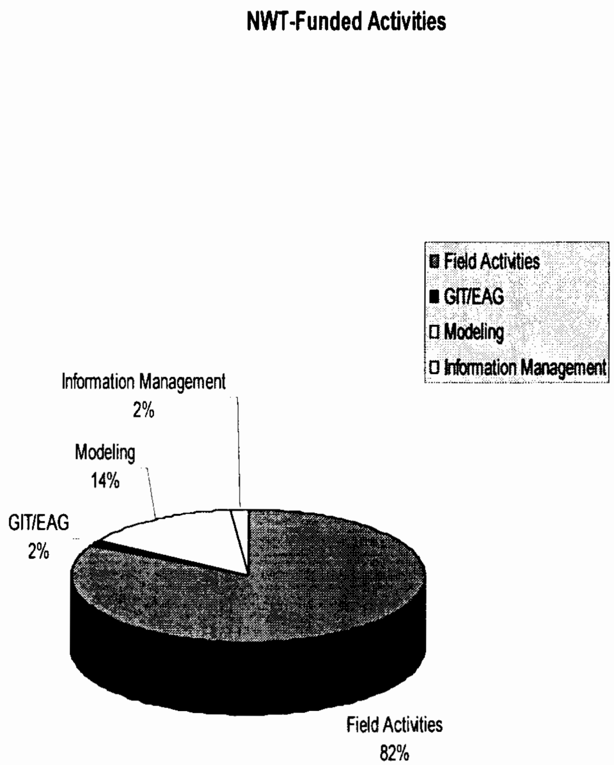
	($K)
MODELLING	400
INFORMATION MANAGEMENT	50
GIT ACTIVITIES	50
WELL CONSTRUCTION	2,350
R25 COMPLETION	
R31	
R5	
R28 STARTUP	
TOTAL FY 00 BUDGET	2,850

FY 00 BUDGET FOR ER FUNDED WELLS

	($K)	
R-7	2,523	**
R-9	169	
R-12	998	**
R15	605	(QUARTERLY SAMPLING & DEVELOPMENT)
R19	2,841	**
R-27	2,688	**
TA-15	2,400	
INTERMEDIATE WELLS	-	
ALLUVIAL WELLS	123	
MODELLING	800	
TOTAL FY 00 BUDGET	10,455	

** INCLUDES QUARTERLY SAMPLING IN FY 01

FY00 DP-Funded Budget



- Field Activities (R-31, R-5, R-28): $2,350,000
- GIT/EAG Activities: $50,000
- Modeling: $400,000
- Information Management: $50,000

Modeling of MDA AB, TA-49

Kay Birdsell
T. Cherry, P. Lichtner, B. Travis

October, 1999

TA-49, Area 2 History

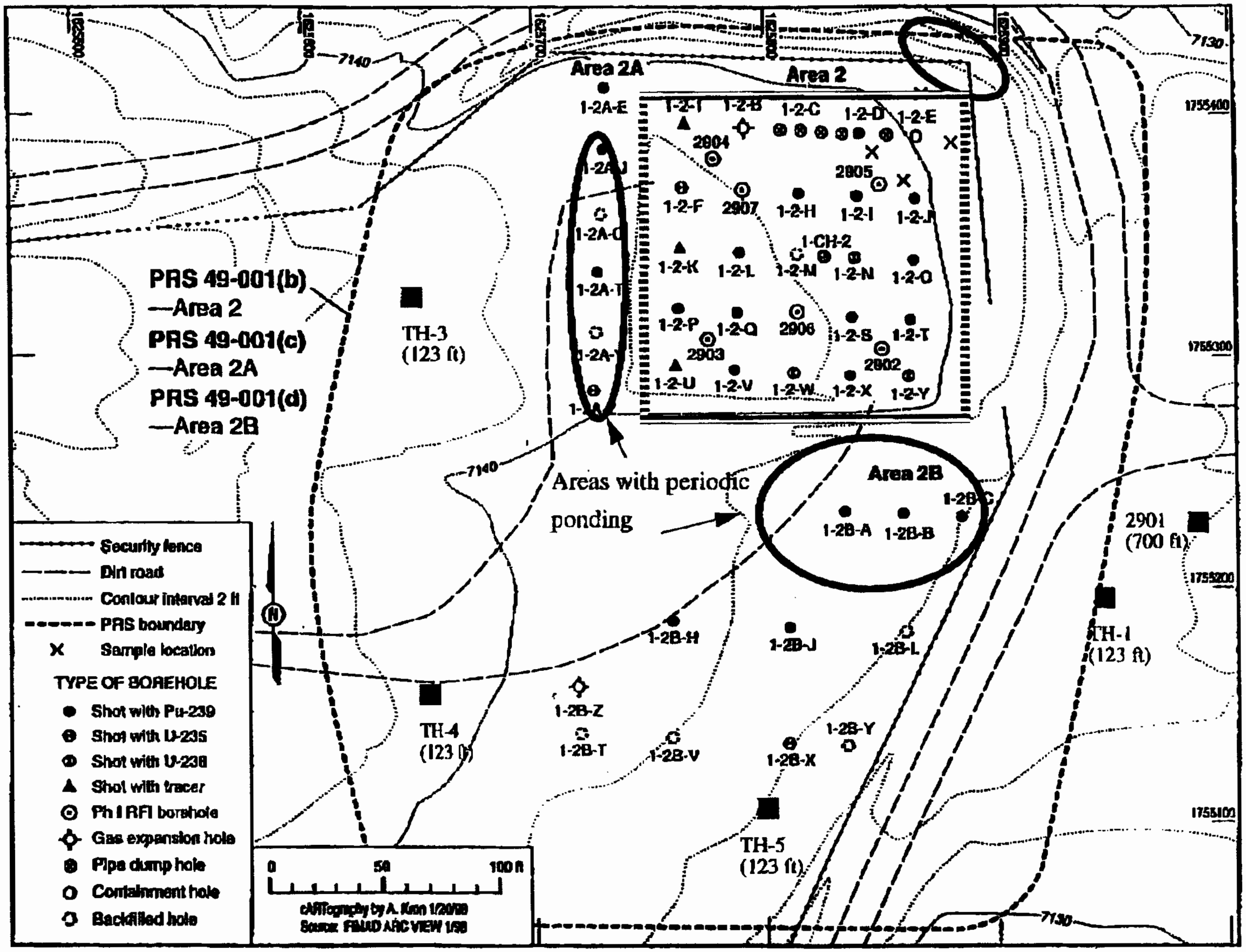
- **Underground experiments related to the safety of nuclear experiments were conducted from late 1959 to mid 1961**

  - Nuclear explosions did not occur

  - Performed in 6-foot diameter shafts at depths of 57 to 78 feet

  - Tests involved explosives, plutonium, uranium, lead , cesium and beryllium

  - Subsequently covered with asphalt pad


PRS 49-001(b)
—Area 2
PRS 49-001(c)
—Area 2A
PRS 49-001(d)
—Area 2B
Area 2A
Area 2
Area 2B
Areas with periodic ponding
TH-3
(123 ft)
TH-4
(123 ft)
TH-5
(123 ft)
TH-1
(123 ft)
2901
(700 ft)
7140
7130
Security fence
Dirt road
Contour interval 2 ft
PRS boundary
Sample location
TYPE OF BOREHOLE
Shot with Pu-239
Shot with U-235
Shot with U-238
Shot with tracer
Ph I RFI borehole
Gas expansion hole
Pipe dump hole
Containment hole
Backfilled hole
0
50
100 ft
cARTography by A. Kron 1/20/98
Source: FIMAD ARC VIEW 1/98

Site Issues (1961-1998)

- Moisture levels beneath the asphalt were elevated
- Effects of Asphalt

  -Trapped moisture by limiting evaporation

  -Concentrated runoff into cracks and areas adjacent to the pad

  -Created poor drainage, resulting in ponds

Interim Measures/BMP

- Interim measure and Best Management Practices were implemented in 1998
  - asphalt pad removed
  - upgradient diversion channel constructed
  - site covered with crushed tuff to eliminate ponding and improve drainage
  - site revegetated

Future Site Work

- Install a directional borehole to define vertical extent of contaminant migration
- Monitor moisture levels in vicinity of old asphalt pad area

Modeling Objectives

- Predict current extent of contaminant migration
  - Site directional borehole
- Assess effectiveness of recent site improvements
  - Predict future migration
  - Predict moisture redistribution
    - help design moisture monitoring system
    - help determine cover requirement
  - Compare improved to unimproved site
- Validate with field data/Reevaluate model

Numerical Model

- 2-Dimensional Grid
  - surface to water table
  - single shaft
- Unsaturated Zone Flow
  - Background - match to field saturation surrounding site
  - Transient - match to field saturation beneath asphalt pad
  - Future - extend simulations for 100 years

Numerical Model

- Source - Located in fractured zone at time zero
  - Uranium
    - particles (low matrix diffusion, no sorption)
    - solubility limited

      (2.76e-7 moles/l, Kd = 2.4 ml/g)
  - Cesium
    - infinite solubility

      (Kd = 428 ml/g)

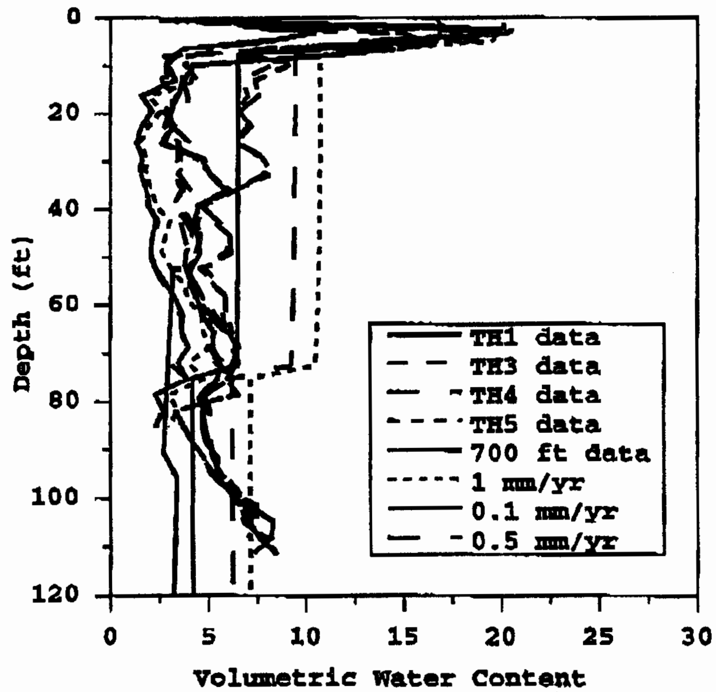


Figure 0-1. Comparison of simulated water content profiles (green) for steady infiltration at 0.1, 0.5 and 1.0 mm/yr to site data from various boreholes surrounding the asphalt pad area, which represent background flow conditions to 120 feet.

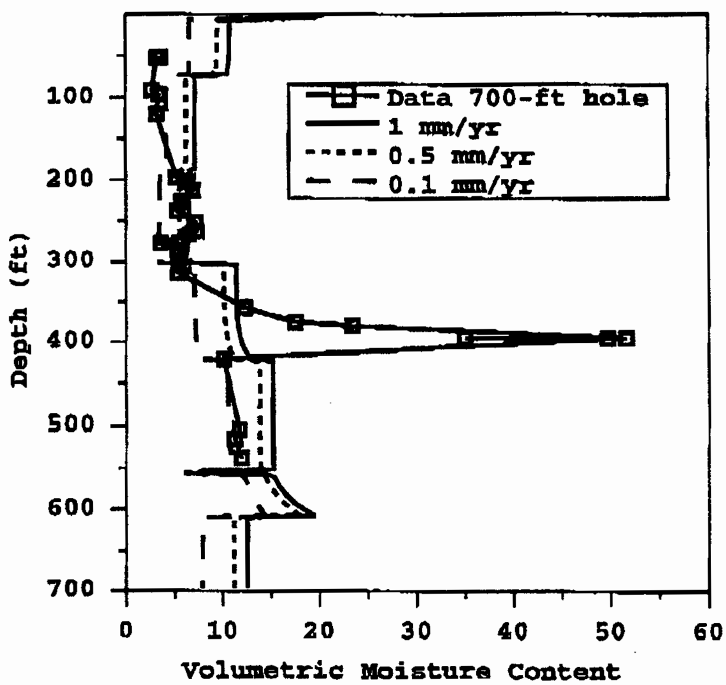


Figure 0-2. Comparison of simulated water content profiles (red) for steady infiltration at 0.1, 0.5 and 1.0 mm/yr to site data (black) from hole 49-2901, which represents background flow conditions to 700 feet.

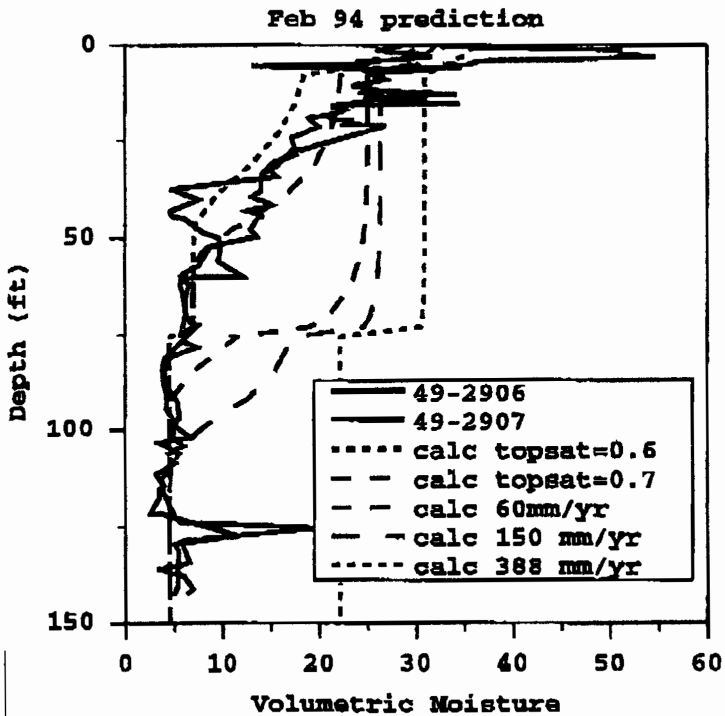


Figure 0-3. Comparison of simulated water content profiles to site data (black) collected in February, 1994, from two boreholes located beneath the asphalt pad. The red curves show results for simulations with fixed saturations of 0.6 and 0.7 in the soil beneath the pad. The blue curves show results for simulations with fixed infiltration rates of 60, 150 and 388 mm/yr.

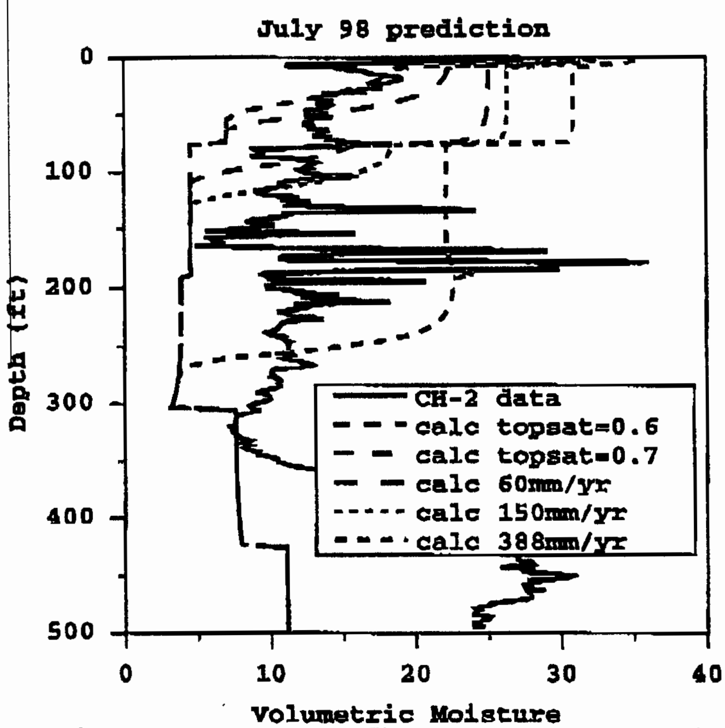
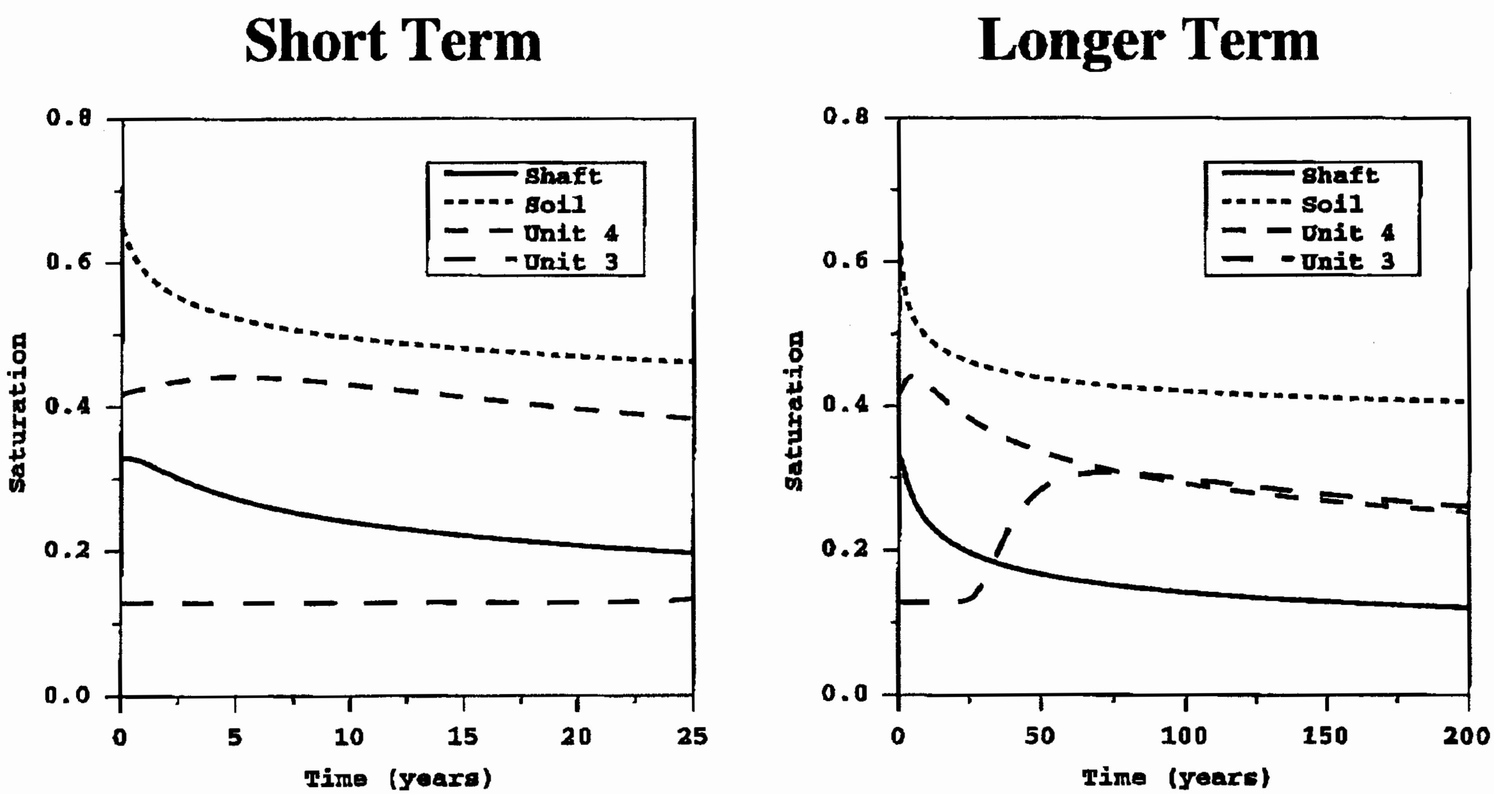


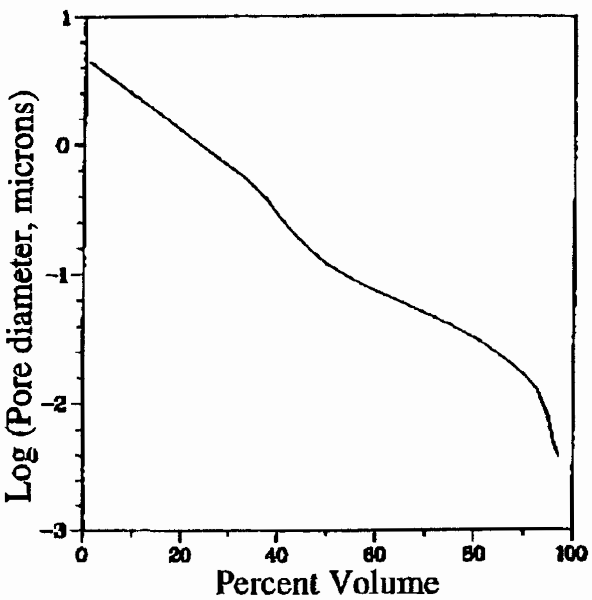
Figure 0-4. Comparison of simulated water content profiles to site data from CH-2 (black) collected in July, 1998, beneath the asphalt pad. The red curves show results for simulations with fixed saturations of 0.6 and 0.7 in the fill beneath the pad. The blue curves show results for simulations with fixed infiltration rates of 60, 150 and 388 mm/yr.

Predicted Evolution of Saturation

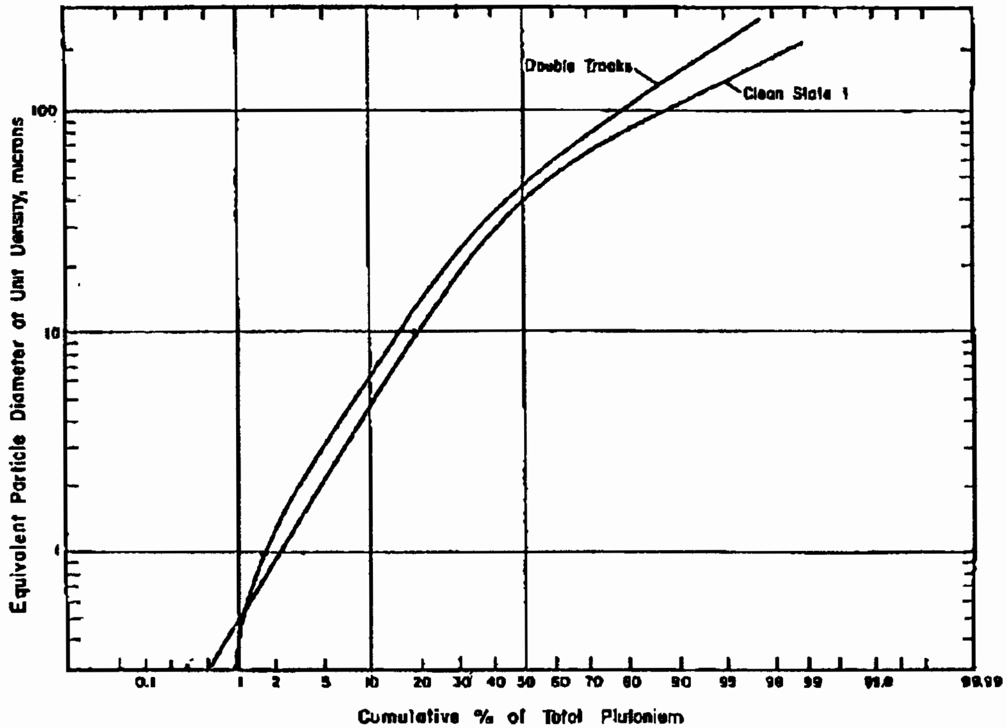


Pore-Size Distribution

Topopah Spring Tuff



Particle-Size Distribution



Numerical Model Results

- Unsaturated Flow
  - Background = 0.1 to 1.0 mm/yr
  - Transient beneath asphalt = 60 to 388 mm/yr
  - Moisture Redistribution will be slow and difficult to monitor
- Transport
  - Most (~99%) of the uranium is located near shaft bottoms, plutonium should be similar
  - Cesium is also near shaft bottoms

Recommendations

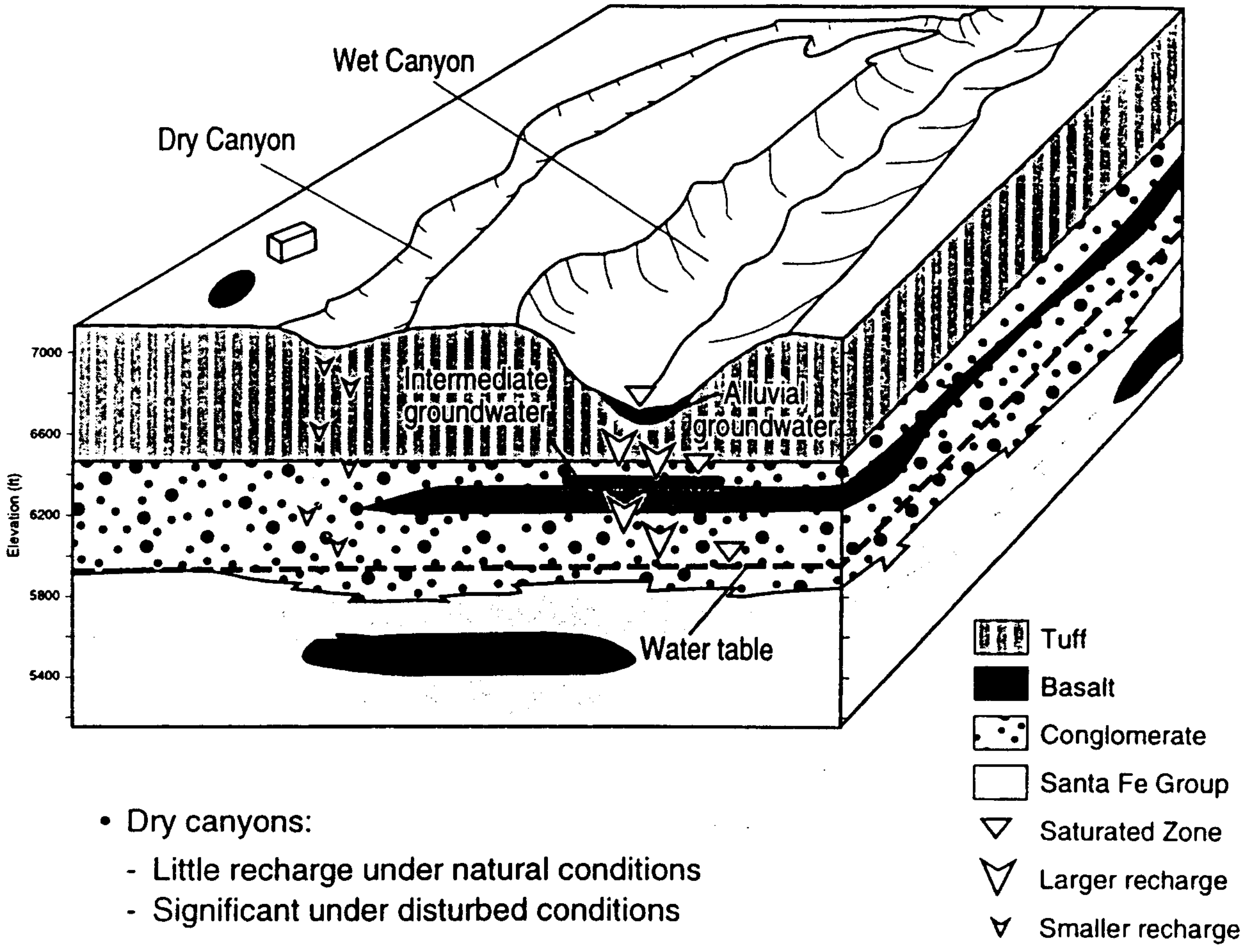
- Field Testing/Monitoring at MDA AB, Area 2
  - Directional borehole
    - should pass close to fractured zone beneath at least one shaft
    - should end no deeper than Unit 2
    - should sample for colloids
  - Moisture Monitoring
    - consider monitoring near surface to get best response
- Other sites - Question the use of asphalt

Numerical Model of Flow and Transport for Los Alamos Canyon

Presentation to External Advisory Group
October 13, 1999

Bruce Robinson
Earth and Environmental Sciences Division
Los Alamos National Laboratory
(505) 667-1910, robinson@lanl.gov

Hydrogeologic Conceptual Model



- Dry canyons:
  - Little recharge under natural conditions
  - Significant under disturbed conditions

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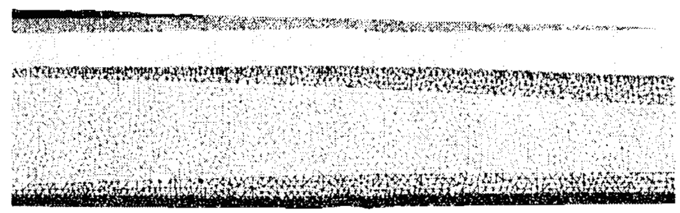
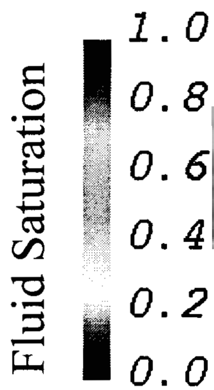
Modeling Approach

Hydrostratigraphy

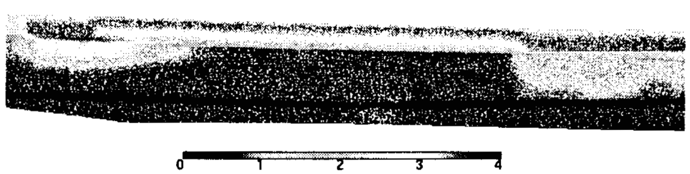
Numerical Grid



Fluid Flow Simulation



Solute Transport Results



Log Tritium Concentration

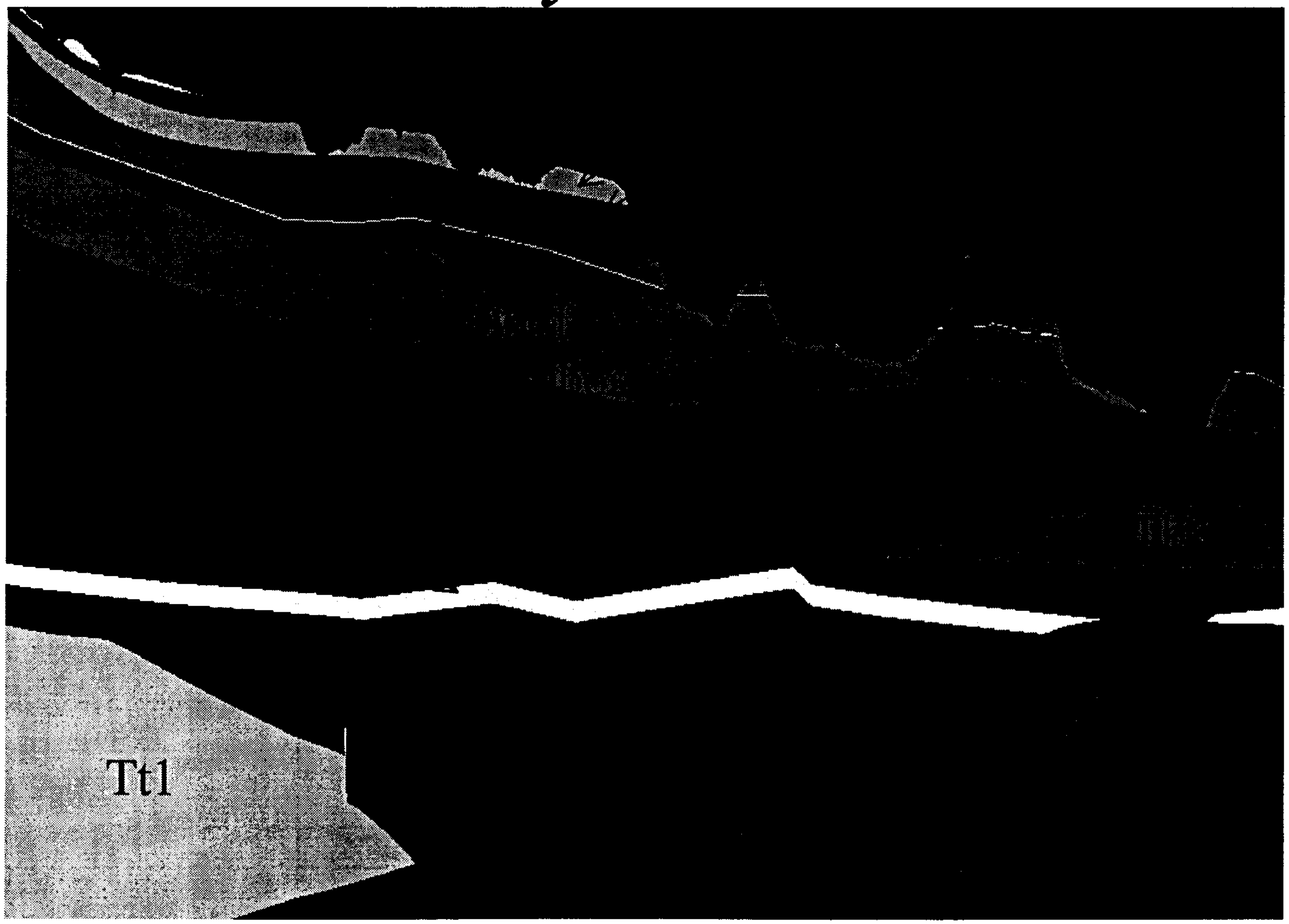
Los Alamos Canyon Stratigraphic Model

• Stratigraphic framework model is developed in the form of discrete layers based on well data, surface mapping, topographic data

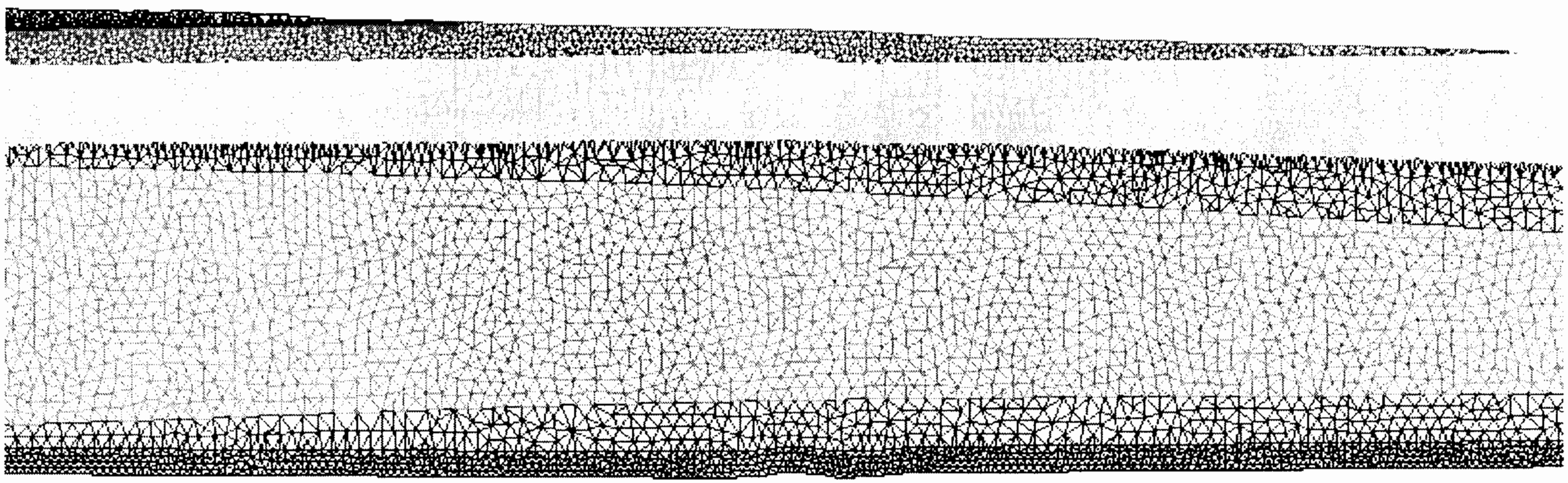
• 3D solid geometry model is constructed from this layer information using commercial software (Stratamodel)

• Data and geologic model results are maintained in LANL databases

Stratigraphy Along Los Alamos Canyon



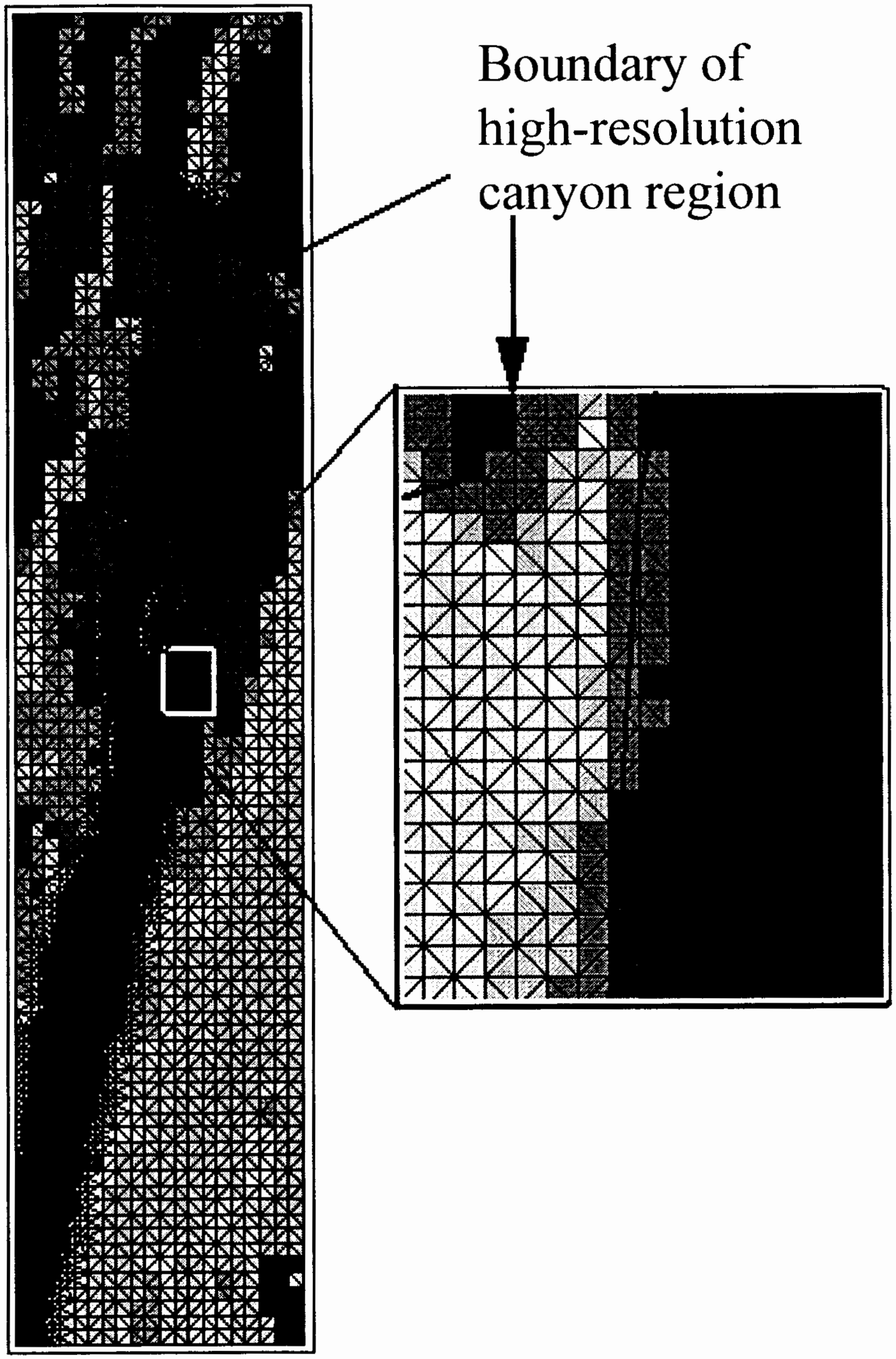
Los Alamos Canyon 2D Numerical Grid



- Hydrostratigraphic model is converted directly to a numerical grid
- LANL software is used to generate grids suitable for flow and transport calculations
- 2D and 3D grids were used in the development of the flow model

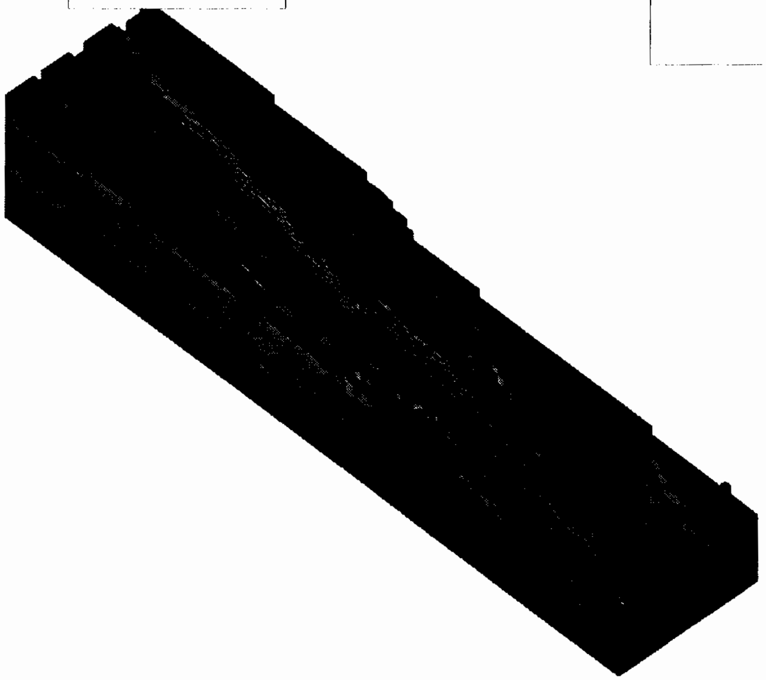
Plan View of 3D Grid

340,415 nodes
1,910,348 elements

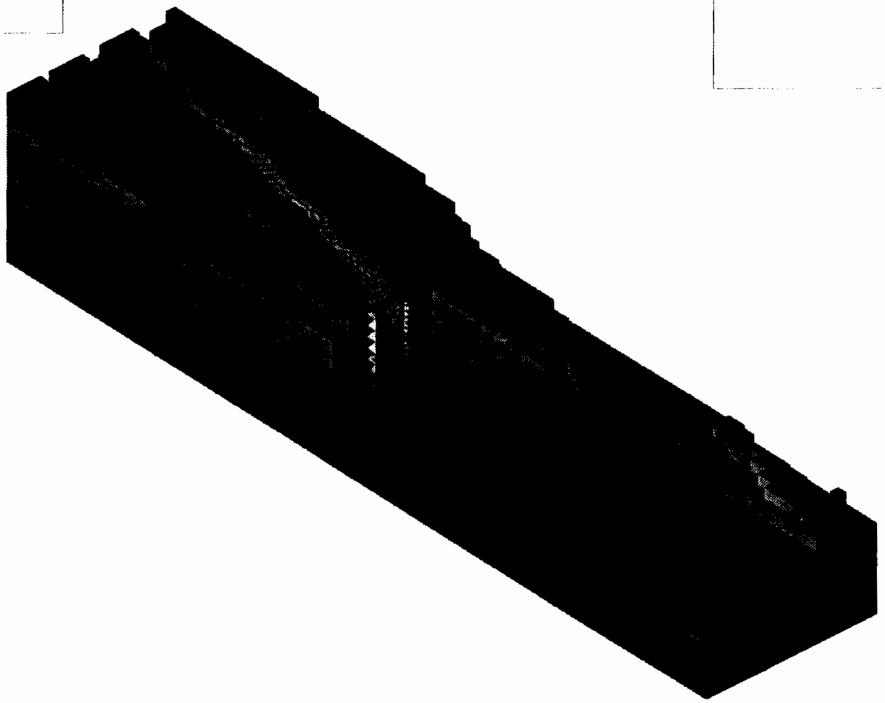


3D Grid of Los Alamos Canyon

Full View



Cut-away View

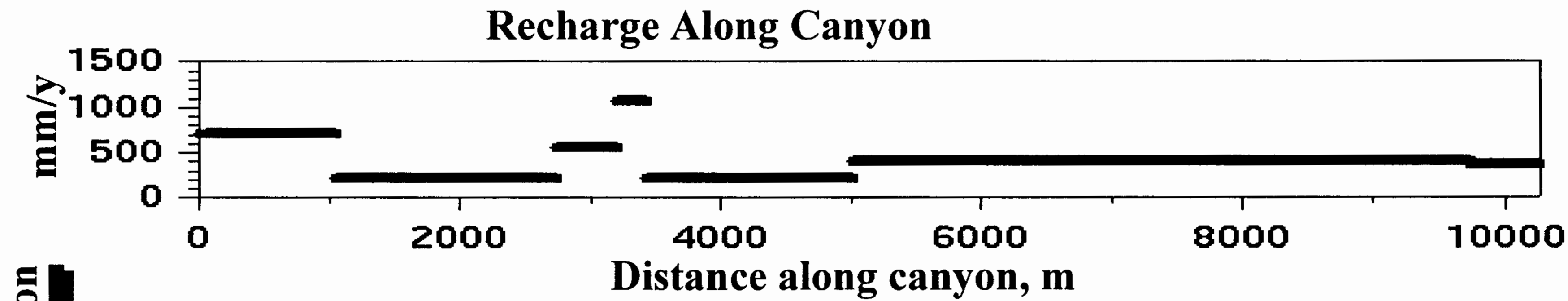


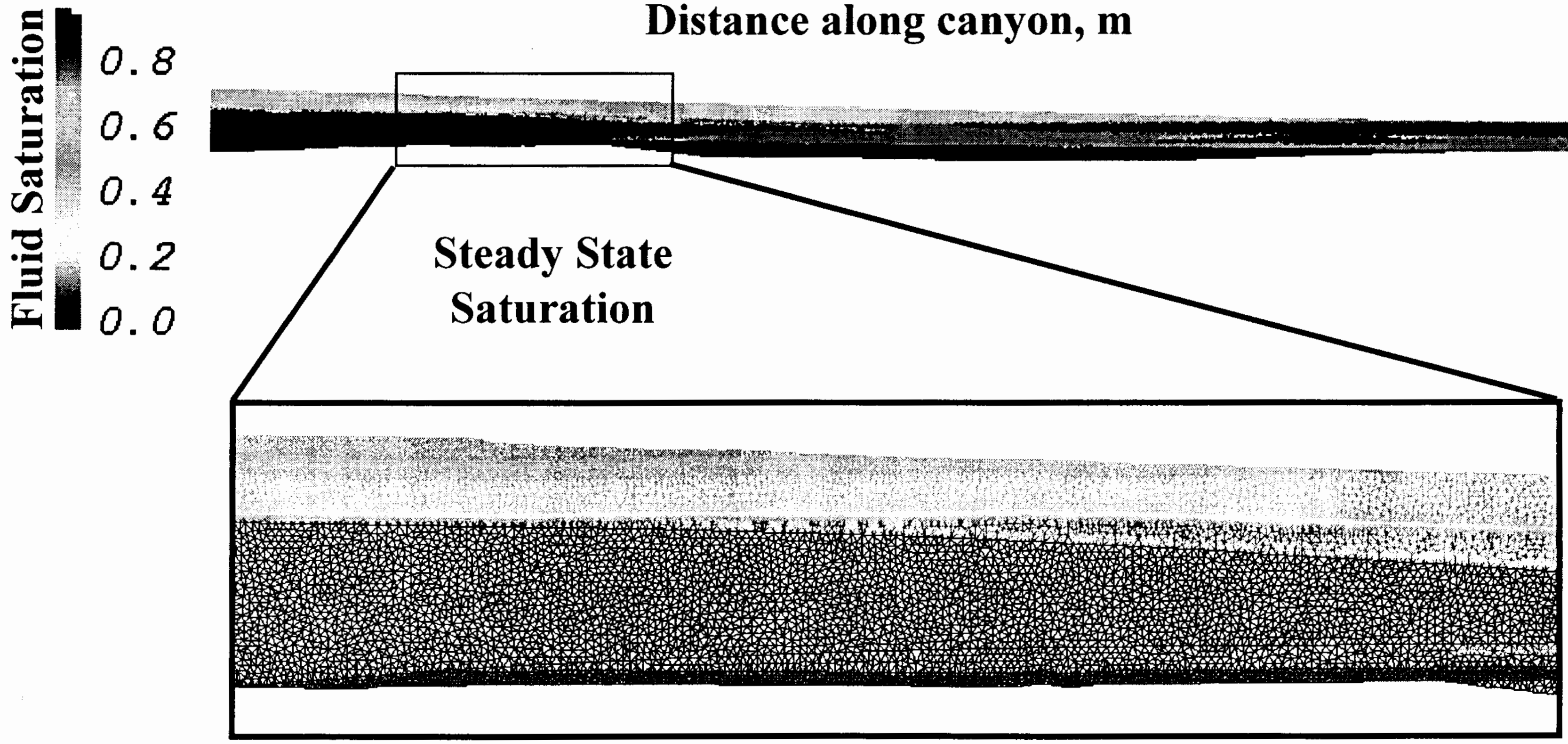
Synthesis of Water Budget Studies

- Gray (1997) prepared a water budget analysis for Los Alamos canyon during 1993-1995 based on the following data sets:
  - precipitation and snowpack measurements
  - streamflow discharge
  - Latent heat energy measurements (for ET estimates)
  - Head measurements in alluvial aquifer wells

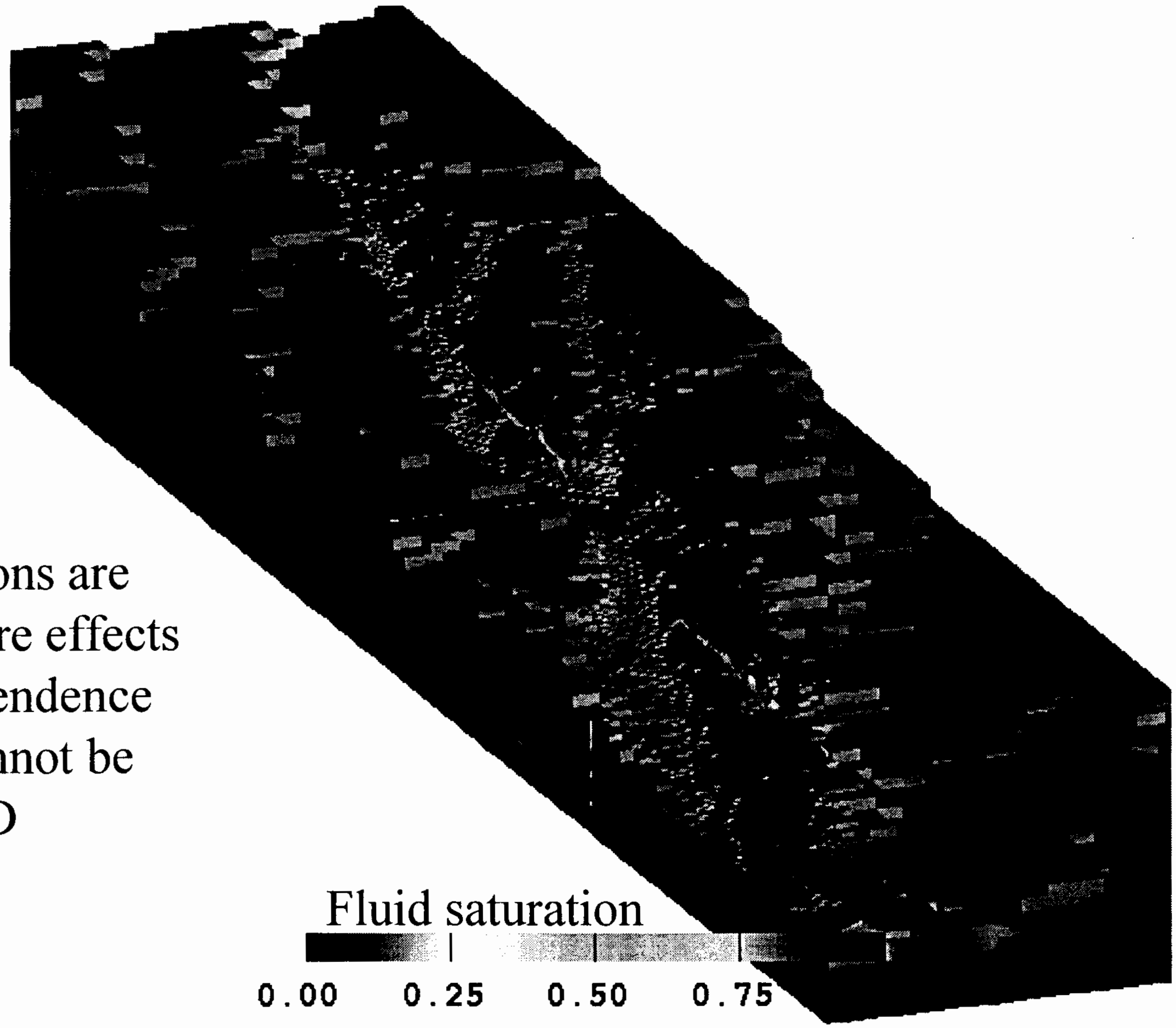
$$I = P - R - ET + \Delta S$$

Los Alamos Canyon 2D Fluid Flow Simulation



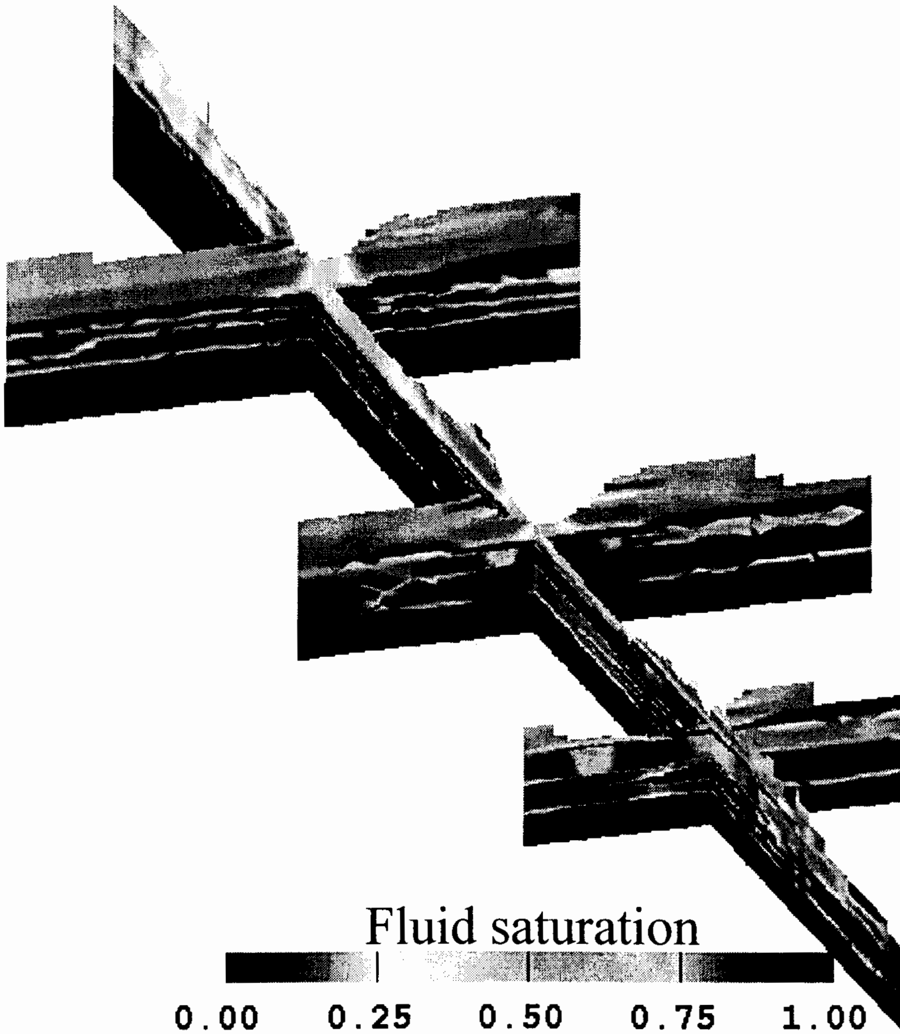


Los Alamos Canyon 3D Fluid Flow Simulation



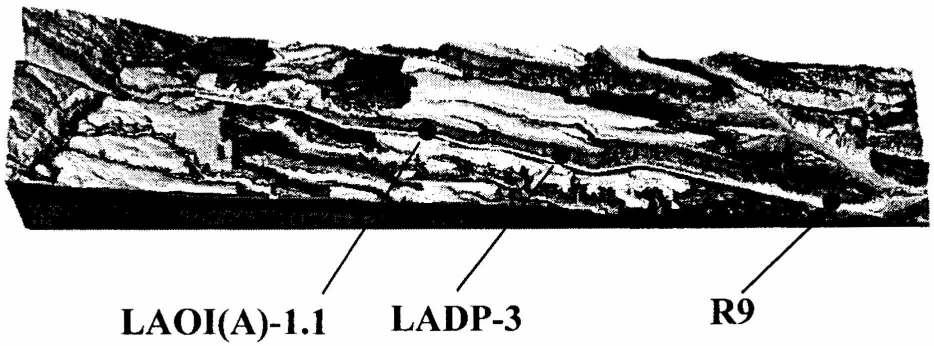
3D model simulations are performed to capture effects such as spatial dependence of recharge that cannot be fully captured in 2D

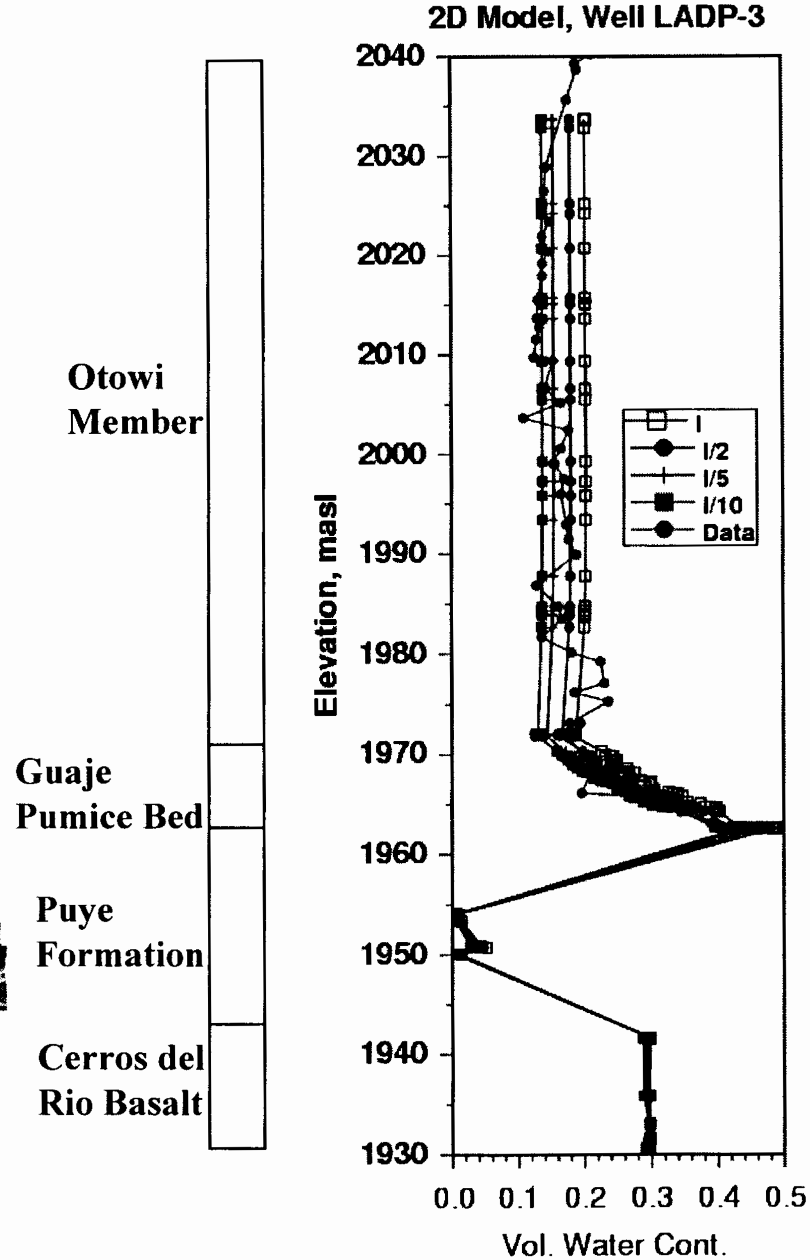
Los Alamos Canyon 3D Fluid Flow Simulation



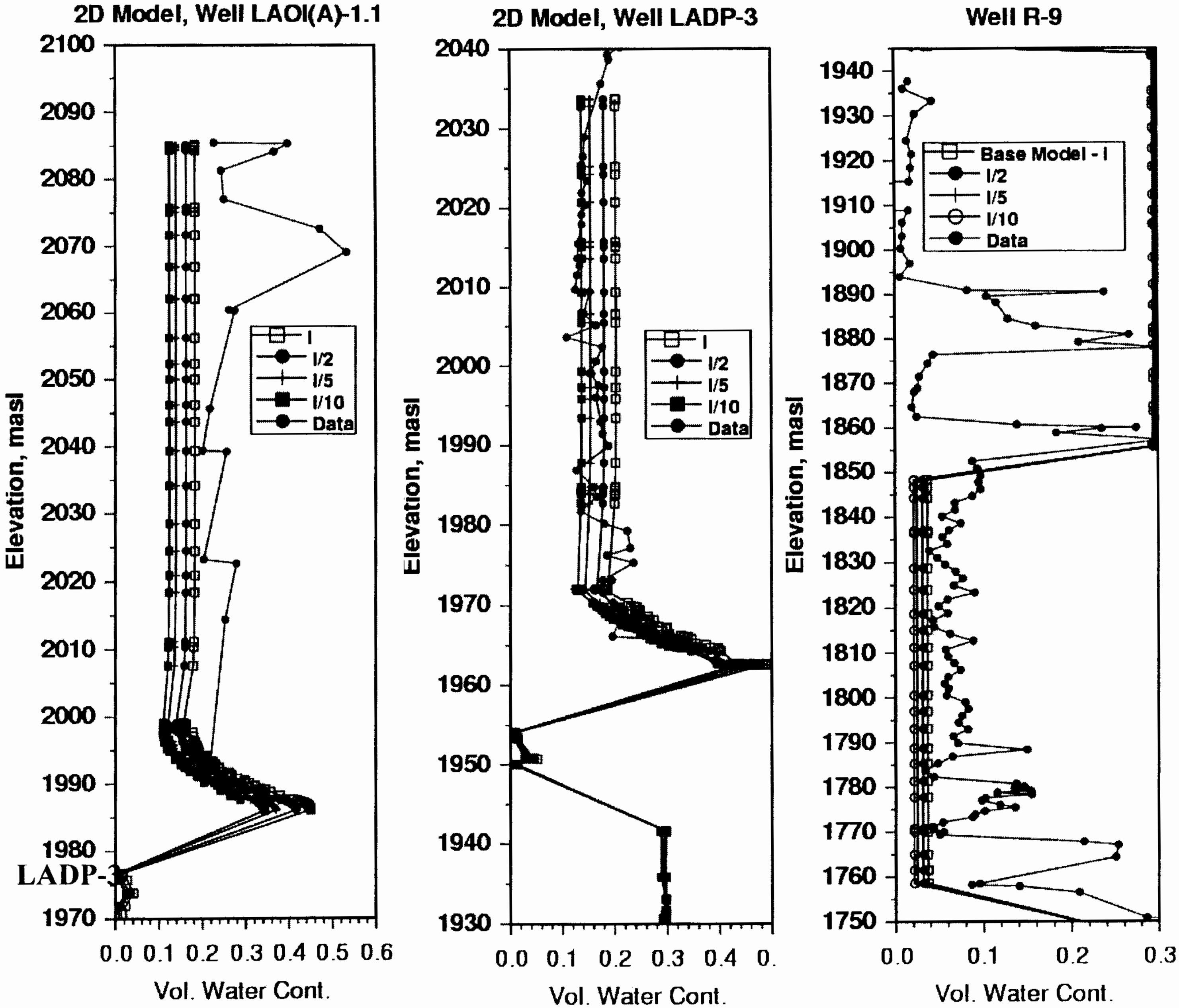
Comparison of 2D model results to data

Water content measurements in Well LADP-3

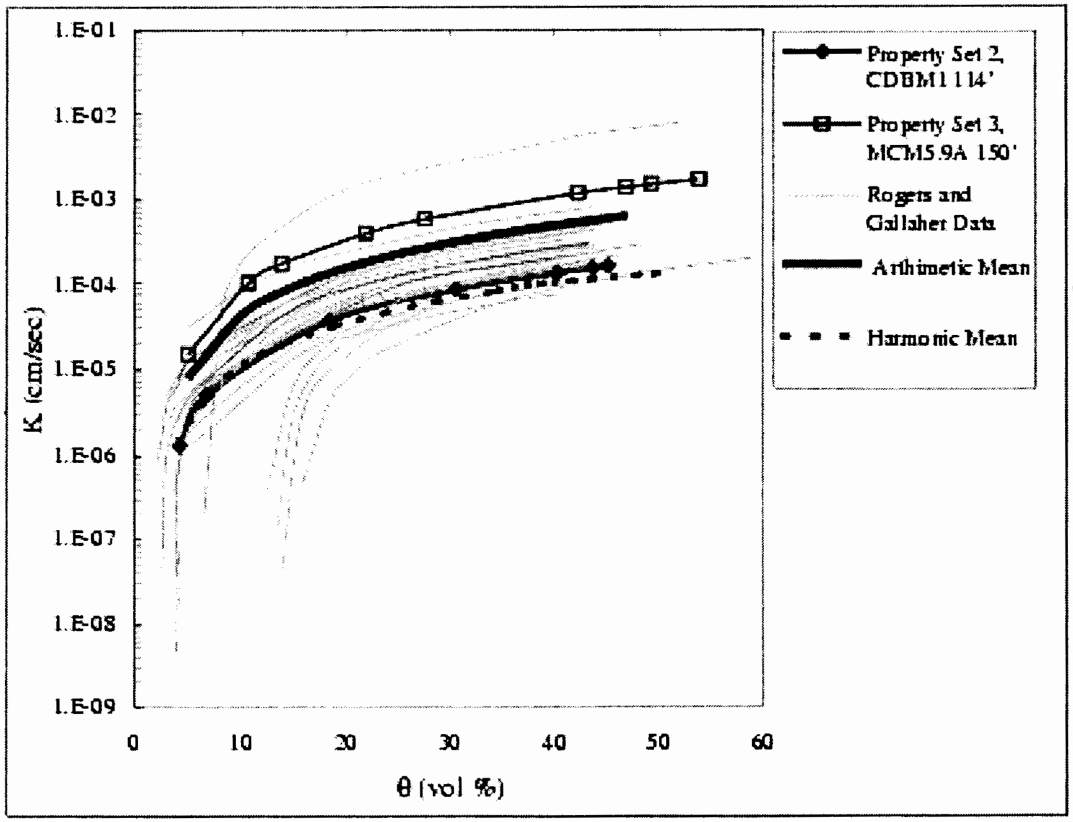


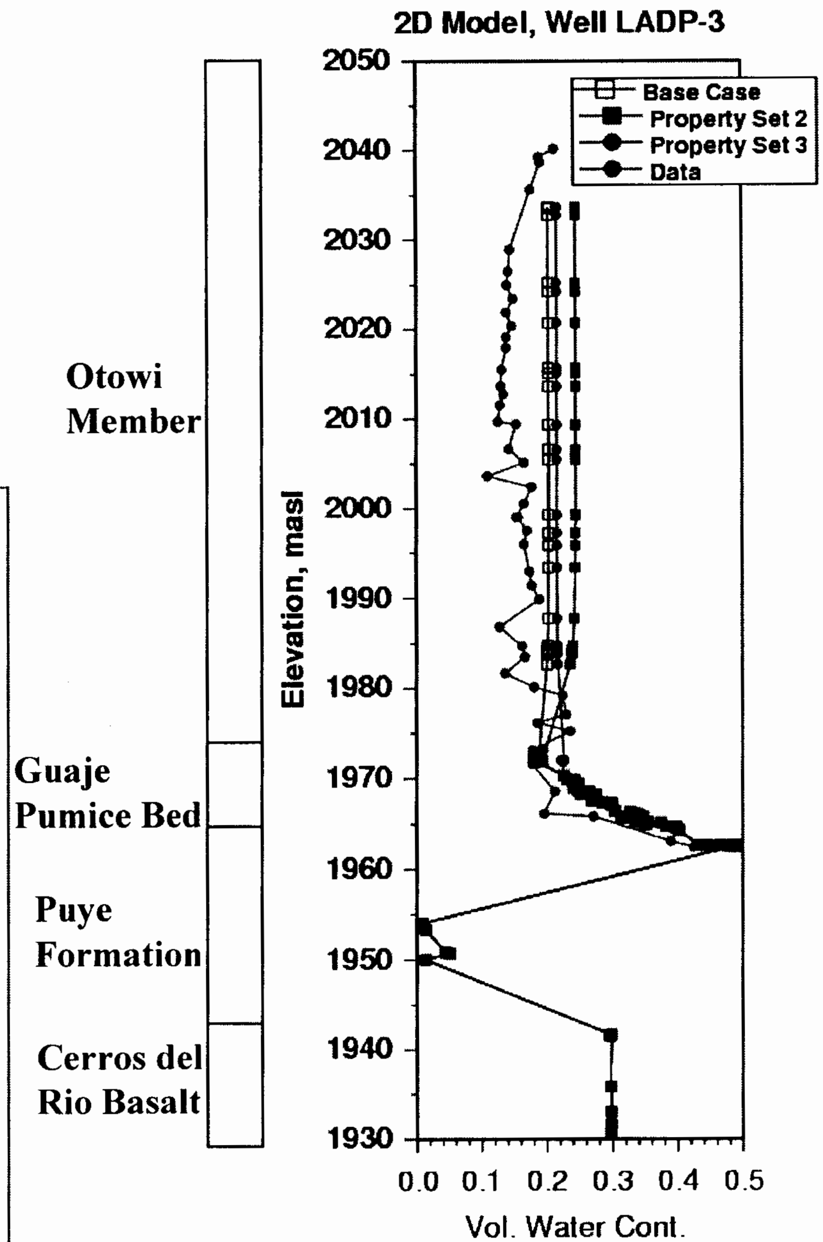


2D Model Calibration Results



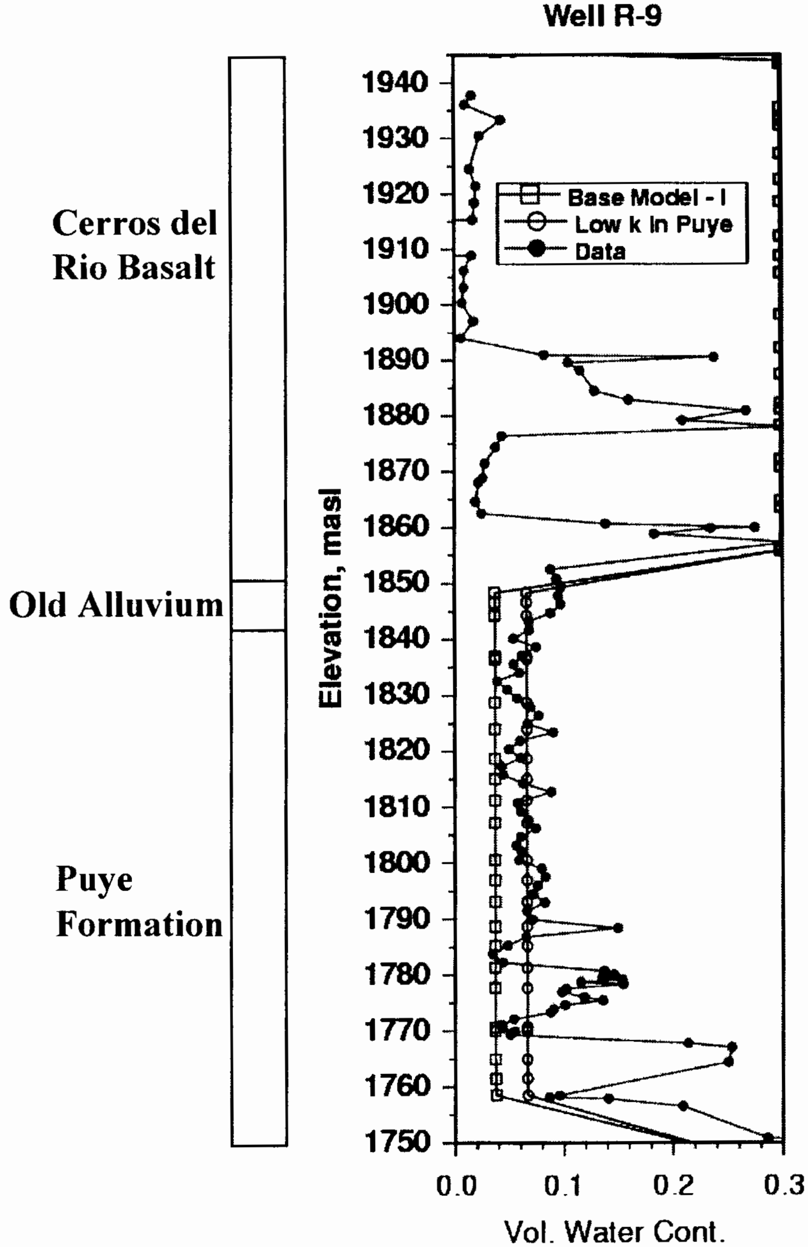
Sensitivity to Hydrologic properties: Otowi Member





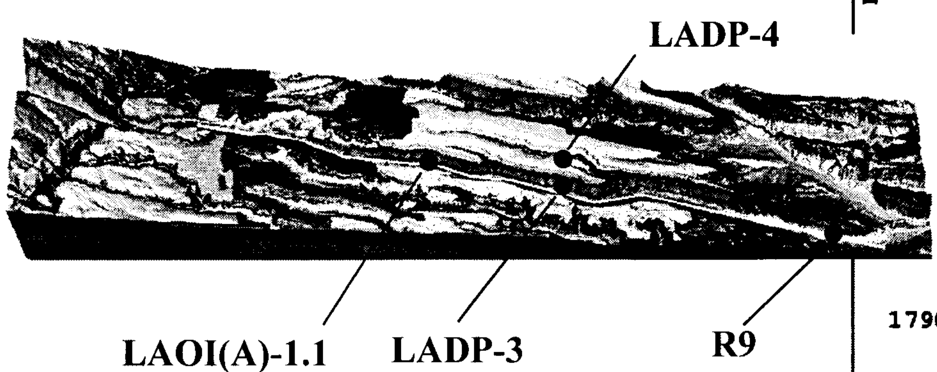
Sensitivity to Hydrologic properties: Puye Formation

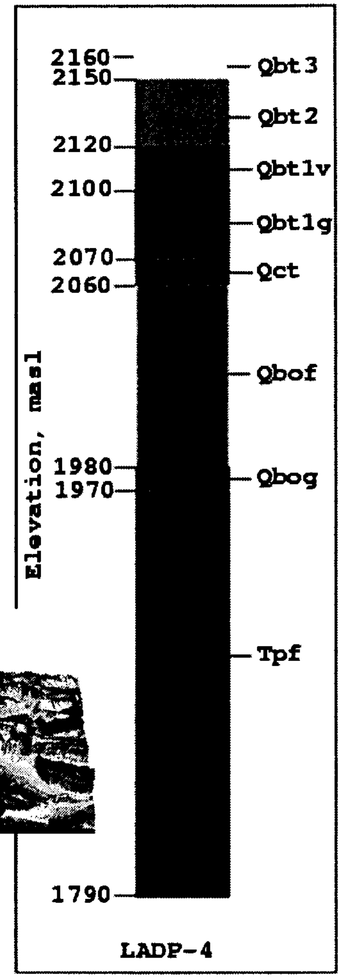
Reduction of the permeability by one order of magnitude from the base-case value yields a good fit to the water content data in the Puye formation. This value is within the range of measurements compiled in the regional aquifer modeling study.

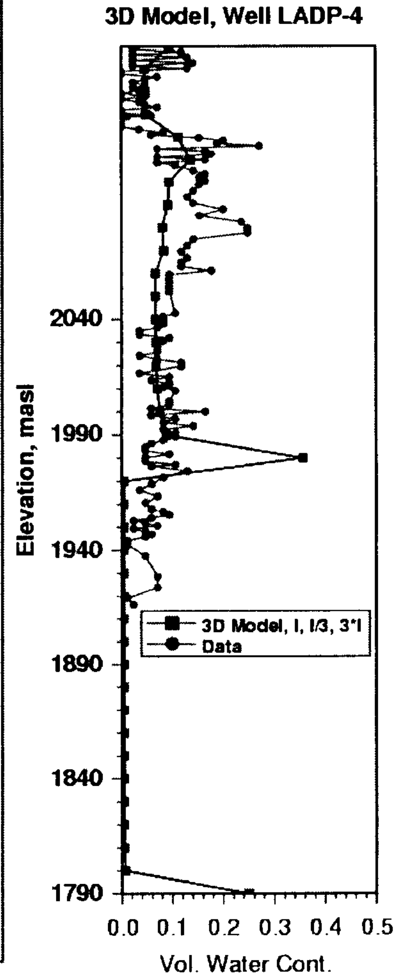


Comparison of 3D model results to data

Water content measurements in Well LADP-4

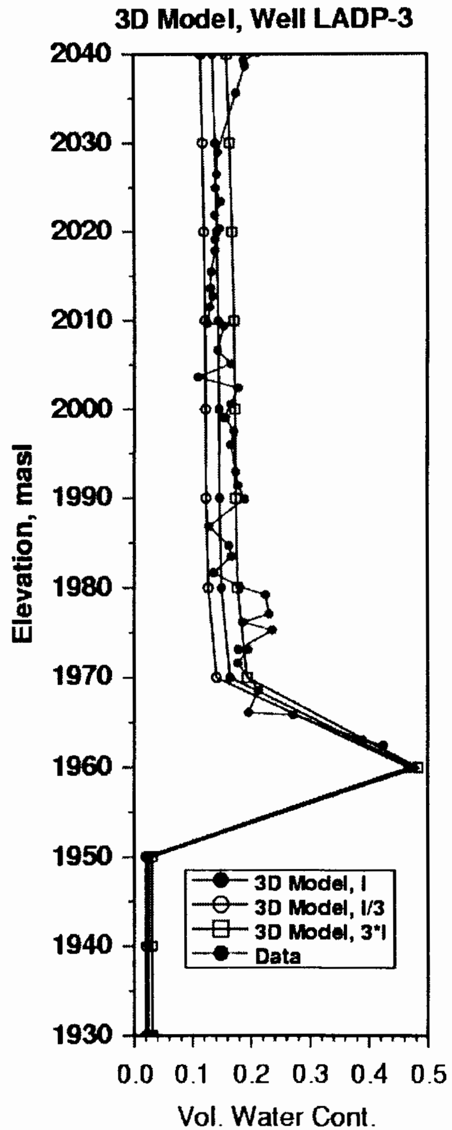


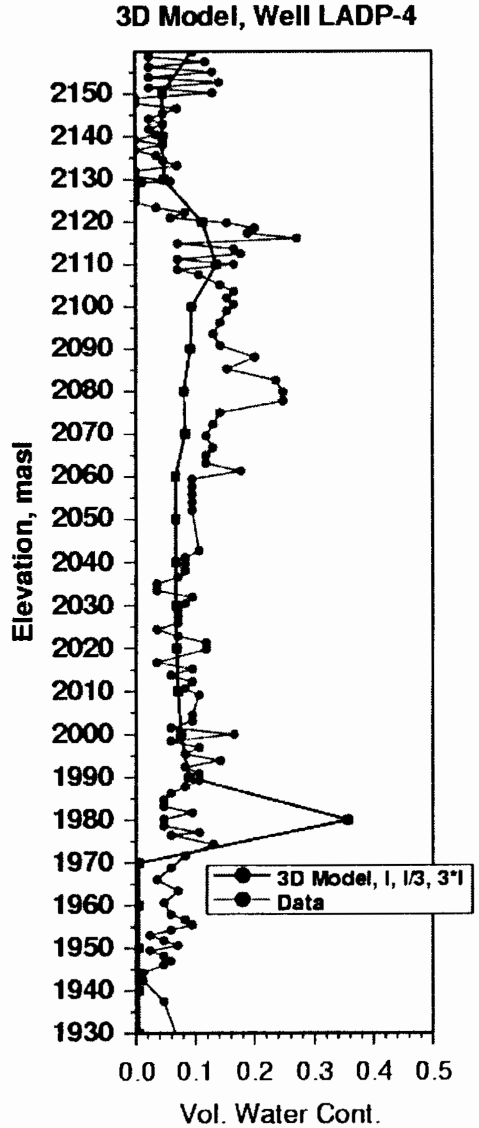




3D Model Result - Canyon Versus Mesa Well

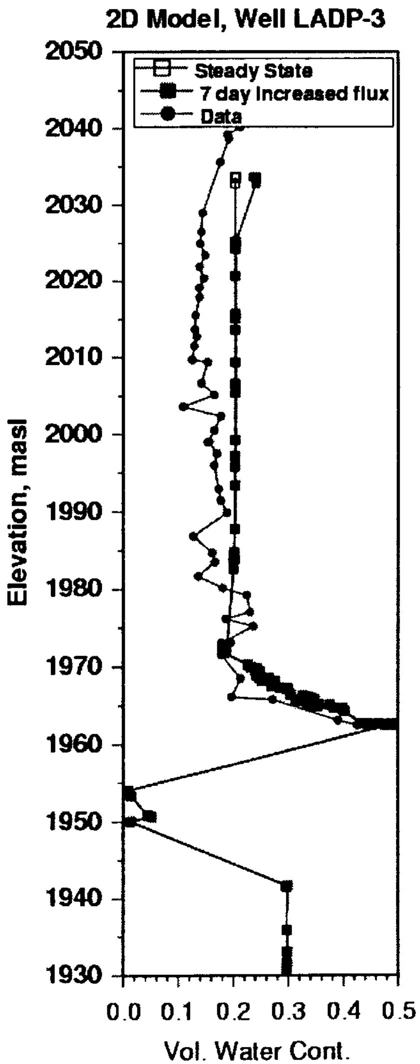
The model captures the wetter conditions in Los Alamos canyon through a spatially varying recharge rate. This approach yields a good fit to the water content data in both the canyons and mesas.





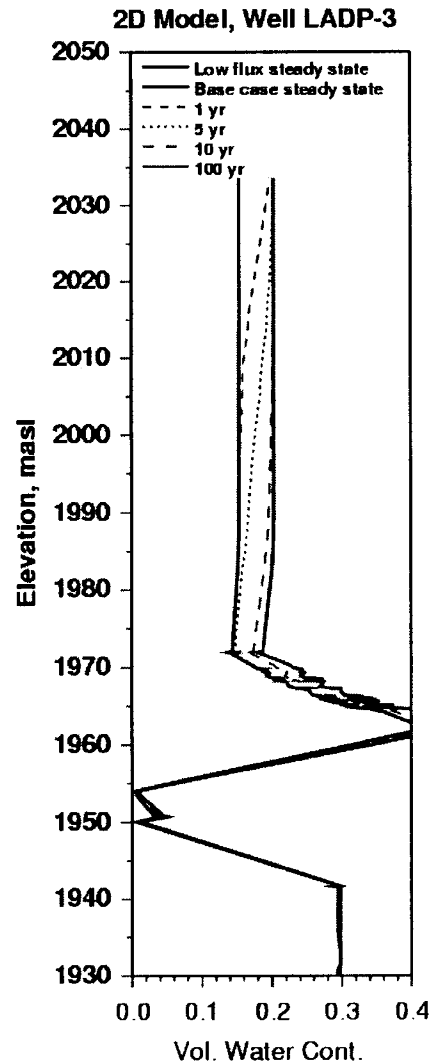
Transient Flow Simulations

Short-term transients are predicted to have very little impact on the hydrologic system as measured by water content profiles



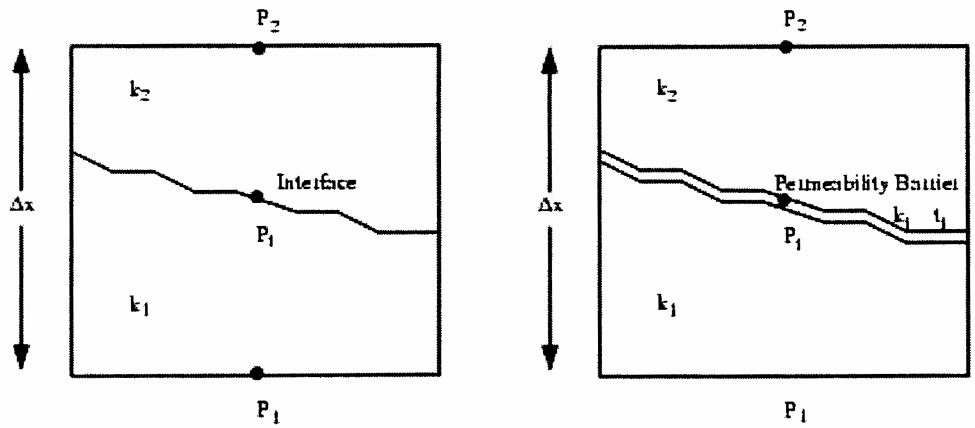
Changes in recharge rate that persist for a decade or more are predicted to impact the water content profiles to significant depths.

- Climate changes
- Laboratory operations



Perched Water Conceptual Model

Low-permeability barriers at the interfaces of specific hydrostratigraphic units exist that provide barriers to downward migration of fluid. These barriers are such that small percolation fluxes may pass through them, but at high enough rates, local saturation and lateral diversion occurs.

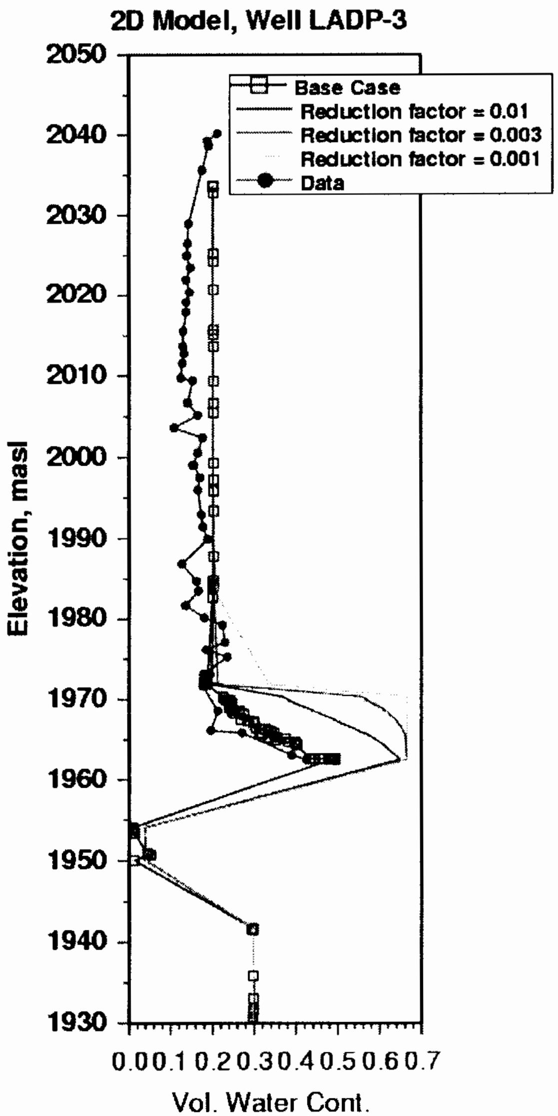


$$k_{harm} = \frac{2k_1k_2}{k_1+k_2}$$

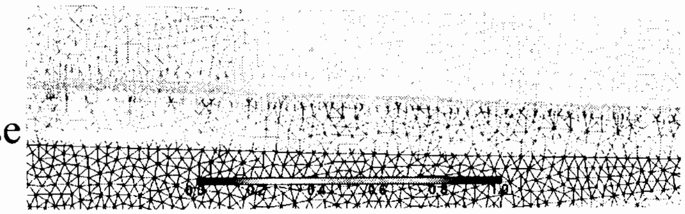
$$k_{comp} = \frac{1}{\frac{1}{2k_1} + \frac{t_i}{\Delta x k_i} + \frac{1}{2k_2}}$$

Code implementation: a reduction factor to the saturated hydraulic conductivity is specified at unit interfaces defined by the user.

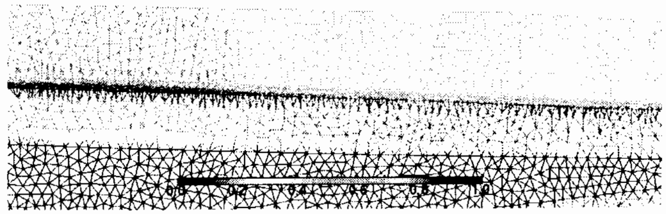
Perched Water Model Results



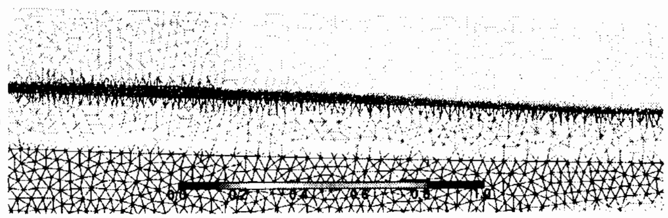
Base case



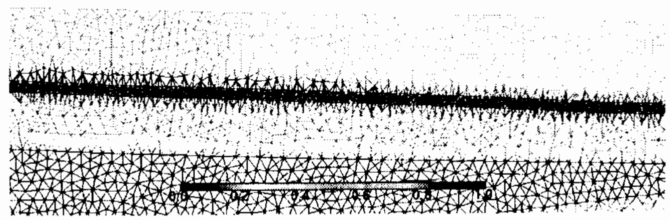
Red. Factor = 0.01



Red. Factor = 0.003



Red. Factor = 0.001



Contaminant Source Term Studies

- Use time-varying contaminant concentrations in shallow alluvial aquifer wells as input to model
- Use known release locations to deduce the direction and velocities of subsurface pathways
- Tritium information has been compiled for first phase of LA canyon study

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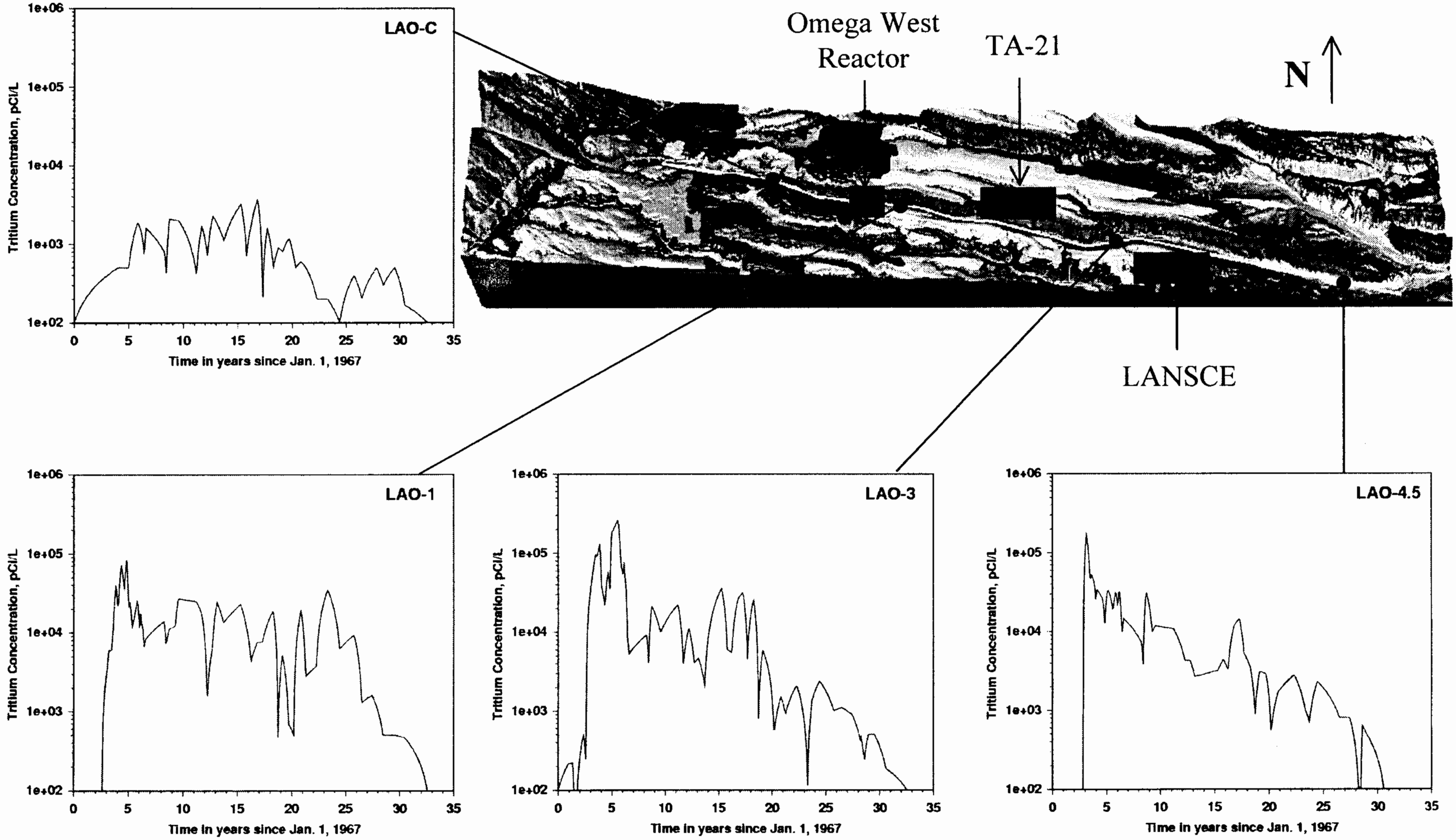
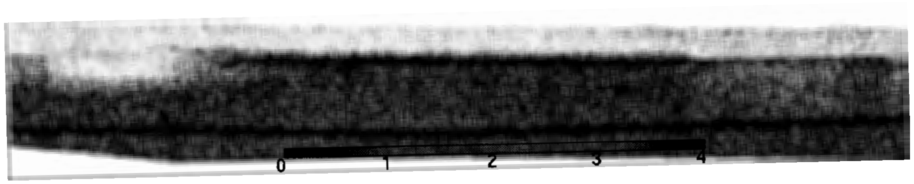
Tritium Concentrations in Alluvial Groundwater

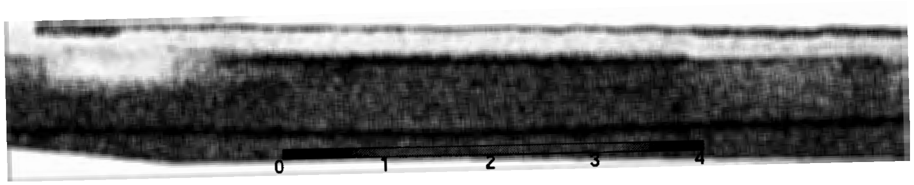


Simulated Tritium Concentrations

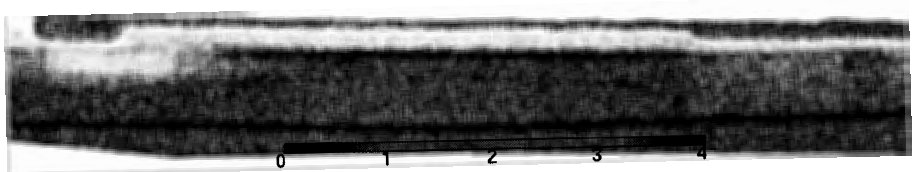
January 1, 1967 (background)



July 8, 1973

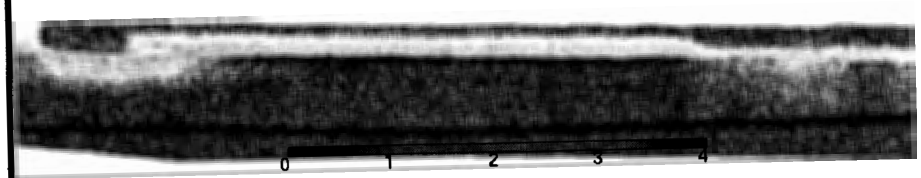


January 13, 1980

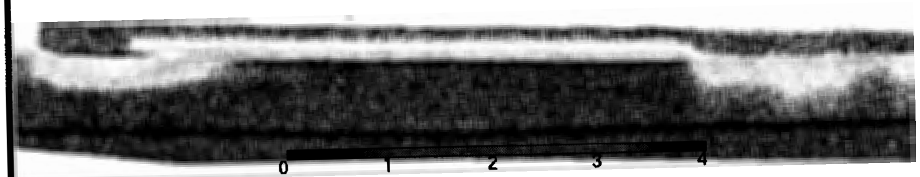


Log C (pCi/l)

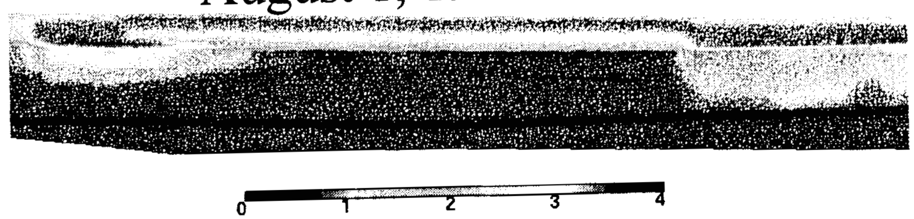
July 20, 1986



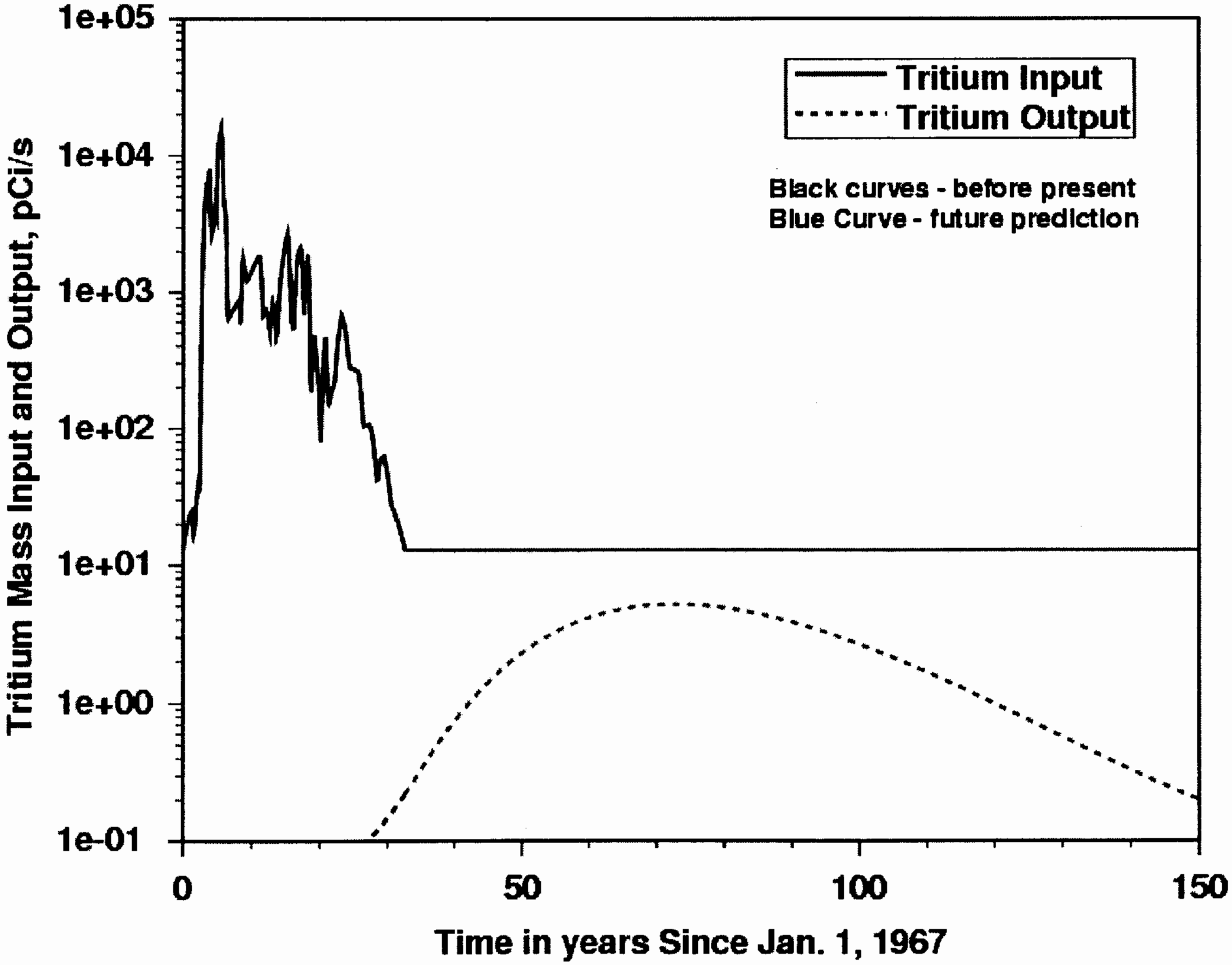
January 24, 1993



August 1, 1999

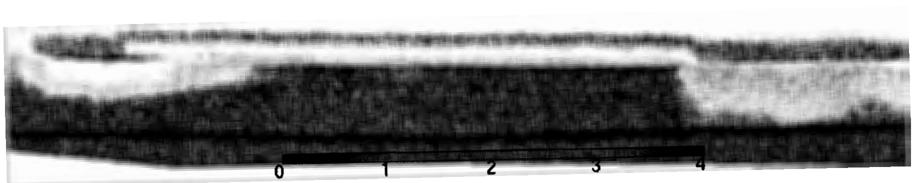


Simulated Tritium Vadose Zone Input and Output

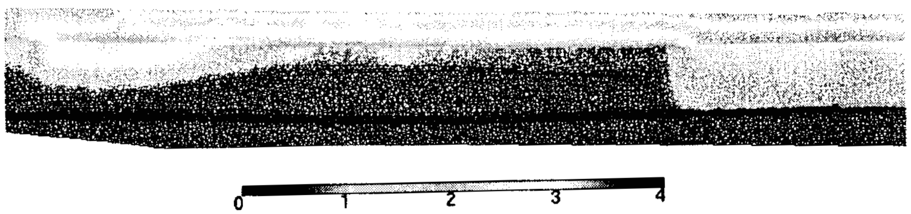


Predicted Future Tritium Concentrations

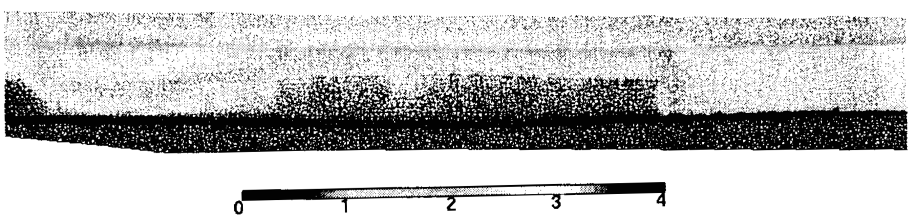
January 1, 1967 (background)



July 8, 1973

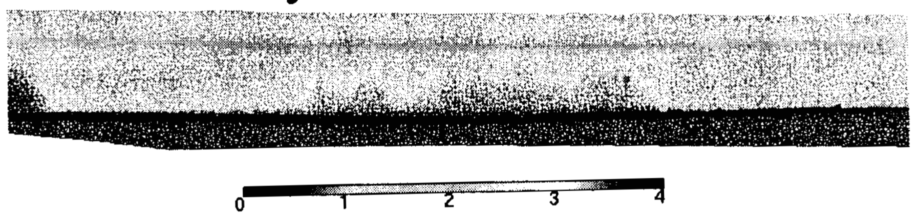


January 13, 1980

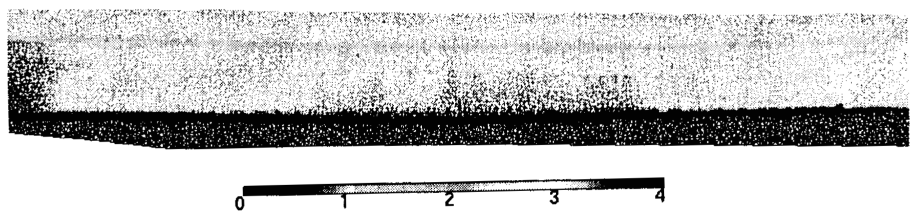


Log C (pCi/l)

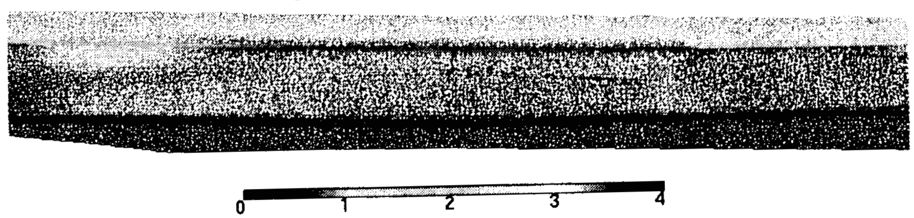
July 20, 1986



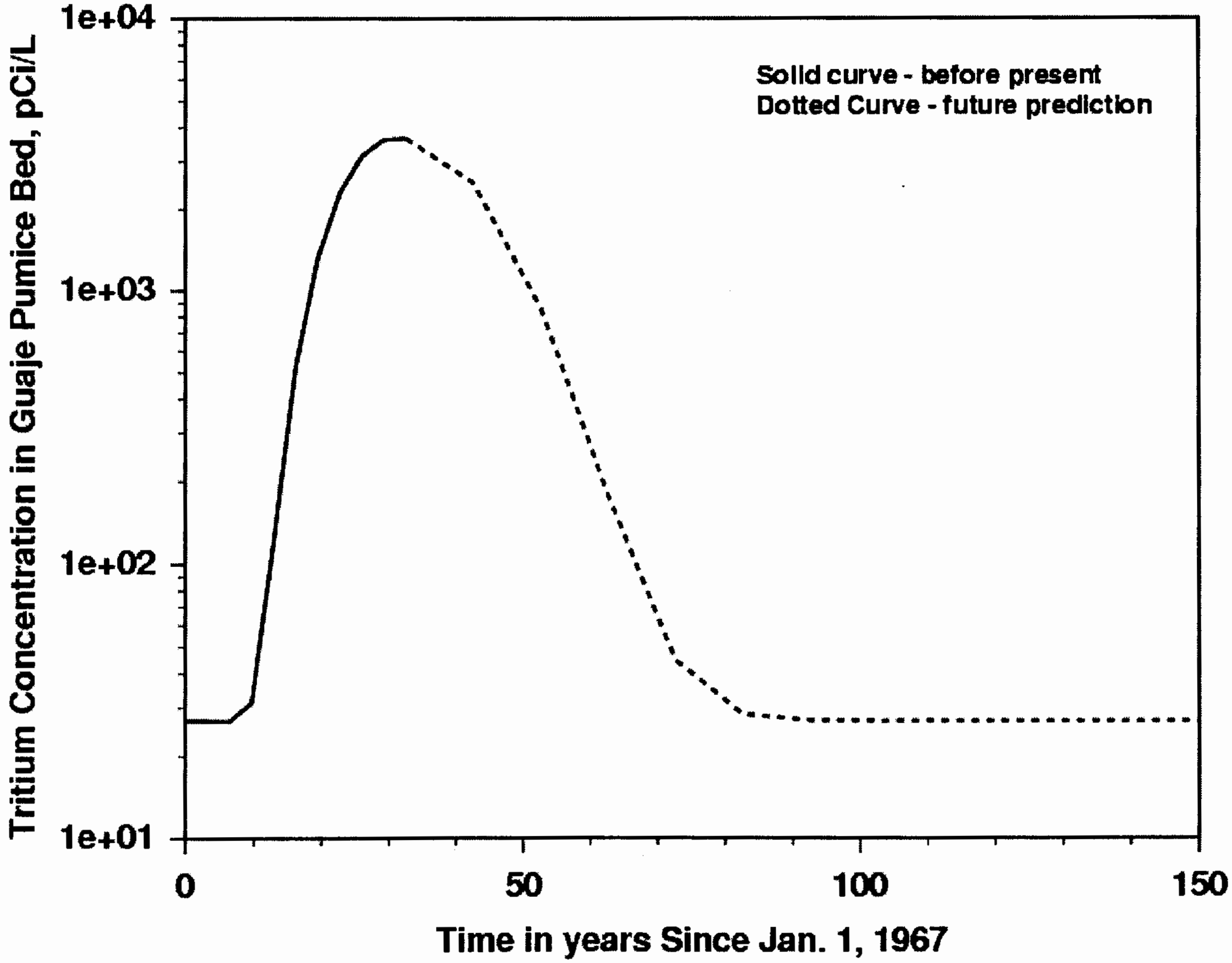
January 24, 1993



August 1, 1999



Simulated Tritium Concentration: Guaje Pumice Bed



Conclusions: Flow Model

- Process for constructing numerical model based on existing geologic framework is workable
- Water budget study provided a reasonable bound on mean average recharge rate entering the deep vadose zone from the canyon bottom
- Flow model calibration using existing hydrologic properties provides a reasonable match to the water content data beneath the canyon and on the mesas
- Flow model is currently being improved:
  - Conceptual model of hydrologic behavior of basalt units
  - Ability of the models to capture known occurrences of perched water

Conclusions: Tritium Transport

- Travel times of 40 years or less through the vadose zone are explained by the model.
- Vadose zone concentrations will naturally decline over the next 50 to 100 years due to dilution by clean fluid, radioactive decay, and mass arrival at the regional aquifer.
- Tritium concentrations in the perched water zones are predicted reasonably well by the model. Values are considerably lower than the measured alluvial groundwater concentrations due to dilution.
- Long-term monitoring of intermediate groundwater concentrations is expected to be a very slow process, with concentrations showing trends only over a time period of decades.

Future Work

- Flow Modeling
  - Perform additional flow calibration runs using newer data and improved concepts for capturing heterogeneous units and perched water
  - Predict water contents in future wells
  - Begin development of Mortendad Canyon model
- Transport Modeling
  - Extend transport model for Los Alamos canyon to other contaminants of interest (U, Sr) using a reactive chemical transport model formulation
  - Use model to integrate multiple contaminant sources

GEOCHEMICAL CONCEPTUAL MODEL OF CANYON SYSTEMS, LOS ALAMOS NATIONAL LABORATORY

By

Patrick Longmire

EES-1, MS D469

Los Alamos National Laboratory

October 13-14, 1999

GEOCHEMICAL CONCEPTUAL MODEL OF CANYON SYSTEMS

Topics of Interest

1. Geochemical Setting of Pajarito Plateau
2. Upper Los Alamos Canyon
3. TA-50 Discharge
4. R-25

GEOCHEMICAL CONCEPTUAL MODEL OF CANYON SYSTEMS

Purpose

Collect, interpret, and integrate geochemical data and information with hydrogeologic and risk data and information. These data and information shall be used to evaluate and quantify:

5. processes influencing water composition and age,

6. water/rock reactions,

7. fate and transport of contaminants, and

8. risk and potential remediation strategies.

GEOCHEMICAL CONCEPTUAL MODEL OF CANYON SYSTEMS

Input data and information needs for developing and refining the geochemical conceptual model include characterization of:

the natural system (background),

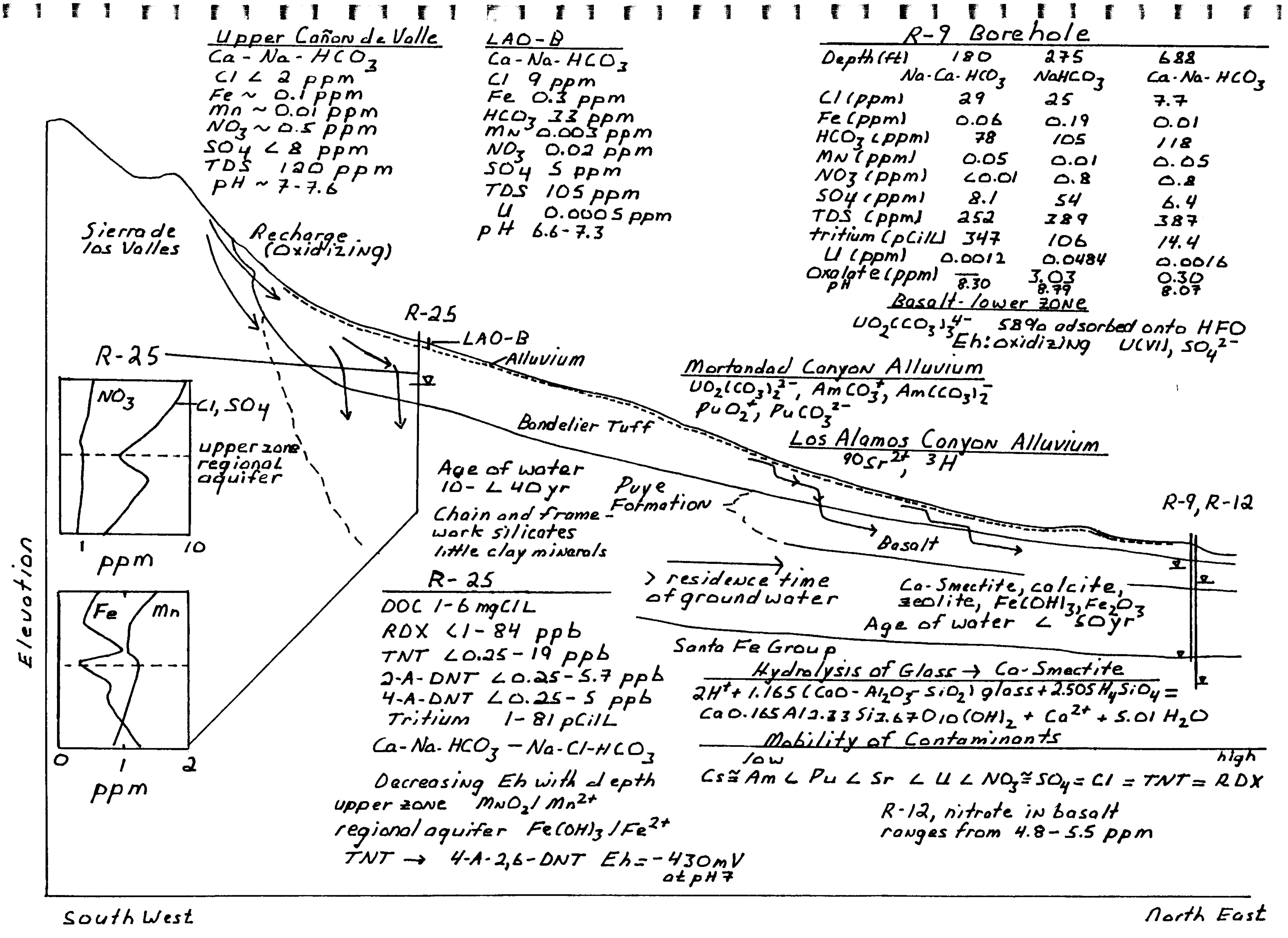
site conditions,

contaminants of concern,

contaminant fate and transport,

remediation strategies, and

risk.


Upper Cañon de Valle
Ca - Na - HCO3
Cl ∠ 2 ppm
Fe ~ 0.1 ppm
Mn ~ 0.01 ppm
NO3 ~ 0.5 ppm
SO4 ∠ 8 ppm
TDS 120 ppm
pH ~ 7-7.6
LAO-B
Ca-Na-HCO3
Cl 9 ppm
Fe 0.3 ppm
HCO3 33 ppm
MN 0.003 ppm
NO3 0.02 ppm
SO4 5 ppm
TDS 105 ppm
U 0.0005 ppm
pH 6.6-7.3
R-9 Borehole
Depth (ft) 180 275 688
Na-Ca-HCO3 NaHCO3 Ca-Na-HCO3
Cl (ppm) 29 25 7.7
Fe (ppm) 0.06 0.19 0.01
HCO3 (ppm) 78 105 118
MN (ppm) 0.05 0.01 0.05
NO3 (ppm) ∠0.01 0.8 0.8
SO4 (ppm) 8.1 54 6.4
TDS (ppm) 252 389 387
tritium (pCi/L) 347 106 14.4
U (ppm) 0.0012 0.0484 0.0016
Oxalate (ppm) — 3.03 0.30
pH 8.30 8.79 8.07
Basalt-lower ZONE
UO2(CO3)3 4- 58% adsorbed onto HFO
Eh: oxidizing U(VI), SO4 2-
Sierra de los Valles
Recharge (Oxidizing)
R-25
LAO-B
Alluvium
R-25
NO3
Cl, SO4
upper zone
regional aquifer
1
10
ppm
Fe
Mn
0
1
2
ppm
Elevation
Mortandad Canyon Alluvium
UO2(CO3)2 2-, AmCO3+, Am(CO3)2-
PuO2+, PuCO3 2-
Bandelier Tuff
Los Alamos Canyon Alluvium
90Sr2+, 3H
Age of water
10- ∠ 40 yr
Puye Formation
Chain and frame-work silicates
little clay minerals
Basalt
R-9, R-12
R-25
DOC 1-6 mgC/L
RDX ∠1-84 ppb
TNT ∠0.25-19 ppb
2-A-DNT ∠0.25-5.7 ppb
4-A-DNT ∠0.25-5 ppb
Tritium 1-81 pCi/L
Ca-Na-HCO3 — Na-Cl-HCO3
> residence time of groundwater
Ca-Smectite, calcite, zeolite, Fe(OH)3, Fe2O3
Age of water ∠ 50 yr
Santa Fe Group
Hydrolysis of Glass → Ca-Smectite
2H+ + 1.165 (CaO-Al2O3-SiO2) glass + 2.505 H4SiO4 =
Ca0.165 Al2.33 Si3.67 O10 (OH)2 + Ca2+ + 5.01 H2O
Mobility of Contaminants
low high
Cs ≅ Am ∠ Pu ∠ Sr ∠ U ∠ NO3 ≅ SO4 = Cl = TNT = RDX
Decreasing Eh with depth
upper zone MnO2/Mn2+
regional aquifer Fe(OH)3/Fe2+
TNT → 4-A-2,6-DNT Eh = -430 mV at pH 7
R-12, nitrate in basalt ranges from 4.8-5.5 ppm
South West
North East

TYPICAL BACKGROUND CONCENTRATIONS OF SELECTED SOLUTES AT LOS ALAMOS NATIONAL LABORATORY (LONGMIRE, GOFF, BERGFELD).

Water/ Saturated Zone	Chloride[1] (ppm)	Nitrate[1] (ppm)	Oxalate[1] (ppm)	Uranium[2] (ppb)	Tritium[3] (pCi/L)
Precipitation	0.5	0.20	-	-	3-11
Alluvium/ Bandelier Tuff	2-12	0.05	<0.02	0.5	1-65
Basalt	3	0.45	<0.02	0.8	<1
Regional Aquifer (Puye Formation/ Santa Fe Group)	2-10	0.38-1.88	<0.02	0.8	0.1-1.1

1. Chloride and nitrate (as N) analyzed by ion chromatography (IC) at LANL and Paragon Analytics, Inc., Fort Collins, Colorado. Oxalate analyzed by ion chromatography (IC) at LANL. 2. Uranium analyzed by laser-induced kinetic phosphorimetry (LIKP) at Paragon Analytics, Inc., Fort Collins, Colorado. 3. Tritium analyses (non-filtered samples) conducted by the University of Miami using direct counting and low-level electrolytic enrichment.

Precipitation samples collected at Pajarito Mountain from 1990-1994 (Adams et al., 1995). Background groundwater samples collected from1997-1998. Alluvial groundwater samples collected at LAO-B, upper Los Alamos Canyon. Bandelier Tuff groundwater samples collected at Water Canyon Gallery, upper Canyon de Valle Spring, Pine Spring, Seven Springs, and LAOI-1.1. Basalt groundwater samples collected at Spring 9B. Regional aquifer samples collected at Spring 1, La Mesita Spring, Pajarito Spring, Otowi-4, Guaje-5, and Sacred Spring.

GEOCHEMICAL CONCEPTUAL MODEL OF LOS ALAMOS CANYON

Major contaminants of concern include

tritium,

strontium-90, and

uranium.

GEOCHEMICAL CONCEPTUAL MODEL OF LOS ALAMOS CANYON

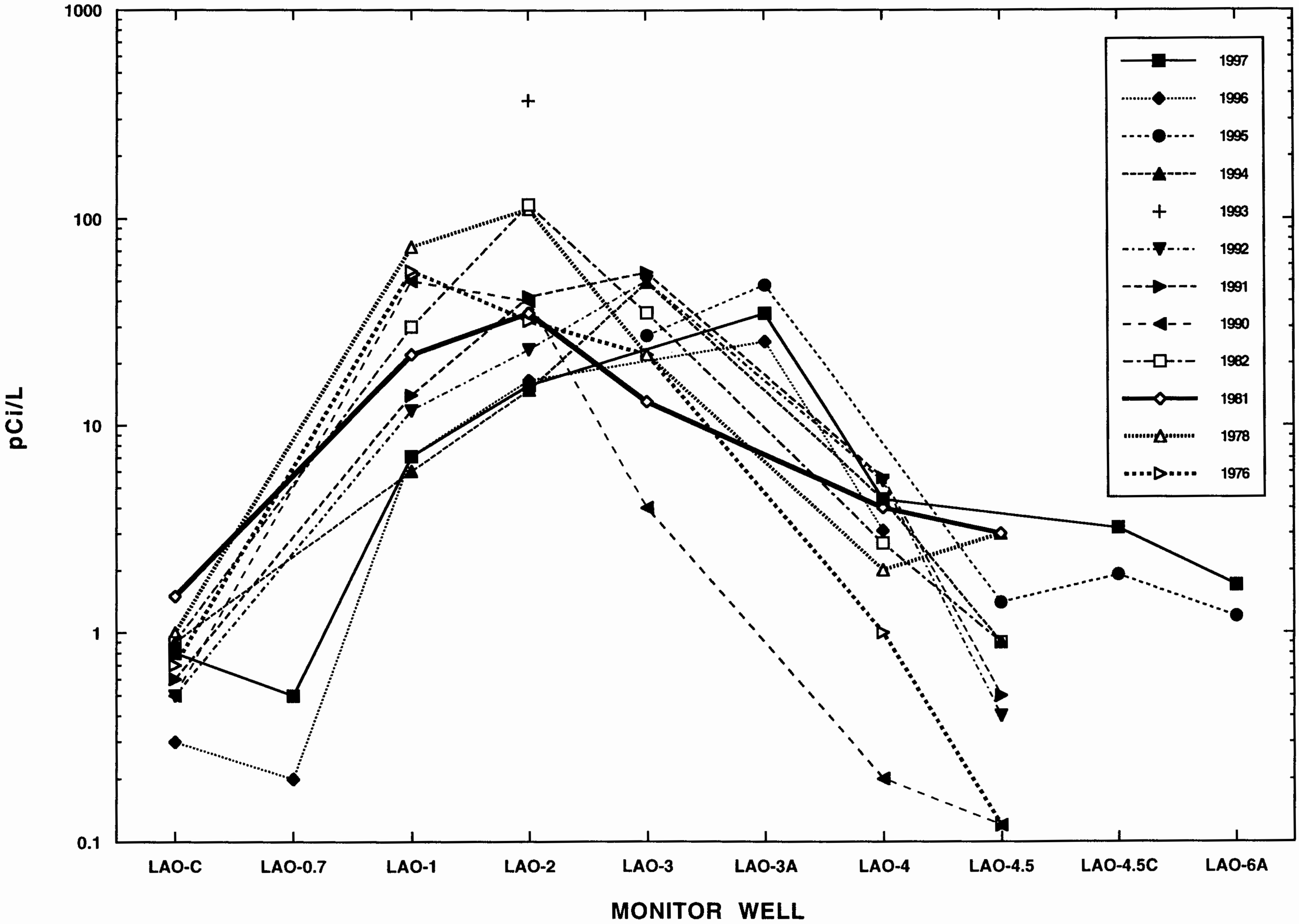
Distribution and speciation of strontium-90

Background: **Dissolved strontium-90 is less than one pCi/L in alluvial groundwater and is predicted to be stable as Sr^{2+}.**

Alluvial wells: **In 1997, activities of dissolved strontium-90 ranged from less than one to 34.8 pCi/L and is predicted to be stable as Sr^{2+}.**

USEPA maximum contaminant level for strontium-90 is 8 pCi/L.

DISTRIBUTION OF STRONTIUM-90 IN UPPER LOS ALAMOS CANYON (SOURCE OF DATA: ESH-18).



ACTIVITY DIAGRAM FOR THE H2O-Sr-SO4-HCO3 SYSTEM, AT 25C. LOGaHCO3- = -2.97 AND LOGaSO4-2 = -4.03.

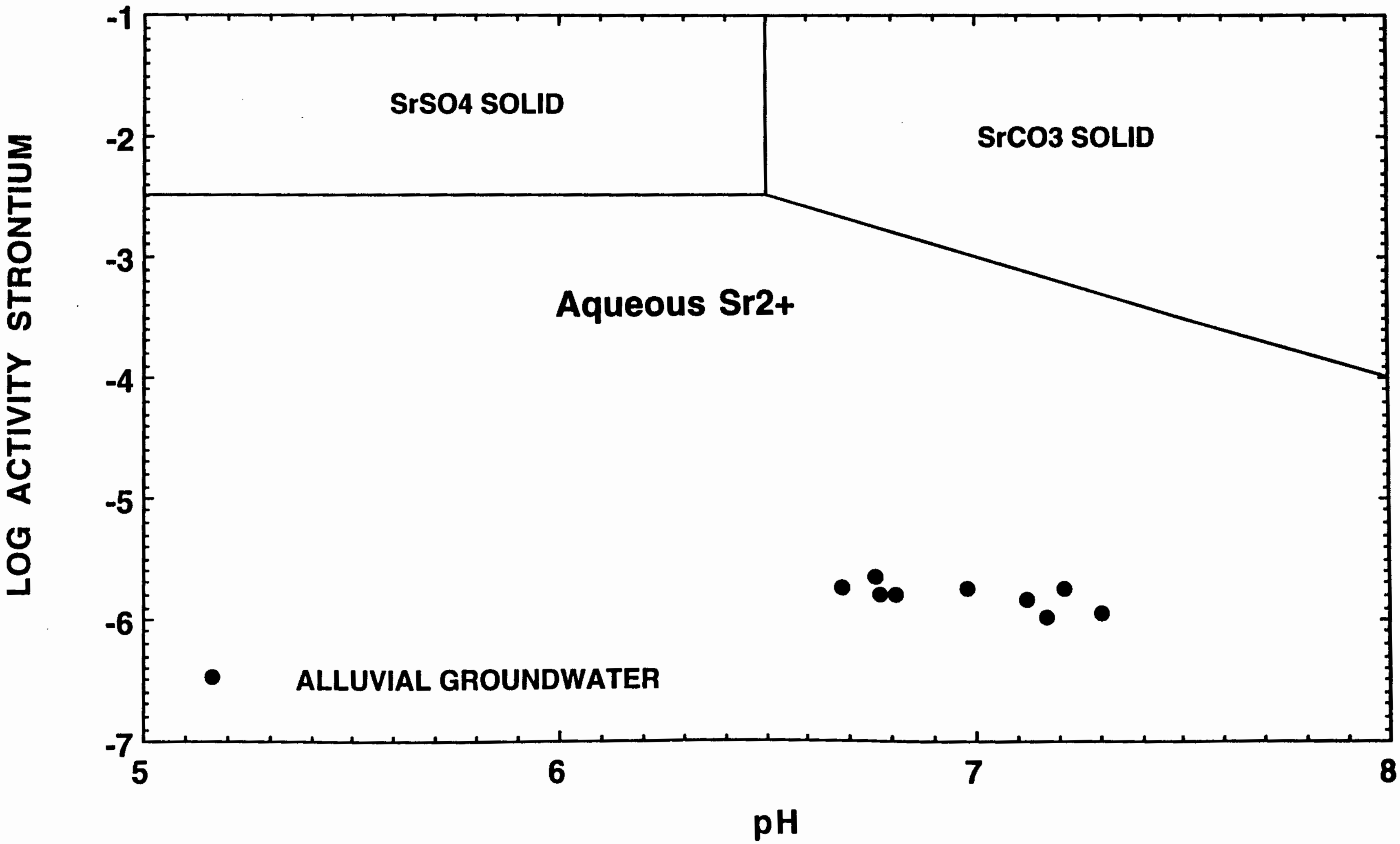
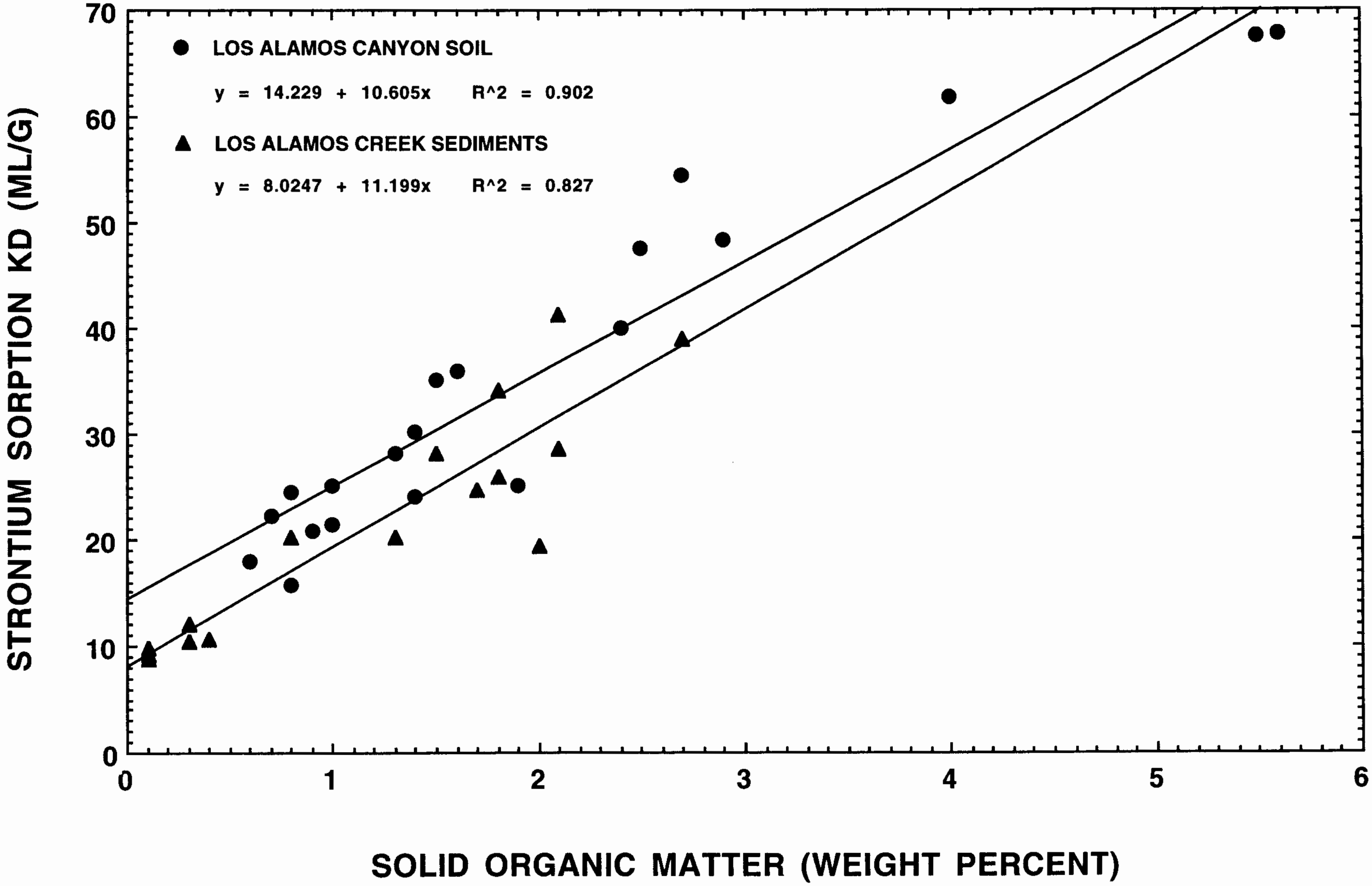


FIGURE 12. CORRELATION BETWEEN STRONTIUM SORPTION COEFFICIENTS AND PERCENTAGE OF SOLID ORGANIC MATTER FOR LOS ALAMOS CANYON SOILS AND CREEK CHANNEL SEDIMENTS (TA-2 AND TA-41) (LONGMIRE ET AL., 1996).



GENERALIZED URANIUM(VI) SPECIATION

Surface water and alluvial groundwater

$UO_2(NO_3)_2^0 + 2HCO_3^- = 2NO_3^- + UO_2(CO_3)_2^{2-} + 2H^+$

Perched groundwater in basalt-R9

$UO_2(CO_3)_2^{2-} + HCO_3^- = + UO_2(CO_3)_3^{4-} + H^+$

Nitric acid is used during uranium processing and when the treated solutions are discharged, dissolved uranium undergoes changes in speciation within alluvial and perched intermediate groundwater.

Formation of uranyl tricarbonato complexes occurs in R9 where groundwater has a pH of 8.8 and total carbonate of 112 ppm.

GROUNDWATER CHEMISTRY OF BOREHOLE R-9, UPPER LOS ALAMOS CANYON (FILTERED SAMPLES)

Saturated Zone (depth in ft)	Chloride[1] (ppm)	Nitrate[1] (ppm)	Oxalate[1] (ppm)	Uranium[2] (ppb)	Tritium[3] (pCi/L)
Basalt					
180	29.2	<0.01	<0.02	1.18	346.7± 12.4
275	25.5	0.82	3.03	48.4	106.3± 7.0
Puye Formation					
579	13.2	2.41	<0.02	2.08± 0.28	2.71 ± 0.58
615	177	0.76	2.85	2.17 ± 0.30	30.3 ± 2.0
624	20.2	1.97	0.48	1.41± 0.19	13.93 ± 0.90
Santa Fe Group					
688	7.67	0.78	0.30	1.63± 0.22	14.43 ± 0.96

1. Chloride and nitrate (as N) analyzed by ion chromatography (IC) at LANL and Paragon Analytics, Inc., Fort Collins, Colorado. Oxalate analyzed by ion chromatography (IC) at LANL.

2. Uranium in basalt analyzed by thermal ionization mass spectrometry (TIMS) at LANL and uranium in Puye Fm. analyzed by laser-induced kinetic phosphorimetry (LIKP) at Paragon with an error of 2 standard deviations.

3. Tritium analyses (non filtered samples) conducted by the University of Miami using direct counting and low-level electrolytic enrichment with an error of two standard deviations.

GEOCHEMICAL CONCEPTUAL MODEL OF LOS ALAMOS CANYON

Distribution and speciation of uranium(VI)

Background: **Dissolved uranium is less than one ppb in alluvial groundwater and is predicted to be stable as $UO_2(CO_3)_2^{2-}$ and $UO_2CO_3^0$.**

R-9: **Dissolved uranium is 48.4 ppb in lower perched zone in basalt and is predicted to be stable as $UO_2(CO_3)_3^{4-}$ and $UO_2(CO_3)_2^{2-}$.**

Proposed USEPA maximum contaminant level for uranium is 20 ppb.

FACTORS AFFECTING ADSORPTION OF RADIONUCLIDES IN THE BANDELIER TUFF AND ALLUVIAL GROUNDWATER, LOS ALAMOS, NEW MEXICO

Aquifer Material (Most Important Adsorbents)					Hydrochemical Conditions (Important Solution Variables)			
Fe-Al-Mn Oxides	Clays	Amorph. Al-Silicates	Carbonates	Org C	pH	Eh	Competing Ions	Complexing Ions
Fission Products (Sr-90, Cs-137)(Mobility of Sr-90 > Cs-137)								
X	X	X	O	X	X	NA	X	NA
Actinides (Mobility of U >> Pu > Am) (U-235, U-236, U-238, Pu-238, Pu-239/240, Am-241)								
X	X	X	O	O	X	X	X	X
Tritium (Little or no adsorption, very mobile, stable as HTO)								

X = Demonstrated Importance. O = Anticipated importance but data are absent. NA = Not applicable. Sources of information: TA-54 Performance Assessment, Longmire et al. (1996), ESH-18.

ACTIVITY DIAGRAM OF LOG[H4SiO4] VERSUS LOG([Ca2+]/H+2]) AT 25C FOR SEVERAL GROUNDWATERS WITHIN LOS ALAMOS AND WHITE ROCK CANYONS.

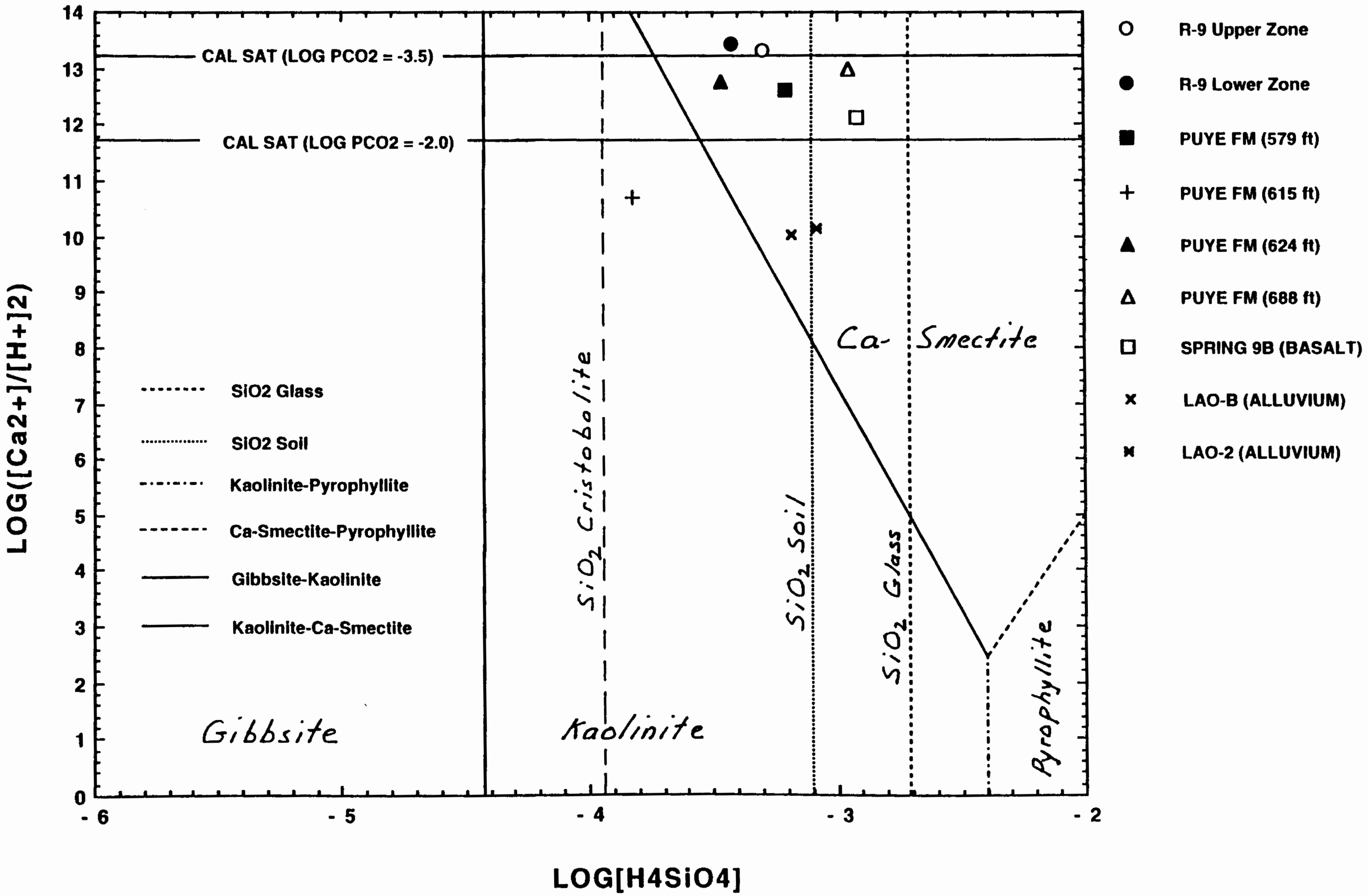


Table 1. Summary of Statistical Parameters for Distribution Coefficients (K_d) (ml/g) for the Bandelier Tuff (Core Hole 1107) using Water Canyon Gallery Groundwater, Material Disposal Area G, Technical Area 54, Los Alamos National Laboratory, Los Alamos, New Mexico.

Statistic	Americium	Neptunium	Plutonium	Uranium
Mean	144	0.253	20.41	5.14
Median	141	0.151	13.95	4.85
Stand. Dev.	13	0.239	18.78	2.98
Skewness	0.30	1.57	2.60	0.10
Minimum	122	0.082	7.64	1.33
Maximum	164	0.525	74.60	9.19
Samples	12	3	12	12

The pH of Water Canyon Gallery groundwater after sorption = 7.3 at 25 C. Sample depth intervals for the Bandelier Tuff are 65.0-66.0 ft, 74.0-75.0 ft, 79.1-79.7 ft, 79.9-80.0 ft, 91.0-91.5 ft, and 108.5-109.0 ft BGS. Two rock samples from each depth interval were used in the sorption experiments. For ^{237}Np, nine sorption experiments yielded negative K_d values because of the low distribution coefficients for this radionuclide. Source: Longmire et al., 1996.

THE Kd CONCEPT

A measure of the ratio of the amount of the element bound to the solid phase relative to the amount that is in solution.

1. **Empirical value measured in laboratory experiment or determined from nonfiltered and filtered water samples.**
2. **Concentrations of suspended uranium in perched zone are 0.112 mg/kg.**
3. **Concentrations of dissolved uranium in perched zone are 0.048 mg/L (Proposed EPA MCL for uranium is 0.020 mg/L).**
4. **Kd has the units of volume per mass. (ml/g, cm^3/g, or L/kg).**

For R-9, Kd = 0.112 mg/kg U/0.0484 mg/L U

Kd = 2.31 L/kg or 2.31 ml/g for U.

SURFACE COMPLEXATION MODELING OF R-9 GROUND WATER: DIFFUSE LAYER MODEL

The diffuse-layer adsorption model considers solution speciation and aqueous ion activities. The model uses the electric double-layer (EDL) theory. EDL theory assumes that the + or – surface charge of a sorbent in contact with solution generates an electrostatic potential that declines rapidly away from the sorbent surface. The potential is the same at the zero (sorbent surface) and d (solution) planes.

The concentration of hydrous ferric oxide (HFO) at 275 ft is 1.46 g/L.

The specific surface area of HFO is 600 m^2/g.

Model uranyl sorption with one surface containing two sites, high energy (s) (8.2×10^{-5} mol active site HFO/L) and low energy (w) (0.003 mol active site HFO/L). The estimated intrinsic constants for uranyl sorption (Langmuir, 1997) include:

$Fe^{s}OH + UO_2^{2+} = Fe^{s}OHUO_2^{2+}$ ($\log K_1 = 5.2$) and

$Fe^{w}OH + UO_2^{2+} - H^{+} = Fe^{w}OUO_2^{+}$ ($\log K_2 = 2.8$).

SURFACE COMPLEXATION MODELING OF R-9 GROUND WATER: DIFFUSE LAYER MODEL

The DLM predicts that 112 ppb total uranium in the 275 ft perched zone at pH 9 occurs as

57.5 percent uranyl bound as $SO2UO_2^+$ (64 ppb sorbed U),

5.1 percent uranyl bound as $UO_2(CO_3)_2^{2-}$ (7 ppb dissolved U), and

36.6 percent uranyl bound as $UO_2(CO_3)_3^{4-}$ (41 ppb dissolved U) (calculated total dissolved U is 48 ppb, measured dissolved U is 48.4 ppb).

The Kd, based on the DLM, is

(U sorbed M)/(U dissolved M) X (10^3mg/g)/(1.46 mg/ml),

($10^{-6.57}$ M)/($10^{-6.70}$ M) X (10^3mg/g)/(1.46 mg/ml),

$Kd_{(DLM)}$ = 926 ml/g.

GROUNDWATER CHEMISTRY OF BOREHOLE R-12, SANDIA CANYON (FILTERED SAMPLES) (COMPILED BY P. LONGMIRE, 07/28/98)

Saturated Zone (depth in ft)	Chloride[1] (ppm)	Ammonium[1] (ppm)	Nitrate[1] (ppm)	Oxalate[1] (ppm)	Uranium[2] (ppb)	Tritium[3] (pCi/L)
Basalt-Perched Zone(s)						
443	31.5	<0.02	4.9	<0.02	2.51± 0.34	254.7± 16.6
464	200	13.5	0.21	<0.02	2.04± 0.28	208.1± 7.0
495	33.4	0.26	5.5	<0.02	2.46± 0.34	249.3± 8.3
Santa Fe Group-Basalt						
805	10.1	0.02	0.46	<0.02	4.08± 0.56	46.9± 1.6

Chloride and nitrate (as N) analyzed by ion chromatography (IC) at LANL and Paragon Analytics, Inc., Fort Collins, Colorado. Ammonium (as N) analyzed by ion specific electrode (ISE) at LANL. Oxalate analyzed by ion chromatography (IC) at LANL.

2. Uranium in basalt analyzed by laser-induced kinetic phosphorimetry (LIKP) at Paragon with an error of 2 standard deviations.

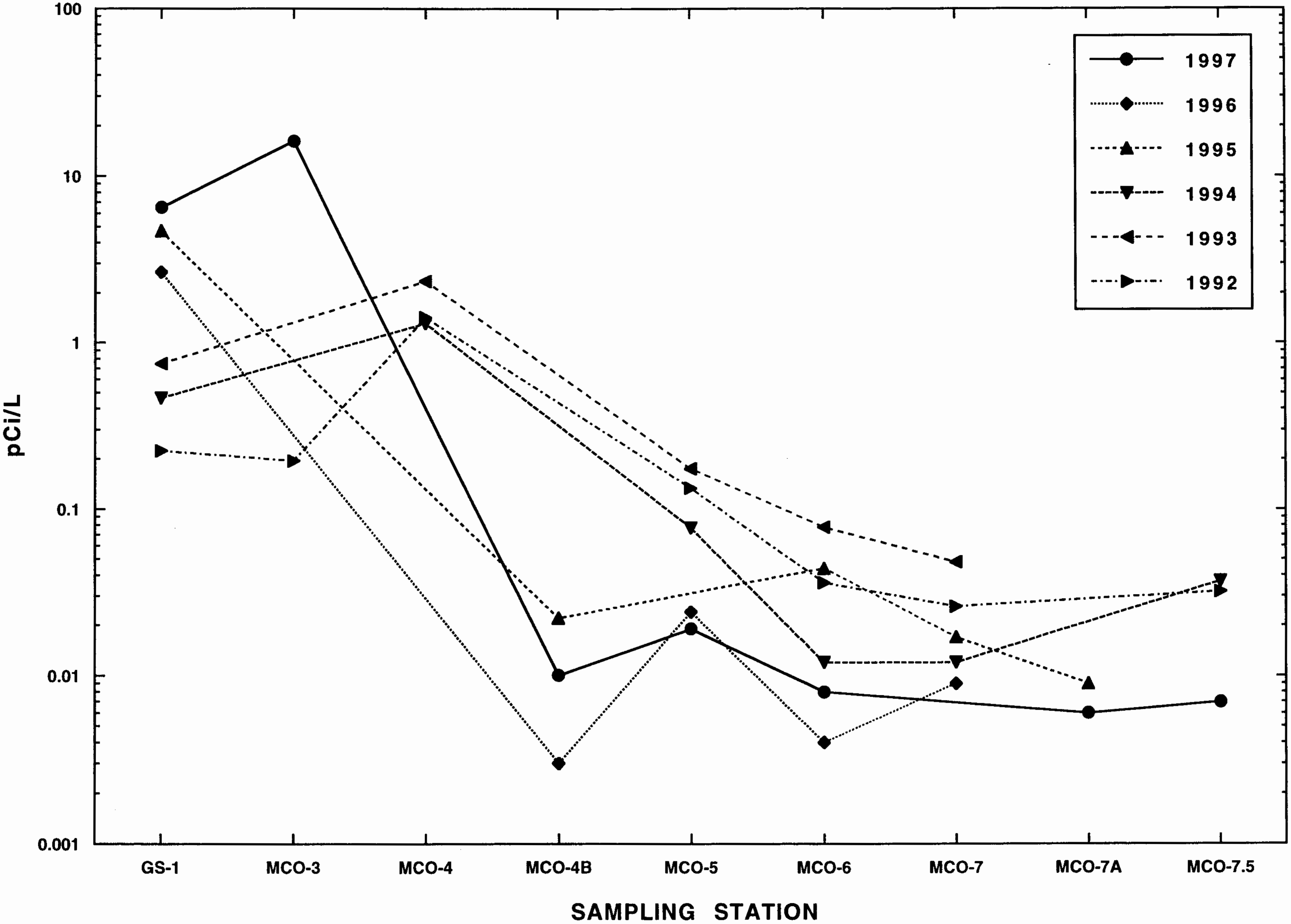
3. Tritium analyses (non filtered samples) conducted by the University of Miami using direct counting and low-level electrolytic enrichment with an error of two standard deviations.

TRITIUM ACTIVITIES IN R-15 GROUNDWATER
(COMPILED BY P. LONGMIRE 08/31/99)

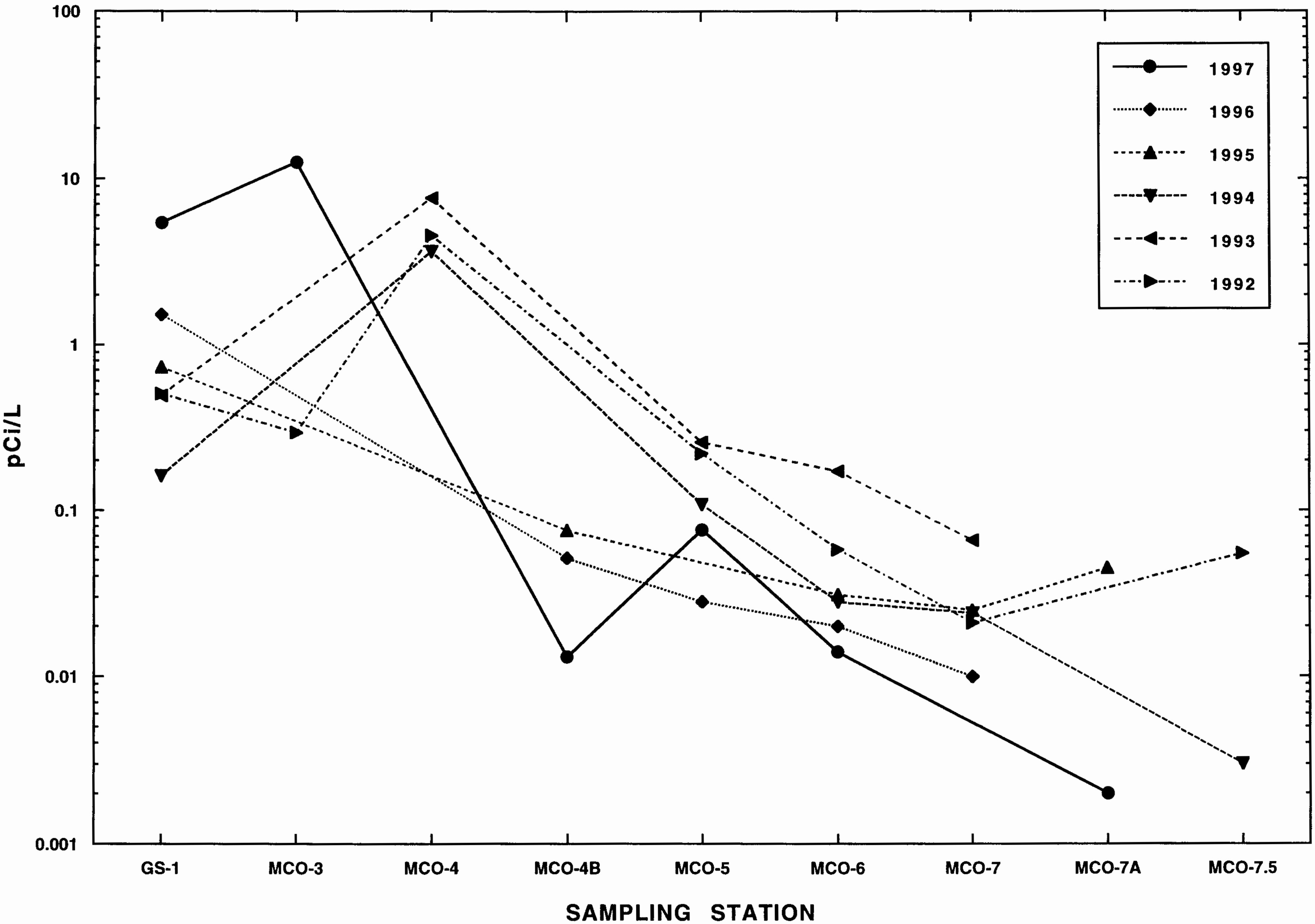
Depth (ft)	Sample Date	Activity (pCi/L)	Analytical Laboratory	Geologic Formation
Perched Zones				
482	(06/25/99)	57.5 ± 9.6	Uni. Miami	Puye Fm.
646	(07/22/99)	3,770 ± 850	CST-9	basalt
646	(07/22/99)	4,151	Uni. Miami (NMED)	basalt
Regional Aquifer				
1,007	(08/23/99)	220 ± 620	CST-9	Puye Fm.
1,007	(08/23/99)	<3.192 ± 9.576	Uni. Miami (NMED)	Puye Fm.
1,100	(08/28/99)	1.21 ± 0.35	Uni. Miami	Puye Fm.

Analytical error is ± 1 standard deviation. LANL and University of Miami performed liquid scintillation and direct counting, respectively, for measuring tritium activity in groundwater samples collected from R-15. University of Miami also performed electrolytic enrichment on the sample collected from 1,100 ft. NMED provided analytical results for groundwater samples collected at 646 and 1,007 ft.

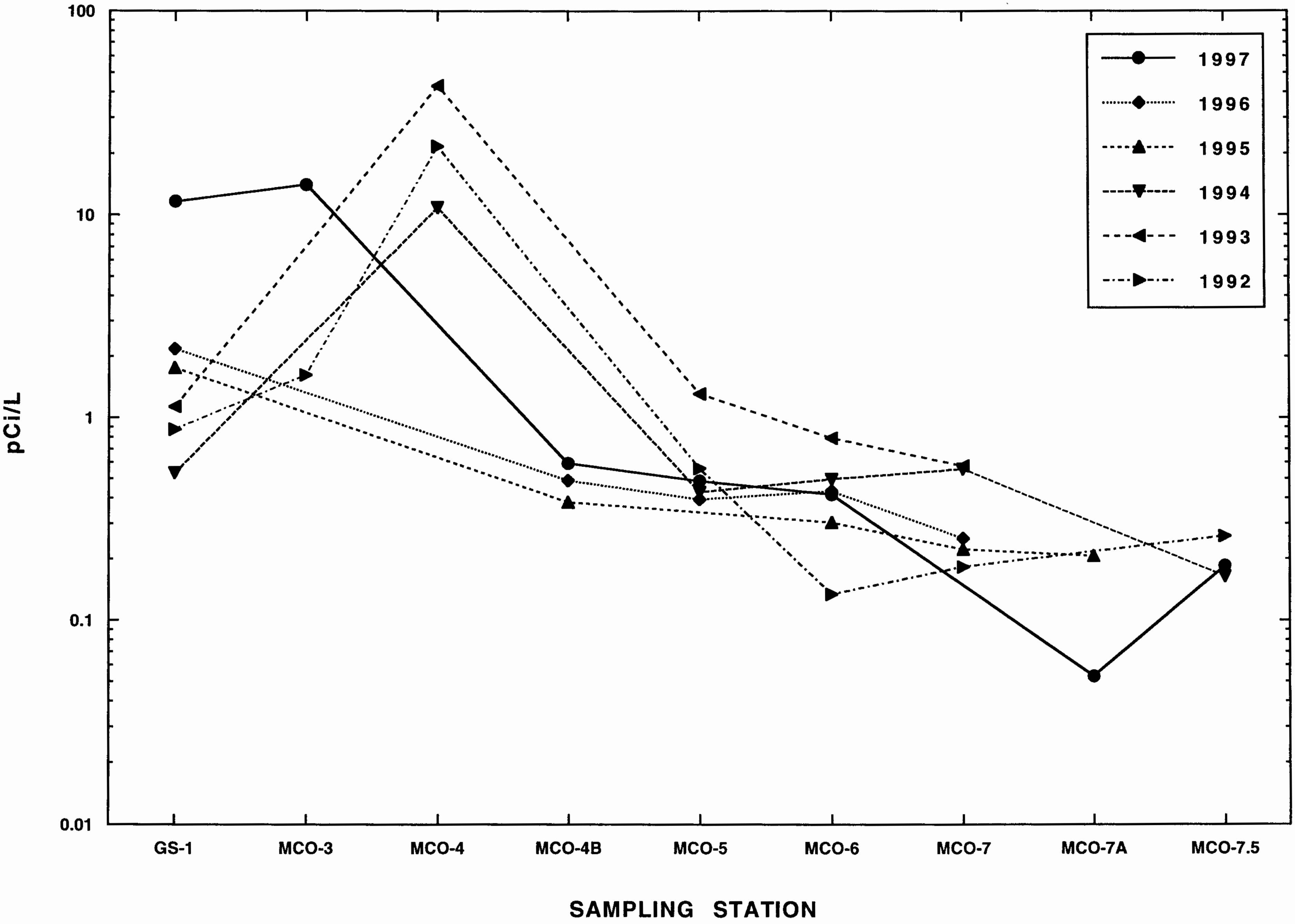
DISTRIBUTION OF PLUTONIUM-238 IN MORTANDAD CANYON (SOURCE OF DATA: ESH-18).



DISTRIBUTION OF PLUTONIUM-239/240 IN MORTANDAD CANYON (SOURCE OF DATA: ESH-18).



DISTRIBUTION OF AMERICIUM-241 IN MORTANDAD CANYON (SOURCE OF DATA: ESH-18).



GENERALIZED TA-50 TREATMENT PROCESS

$$Fe_2(SO_4)_3 + Ca(OH)_2 + PCO_2(g) + 5H_2O =$$

$$3SO_4^{2-} + 2Fe(OH)_3 + 6H^+ + CaCO_3$$

This process enhances the precipitation of $Fe(OH)_3$ and $CaCO_3$ after the addition of CO_2 gas. The treated discharge water has pH values ranging between 6-9. Coarser particles are precipitated; colloidal particles remain in suspension.

TA-50 WATER CHEMISTRY (11/10/97)

Analyte	ppm	Analyte	ppm
Ammonium	2.15	Magnesium	0.50
Bicarbonate	251	Nitrate (N)	68
Calcium	102	Potassium	11.7
Carbonate	24.4	Silica	50.7
Chloride	38.3	Sodium	140
Fluoride	1.01	Sulfate	28.0
Iron	<0.01	TDS	686

^{238}Pu (pCi/L)	11.39
^{239,240}Pu (pCi/L)	4.58
^{241}Am (pCi/L)	58

pH = 8.47, specific conductance = 1,372 μS/cm, ionic strength = 0.0137m. Source: Longmire, 1998.

RESULTS OF SATURATION INDEX CALCULATIONS FOR TA-50 WATER CHEMISTRY USING MINTEQA2 (Longmire, 1998)

Solid Phase	Saturation Index
Calcite	+1.35
Fluorite	-0.55
Silica glass	-0.07
Silica ppt	-0.38
$SrCO_3$	+0.18

pH = 8.47, T = 25C.
Saturation index (SI) = log[(activity product)/(solubility product)].

RESULTS OF SATURATION INDEX CALCULATIONS FOR TA-50 WATER CHEMISTRY USING MINTEQA2 (Longmire, 1998)

Solid Phase	Saturation Index
$Am(OH)_3$	-7.98
$Am(OH)_3am$	-9.48
$AmOHCO_3$	-5.22
PuO_2H_2Oam	-8.97
$Pu(OH)_4$	-9.81
PuO_2	-1.69
PuF_4	-47.05
PuO_2OHam	-9.55
$PuO_2(OH)_2$	-7.55

pH = 8.47, T = 25C

saturation index (SI) = log[(activity product)/(solubility product)]

POINT OF ZERO NET PROTON CHARGE-pH_{pznpc}

Solid Phase	pH_{pznpc}
Calcite	8.5, 10.8
Silica am	3.5
$Fe(OH)_3$	8.5 to 8.8

Anion adsorption dominates on solids at pH values lower than pH_{pznpc} (net positive surface charge) and cation adsorption dominates at pH values higher than pH_{pznpc} (net negative surface charge). Source: Langmuir, 1997.

RESULTS OF SPECIATION CALCULATIONS FOR TA-50 WATER CHEMISTRY (11/10/97) USING MINTEQA2 (Longmire, 1998)

Aqueous Species		Percentage
$Am(CO_3)_2^-$		84.4
$AmCO_3^+$		14.9
Pu(IV)	$Pu(CO_3)_3^{2-}$	17.8
Pu(IV)	$Pu(CO_3)_4^{4-}$	82.2
Pu(V)*	PuO_2^+	94.3
Pu(V)*	PuO_2OH^0	5.7
Pu(VI)	$PuO_2CO_3^0$	97.5
Pu(VI)	$PuO_2(CO_3)_2^{2-}$	1.3
Pu(VI)	$PuO_2(CO_3)_3^{4-}$	1.1

pH = 8.47, T = 25C.

POSSIBLE ADSORBENTS (COLLOIDS) PRESENT IN TA-50 WATER

Solid Phase	Adsorbate	Actinide Species
Calcite	Anion	Am(III), Pu(IV), Pu(VI)
Silica am	Cation	Pu(V), Am(III)
$Fe(OH)_3$	Anion* and Cation	Am(III), Pu(IV, V, VI)

Source: Longmire, 1998.

COLLOIDS PRESENT IN TA-50 WATER, MCO-3, AND MCO-6

Sample Station (Date)	Total Colloids (Particles/mL)	Size Range (nM)
TA-50 (11/10/97)	1.2×10^7	50-130
MCO-3 (05/14/99)	1.1×10^9	50-200
MCO-6 (05/14/99)	2.4×10^7	50-200

Source: Kung and Longmire, 1997 and 1999.

GEOCHEMICAL CONCEPTUAL MODEL OF UPPER CANYON DE VALLE (R-25)

Major contaminants of concern include

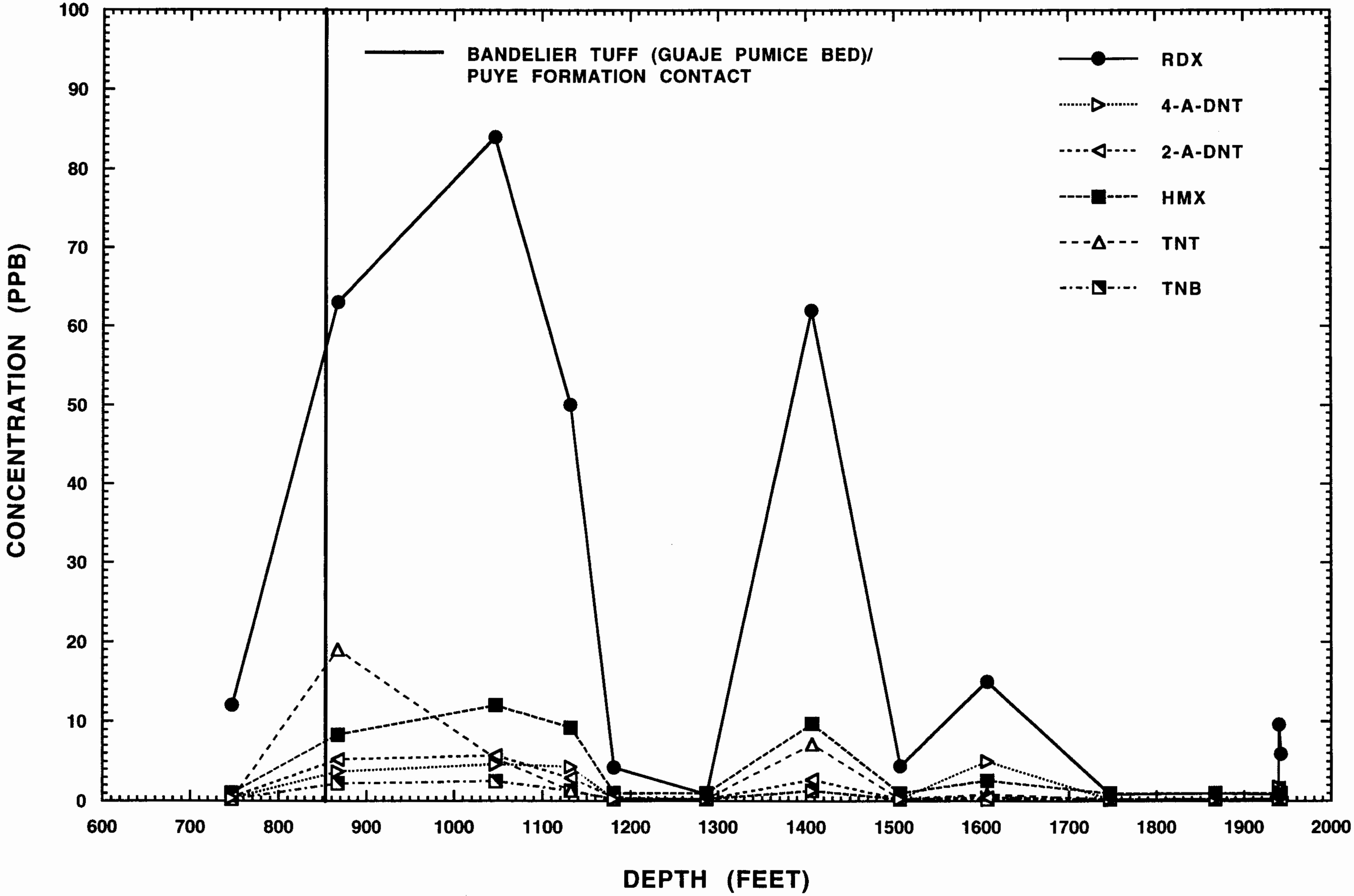
RDX,

TNT,

Degradation products, and

Inorganic species.

DISTRIBUTIONS OF RDX (HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE), HMX (OCTAHYDRO-1,3,5,7-TETRANITRO-1,3,5,7-TETRAZOCINE), 4-A-DNT (4-AMINO-2,6-DINITROTOLUENE), 2-A-DNT (2-AMINO-4,6-DINITROTOLUENE), TNT (2,4,6-TRINITROTOLUENE), AND TNB (1,3,5-TRINITROBENZENE) IN BOREHOLE R-25 (LONGMIRE, 04/29/99).



HIGH EXPLOSIVE CHEMISTRY OF GROUNDWATER SAMPLES COLLECTED AT BOREHOLE R-25

Sample Depth (ft)	RDX[1] (µg/L)	HMX (µg/L)	4-A-DNT (µg/L)	2-A-DNT (µg/L)	TNB (µg/L)	TNT (µg/L)
EPA HA[2] (µg/L)	2	400	-	-	-	2
Upper Saturated Zone						
Otowi Member						
747	12	<1	0.38	0.51	<0.26	<0.25
Puye Formation						
867	63	8.3	3.7	5.2	2.2	19
1,047	84	12	4.6	5.7	<2.5	5.3
1,137	50	9.2	4.3	2.9	<1.3	<1.3
1,181	4.2	<1	<0.25	0.43	<0.26	<0.25
Regional Aquifer						
1,287	<0.84	<1.0	<0.25	<0.25	<0.26	<0.25
1,407	62	9.7	<1.3	2	<1.3	7.1
1,507	4.4	<1	<0.25	<0.26	<0.26	<0.25
1,607	15	2.6	5	0.46	<0.26	0.84
1,747	<0.84	<1	<0.25	<0.25	<0.25	<0.25
1,867	0.97	<1	<0.25	<0.25	<0.26	<0.25
1,939	<0.84	<1	<0.25	<0.25	<0.26	<0.25
1,940 (air lifted)	8.8	1.5	1.7	0.69	<0.26	0.77
1,940 (bailer)	9.6	1.6	1.8	0.79	<0.26	1.1
1,942	5.9	<1	1.1	<0.25	<0.26	0.64

9. RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), 4-A-DNT (4-amino-2,6-dinitrotoluene), 2-A-DNT (2-amino-4,6-dinitrotoluene), TNB (1,3,5-trinitrobenzene), and TNT (2,4,6-trinitrotoluene) analyzed by high pressure liquid chromatography (HPLC) (EPA Method 8330) at Paragon Analytics, Inc., Fort Collins, Colorado.
2. USEPA (Region 6) lifetime health advisory level.

PREDICTED MOBILITY OF RDX AND TNT AT R-25

RDX and TNT are considered to be the most important contaminants from a risk perspective based on their concentration distributions at R-25 and EPA lifetime health advisory levels of 2 µg/L.

The Koc values for RDX and TNT are 100 cm^3/g and 525 cm^3/g, respectively (Rosenblatt et al., 1991).

$Kd = (Koc)(foc)$,

$Kd_{RDX} = (100\ cm^3/g)(0.0001) = 1.00 \times 10^{-2}\ cm^3/g$.

$Kd_{TNT} = (525\ cm^3/g)(0.0001) = 5.25 \times 10^{-2}\ cm^3/g$.

These calculated distribution coefficients are small, implying that RDX and TNT are very mobile in aqueous systems with small amounts of organic carbon present at R-25.

PREDICTED MOBILITY OF RDX AT R-25

The rate of movement of groundwater (average flow speed or velocity) relative to the rate of movement of a given contaminant, such as RDX, is determined by calculating a retardation factor (Rf) for the contaminant of interest. Non-sorbing chemicals have a retardation factor of unity. The retardation factor is given by the following equation:

(Rf) = 1 + pKd/ne.

The bulk density (p) and effective porosity (ne) of the Otowi Member are 1.18 $\pm$ 0.10 g/cm^3 and 0.47 $\pm$ 0.05, respectively (Rogers and Gallaher, 1995).

The retardation factor for RDX in groundwater at R-25 is

Rf = 1 + [(1.18 g/cm^3)(1.00 X 10^{-2} cm^3/g)/(0.47)]

Rf = 1.025.

PREDICTED MOBILITY OF TNT AT R-25

The retardation factor for TNT in groundwater at R-25 is

$Rf = 1 + [(1.18\ g/cm^3)(5.25 \times 10^{-2}\ cm^3/g)/(0.47)]$

$Rf = 1.132.$

Both compounds are predicted to migrate close to the same rate as the average groundwater flow velocity or speed, based on the calculated retardation factors.

TRANSFORMATION OF TNT

General reaction

$Ar\text{-}NO_2(TNT) + 6H^+ + 6e^- =$

$$AR\text{-}NH_2\ (4\text{-}A\text{-}2,6\text{-}DNT \text{ or } 2\text{-}A\text{-}4,6\text{-}DNT) + 2H_2O.$$

The oxidation-reduction potential (Eh) for the TNT/4-A-2,6-DNT half-cell reaction is equal to –430 mV at pH7 (Hofstetter et al., 1999).

The oxidation-reduction potential (Eh) for the TNT/2-A-4,6-DNT half-cell reaction is equal to –390 mV at pH7 (Hofstetter et al., 1999).

An electron donor (dissolved organic carbon) is required for this reaction. Dissolved organic carbon concentrations at R-25 are greater than one mgC/L, which are sufficient to enhance the reduction of TNT to 4-A-2,6-DNT or to 2-A-4,6-DNT.

TRANSFORMATION OF TNT

TNT initially degrades to 4-A-2,6-DNT or 2-A-4,6-DNT followed by the formation of di-aminototuene compounds, including 2-4-DA-6-NT or 2,6-DA-4-NT under reducing Eh conditions (2,4-DA-6-NT, Eh = -515 mV at pH7; 2,6-DA-4-NT, Eh = -495 mV at pH7) (Hofstetter et al., 1999).

The mono-amino toluene compounds are present at R-25 and the di-amino toluene compounds have not been identified at R-25 using the EPA 8330 method.

Presentation Outline

1. Goals
2. Time line
3. Recent work
4. Results

Goals of regional aquifer flow and transport modeling

- Integrate geologic, hydrologic, and geochemical data into a single, self-consistent flow and transport model
- Test hypotheses, provide feedback to conceptual model
- Inform data collection activities
- Provide predictions of fate and transport of contaminants in regional aquifer

Modeling tasks: framework development

- Compile geologic, hydrologic, and permeability data from a broad range of sources
- Build hydrogeologic framework model
- Build flow model (using FEHM) based on geometries defined in framework model
- Identify appropriate boundary conditions for the model
- Develop general model of recharge
- Define model calibration targets (water levels, flux estimates at model boundaries)

Modeling tasks: calibration

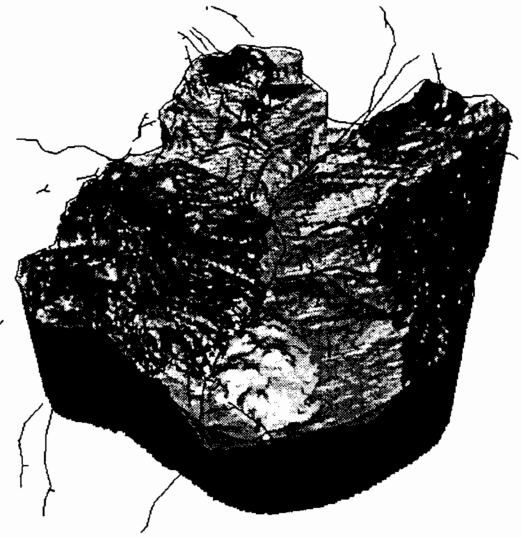
- Calibrate steady-state flow model: simulate pre-development conditions
- Calibrate transient-flow model: simulate water level responses to pumping over 50 year period
- Calibrate flow and transport model to geochemistry data (stable isotopes, major ions)
- Evaluate model performance
  - Are we modeling recharge appropriately?
  - Does conceptual model need updating?
  - Is hydrostratigraphic framework model adequate?
  - What data could be collected to improve the model?

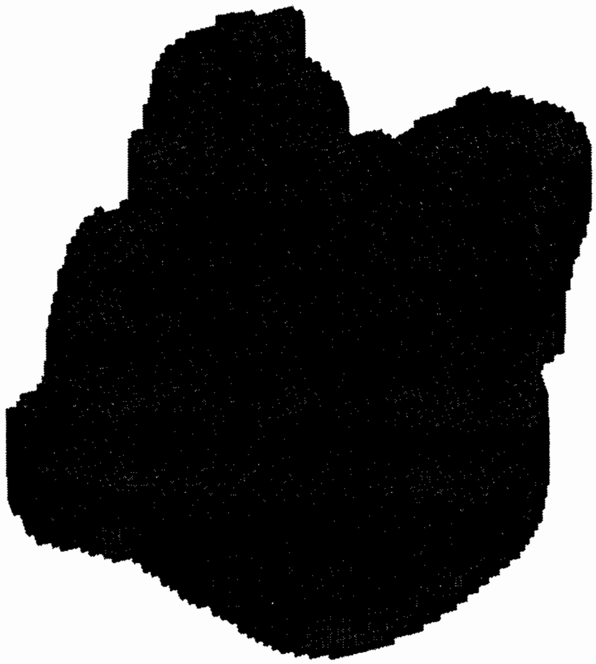
Modeling tasks: applications

- **Predict fate and transport of contaminants**
- **Evaluate uncertainties**

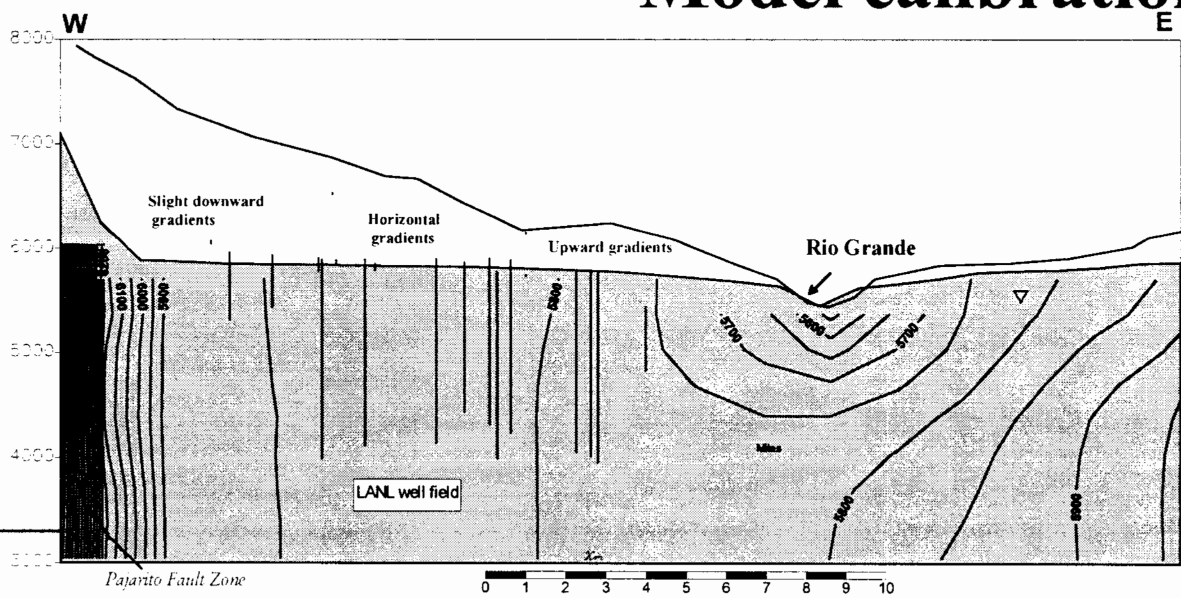
Model development

Feb 1998





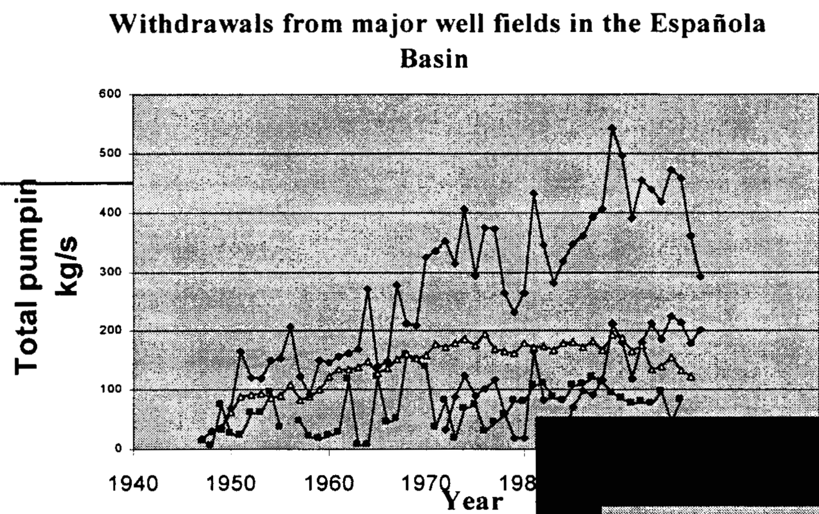
Model calibration

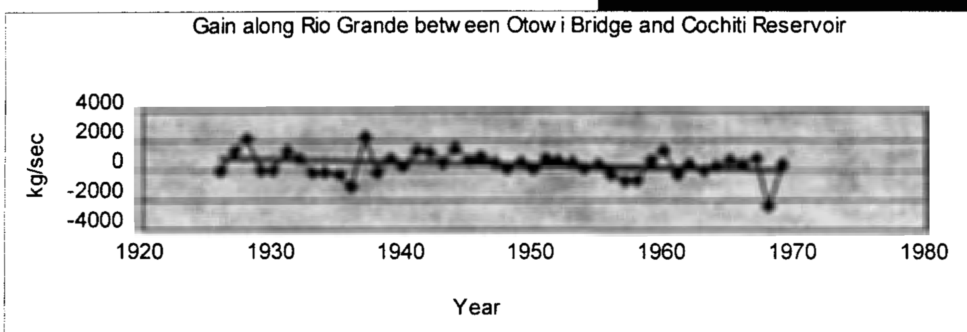


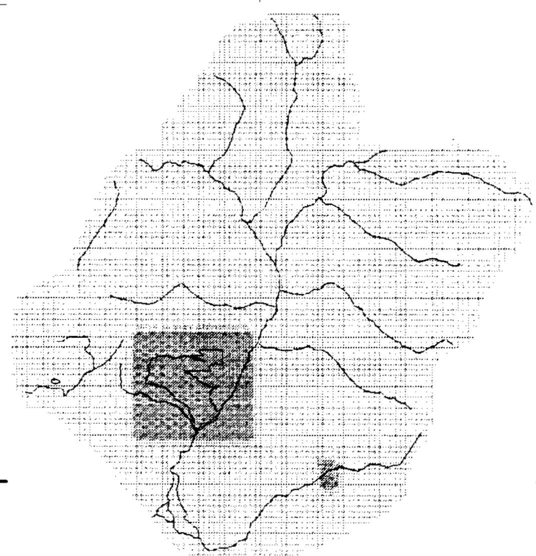
Km

Additional model development & calibration

Jan 1999

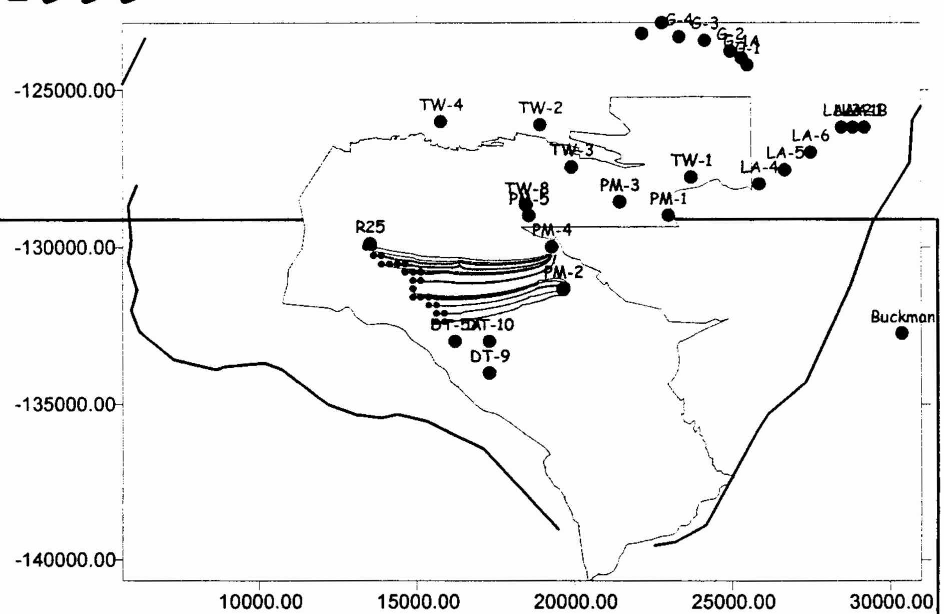






Model application

Aug 1999



Oct 1999

Additional model development & calibration

* Evaluating alternative recharge models
* Incorporating geochemistry data
* Incorporate updated hydrostratigraphic model

Jan 2000

- Evaluate model performance
- Apply model results
- Update with new data collected during drilling

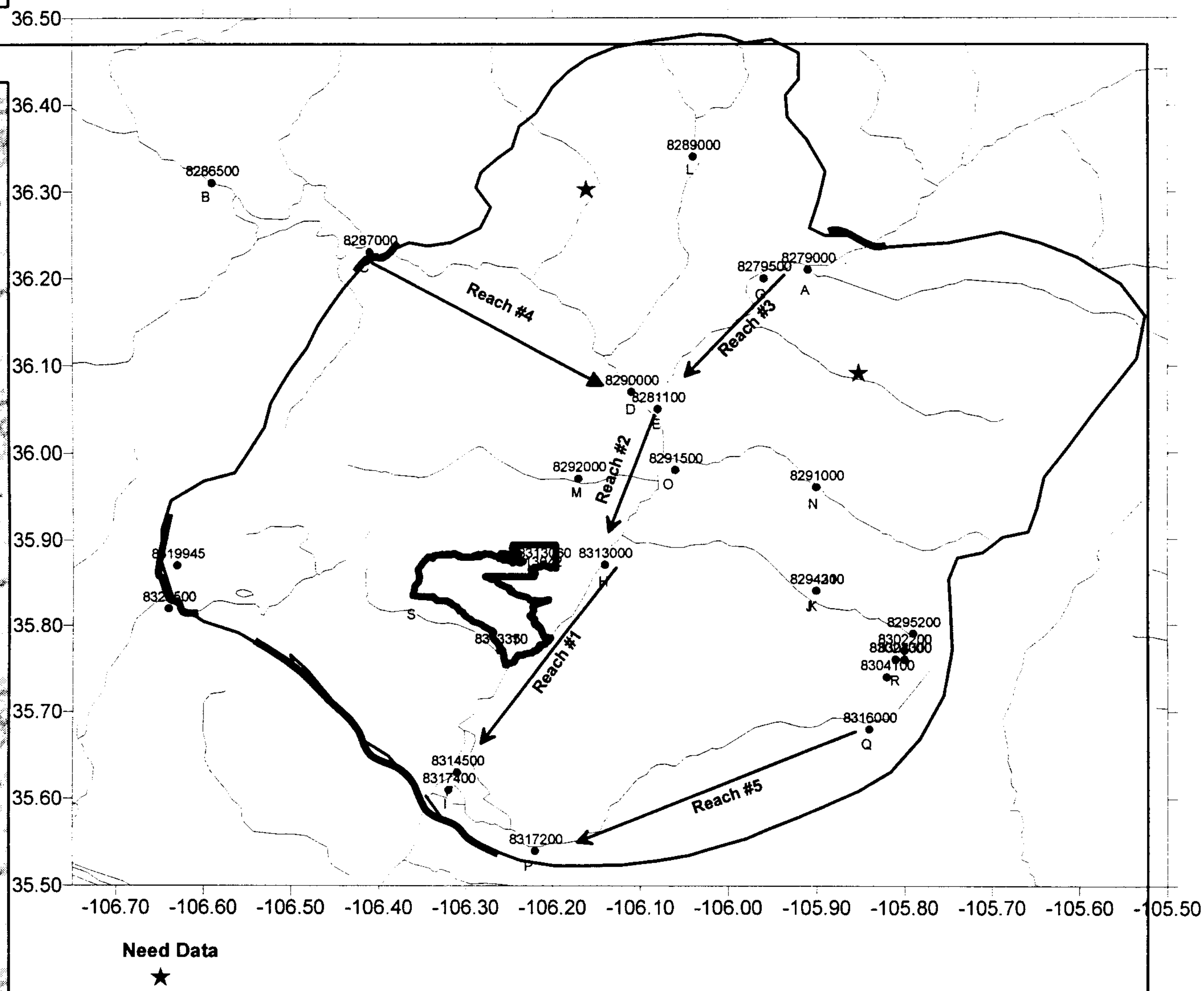
Recent work

Steady state flow model, approximating pre-development conditions

- New information on fluxes at model boundaries
- Detailed evaluation of recharge rates
- Water budget calculations
- Preliminary information on aquifer characteristics (permeability) and model sensitivity

Fluxes at model boundaries

Stream reaches used for flux calculations

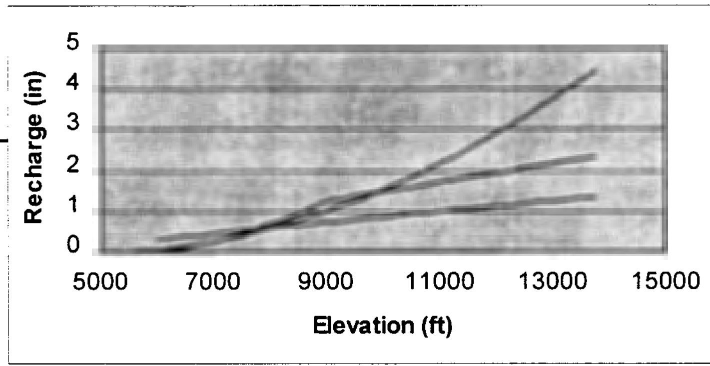


·River/groundwater interfaces
·Lateral boundaries

Fluxes at river/groundwater interfaces

	Reach #1 Otowi to Cochiti	Reach #2 Espanola to Otowi	Reach #3 Rio Grande north of Espanola[1]	Reach #4 Chama River	Reach #5 Santa Fe River	Reach #6 Jemez River at East Fork
Mean	12.93	31.44	28.58	19.31	8.08	14.86
Std. Error	4.34	71.66	1.04	3.18	0.54	0.90
Median	13.70	-5.7	29.49	19.2	8	14
Mode	-8.3	---	---	14.7	8	12
Std. Dev.	28.81	343.65	4.99	19.36	2.88	4.65
Variance	829.8	118096.8	24.96	374.9	8.27	21.63
Kurtosis	2.70	1.55	0.50	1.83	-0.24	2.58
Skewness	-0.61	0.41	0.11	0.21	0.51	1.45
Range	166	1530.9	22.3	107.7	10.6	20.6
Minimum	-87.3	-687.8	18.3	-30.6	3.8	9
Maximum	78.7	843.1	40.65	77.1	14.4	29.6
Sum	568.8	723.1	657.3	714.4	226.3	401.3
Count	44	23	23	37	28	27

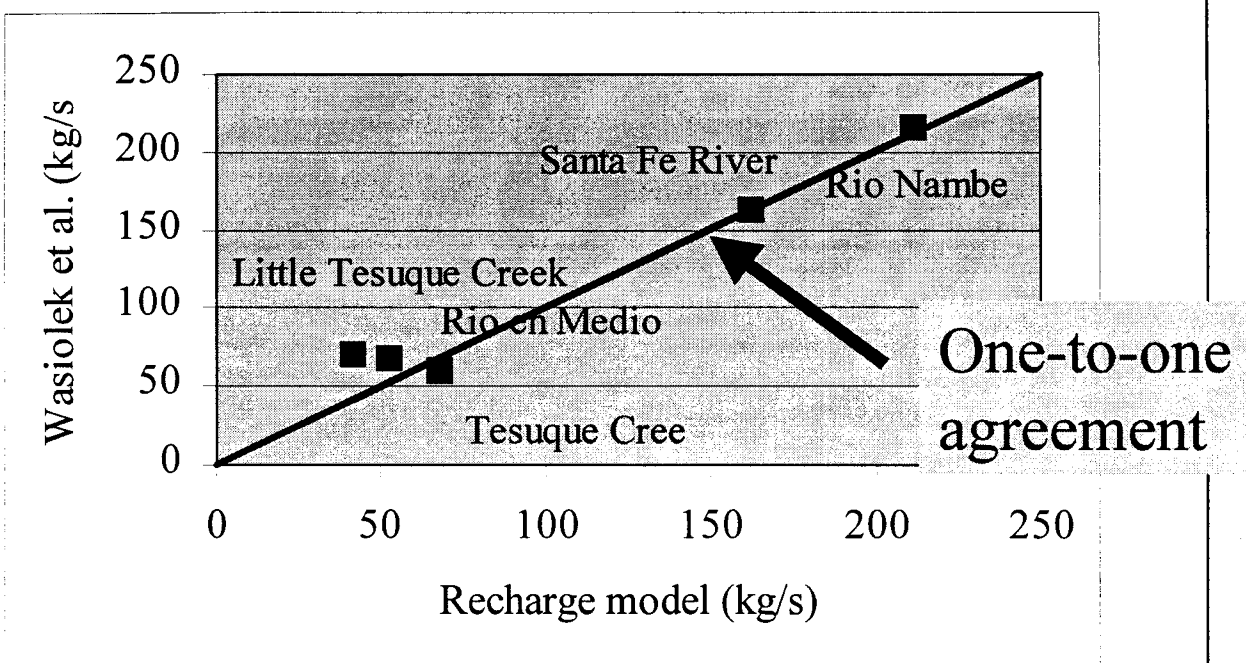
Recharge model



$$R(z) = P(z) \bullet \alpha \bullet (z - Z_{min})/(Z_{max} - Z_{min}) \quad \text{for } z < Z_{max}$$

$$R(z) = P(z) \bullet \alpha \quad \text{for } z > Z_{max}$$

$$R(z) = 0 \quad \text{for } z < Z_{min}$$



Pajarito Plateau water budget analysis (Kwicklis, 1999)

Precipitation

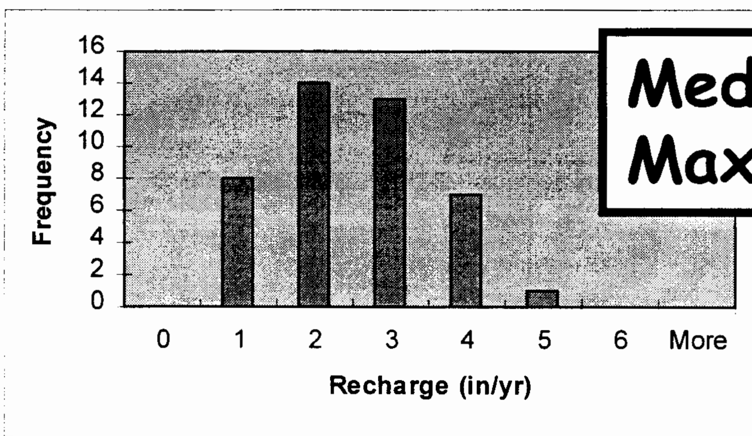
Runoff

ET estimates

* data collected at TA-6
* model developed by Troendle and Leaf, 1980

1 - 1.5 in/yr

Chloride mass balance method



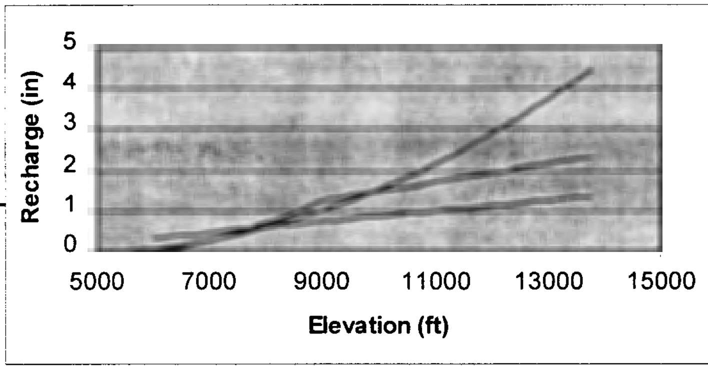
Median = 1.9 in/yr
Maximum = 4.0 in/yr

These estimates are *much* too high, when compared to calculated baseflow to the Rio Grande

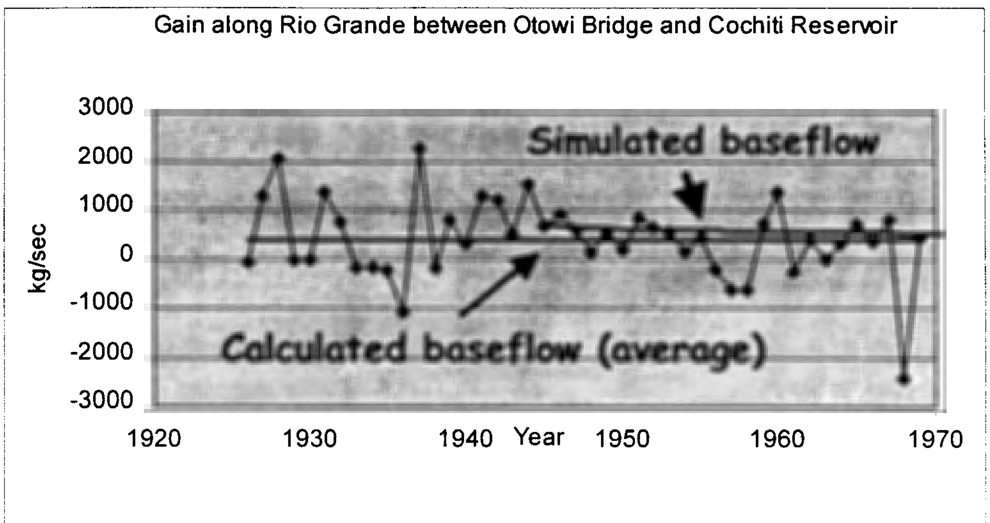
Summary of recharge estimates

	Recharge (in/yr)	Comments
Sangre de Cristo Mountains	2.7 – 4.4	
Los Alamos Canyon (Gray, 1997)	4 - 7	Water years 93,94,95
Pajarito Plateau, Chloride mass balance (Kwicklis, 1999)	0.17 – 4.0 (Median = 1.9)	*inconsistent* with baseflow to Rio Grande
Pajarito Plateau, Water balance (Kwicklis, 1999)	1.0 – 1.5	*inconsistent* with baseflow to Rio Grande
U.S.G.S. numerical flow models	0.20 – 0.15	*consistent* with baseflow to Rio Grande
LANL flow model	0.22 – 0.40	*consistent* with baseflow to Rio Grande

Recharge model



Simulated and observed baseflow to Rio Grande between Otowi Bridge and Cochiti Reservoir

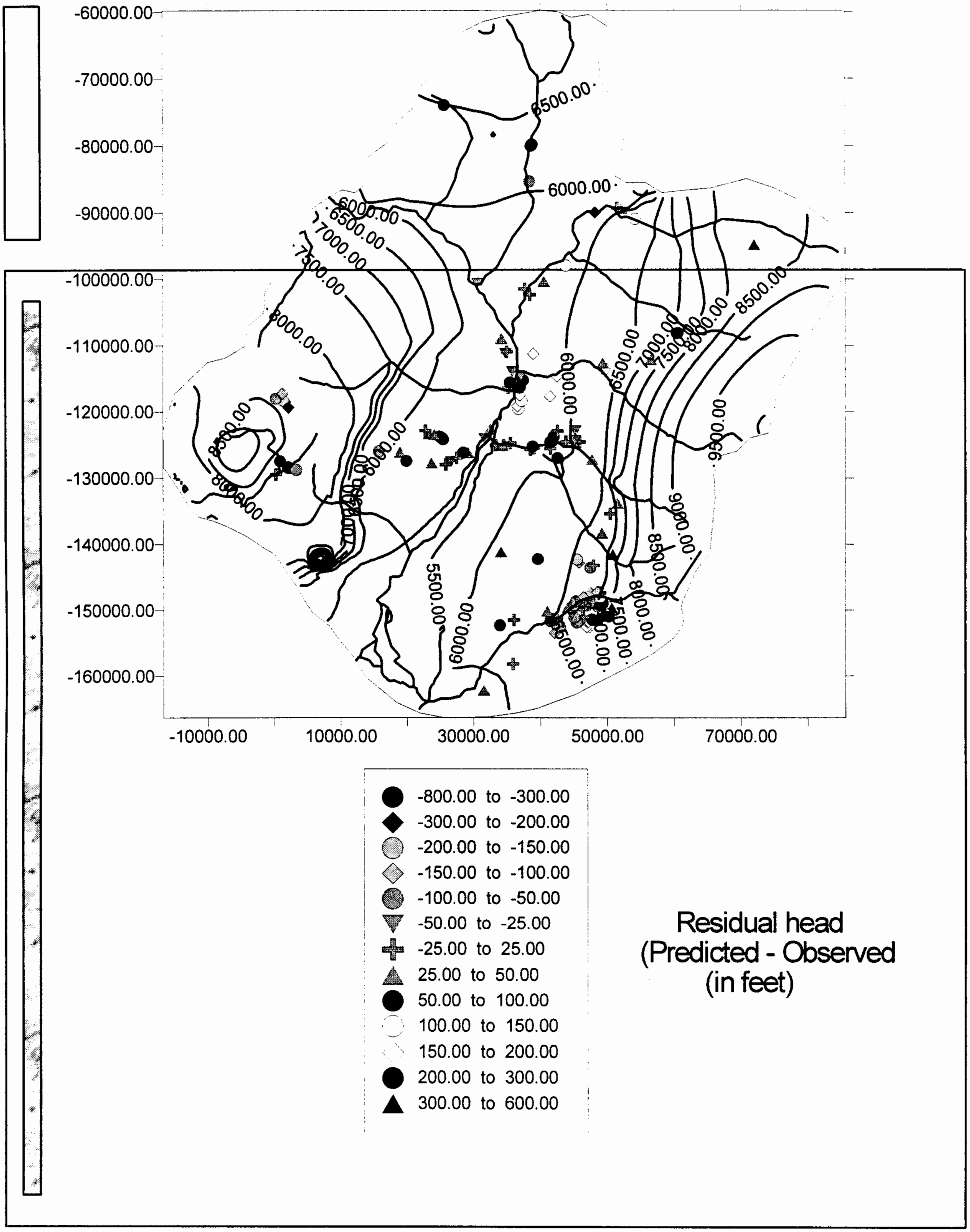


Preliminary information on aquifer characteristics (permeability) and model sensitivity

Assumptions

1. Total recharge is well constrained; spatial/temporal variations are unclear

2. Pre-development water levels should be primarily influenced by permeability of aquifer rocks.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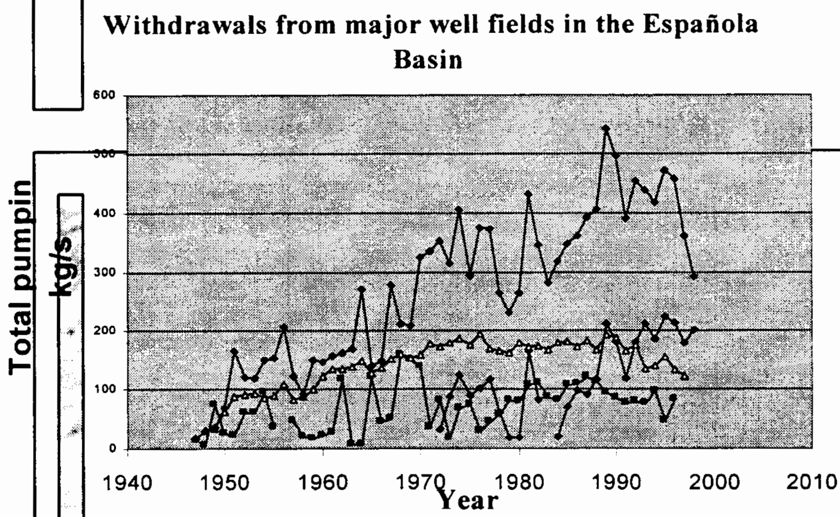
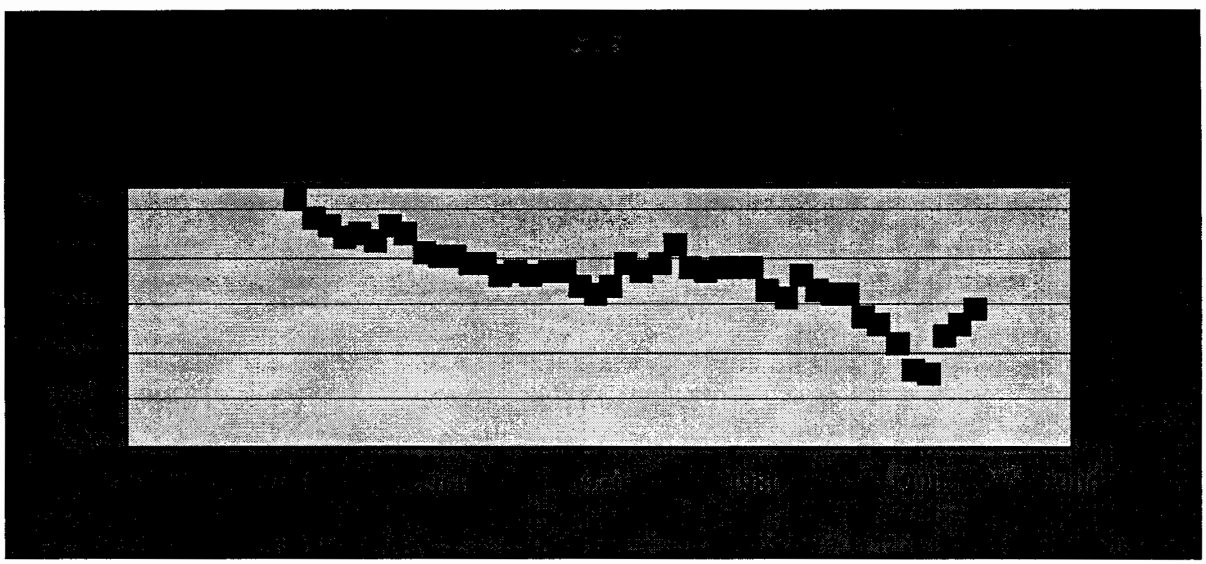
-150.00 to -100.00
-100.00 to -50.00
-50.00 to -25.00
-25.00 to 25.00
25.00 to 50.00
50.00 to 100.00
100.00 to 150.00
150.00 to 200.00
200.00 to 300.00
300.00 to 600.00
Residual head
(Predicted - Observed
(in feet)

Permeability estimates

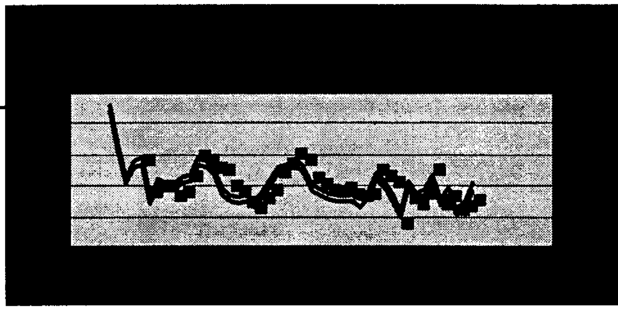
Hydrogeologic unit	Permeability (m^2)	Lower 95% Confidence Limit (m^2)	Upper 95% Confidence Limit (m^2)	Best-fit trial and error permeability (m^2)	Mean measured Permeability (m^2)	Number Of Samples	Permeability Range (m^2)
Basement rocks	5.00×10^{-16}	-----	-----	5.00×10^{-16}	-----	-----	-----
Paleozoic/ Mezozoic Rocks	2.00×10^{-17}	1.03×10^{-76}	$9.75 \times 10^{+41}$	2.00×10^{-17}	-----	-----	-----
Shallow Sange de Cristo	1.85×10^{-14}	1.45×10^{-14}	2.36×10^{-14}	1.00×10^{-14}	4.24×10^{-14}	16	1.08×10^{-15} to 1.30×10^{-11}
Deep Santa Fe Group	1.21×10^{-14}	2.09×10^{-15}	6.96×10^{-14}	1.00×10^{-15}	-----	-----	-----
Eastern Santa Fe Group	2.07×10^{-13} a	1.24×10^{-13}	3.45×10^{-13}	1.90×10^{-13} b	1.65×10^{-13}	15	2.91×10^{-14} to 5.19×10^{-12}
Western Santa Fe Group	1.40×10^{-13} a	1.14×10^{-13}	1.71×10^{-13}	6.00×10^{-14} b	2.44×10^{-13}	7	1.45×10^{-13} to 4.49×10^{-13}
Northern Santa Fe Group	1.50×10^{-14}	6.89×10^{-15}	3.25×10^{-14}	3.00×10^{-14}	-----	-----	-----
Pojoaque area Santa Fe Group	7.14×10^{-15} a	1.20×10^{-17}	4.26×10^{-12}	1.00×10^{-14}	-----	-----	-----
Aqua Fria Fault	4.49×10^{-15}	1.18×10^{-19}	1.71×10^{-10}	4.49×10^{-15}	-----	-----	-----
Airport Area Santa Fe Group	1.00×10^{-11} a	7.13×10^{-20}	1.40×10^{-03}	1.00×10^{-11} b	-----	-----	-----
Ancha Formation	1.34×10^{-13} a	1.52×10^{-15}	1.18×10^{-11}	4.00×10^{-14} b	6.27×10^{-15}	1	-----
Tshicoma	7.10×10^{-16}	1.02×10^{-16}	4.94×10^{-15}	1.25×10^{-15}	9.17×10^{-13}	1	-----
Pajarito Fault	2.13×10^{-15}	1.52×10^{-15}	2.97×10^{-15}	2.50×10^{-15}	-----	-----	-----
Cerros basalts	1.00×10^{-15}	1.00×10^{-315}	$1.00 \times 10^{+285}$	1.00×10^{-15}	-----	-----	-----
Puye Formation	2.38×10^{-13}	7.66×10^{-37}	7.38×10^{10}	4.70×10^{-14}	1.59×10^{-12}	14	1.93×10^{-13} to 1.16×10^{-11}
Totavi Lentil	1.00×10^{-13}	3.69×10^{-45}	2.71×10^{18}	1.00×10^{-12}	-----	-----	-----
Chaquequi	1.00×10^{-13}	3.36×10^{-15}	2.97×10^{-12}	1.00×10^{-12}	9.14×10^{-13}	16	2.56×10^{-13} to 8.63×10^{-12}
Bandelier Tuff	3.95×10^{-14}	9.42×10^{-161}	$1.65 \times 10^{+133}$	1.00×10^{-13}	1.02×10^{-13}	?	4.06×10^{-14} to 2.56×10^{-13}
Southern Cerros Basalts	1.00×10^{-16}	2.42×10^{-48}	$4.13 \times 10^{+15}$	1.00×10^{-16}	-----	-----	-----
Penasco	4.67×10^{-13}	2.51×10^{-13}	8.68×10^{-13}	1.50×10^{-13} b	-----	-----	-----
Ojo Caliente Formation	2.20×10^{-14}	1.31×10^{-14}	3.67×10^{-14}	3.25×10^{-14}	-----	-----	-----

Simulating transient changes in water levels over a 50 year period

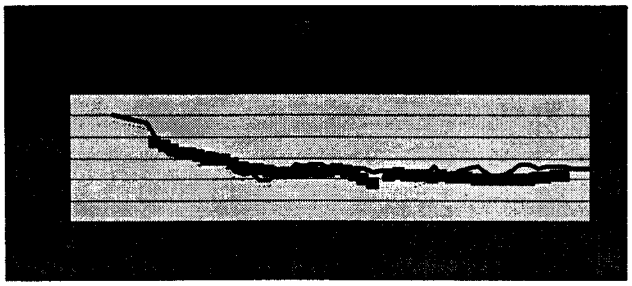




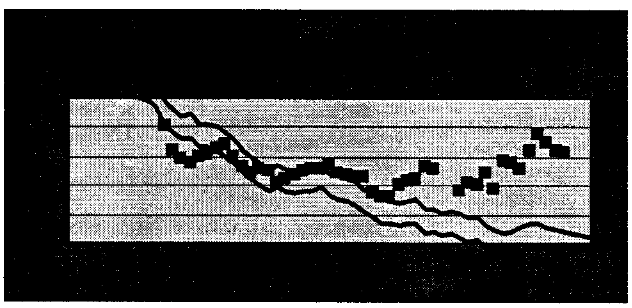
Evaluating transient simulation results

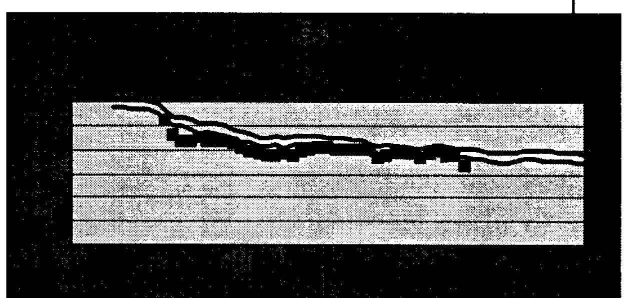


Wells completed in Santa Fe Group rocks

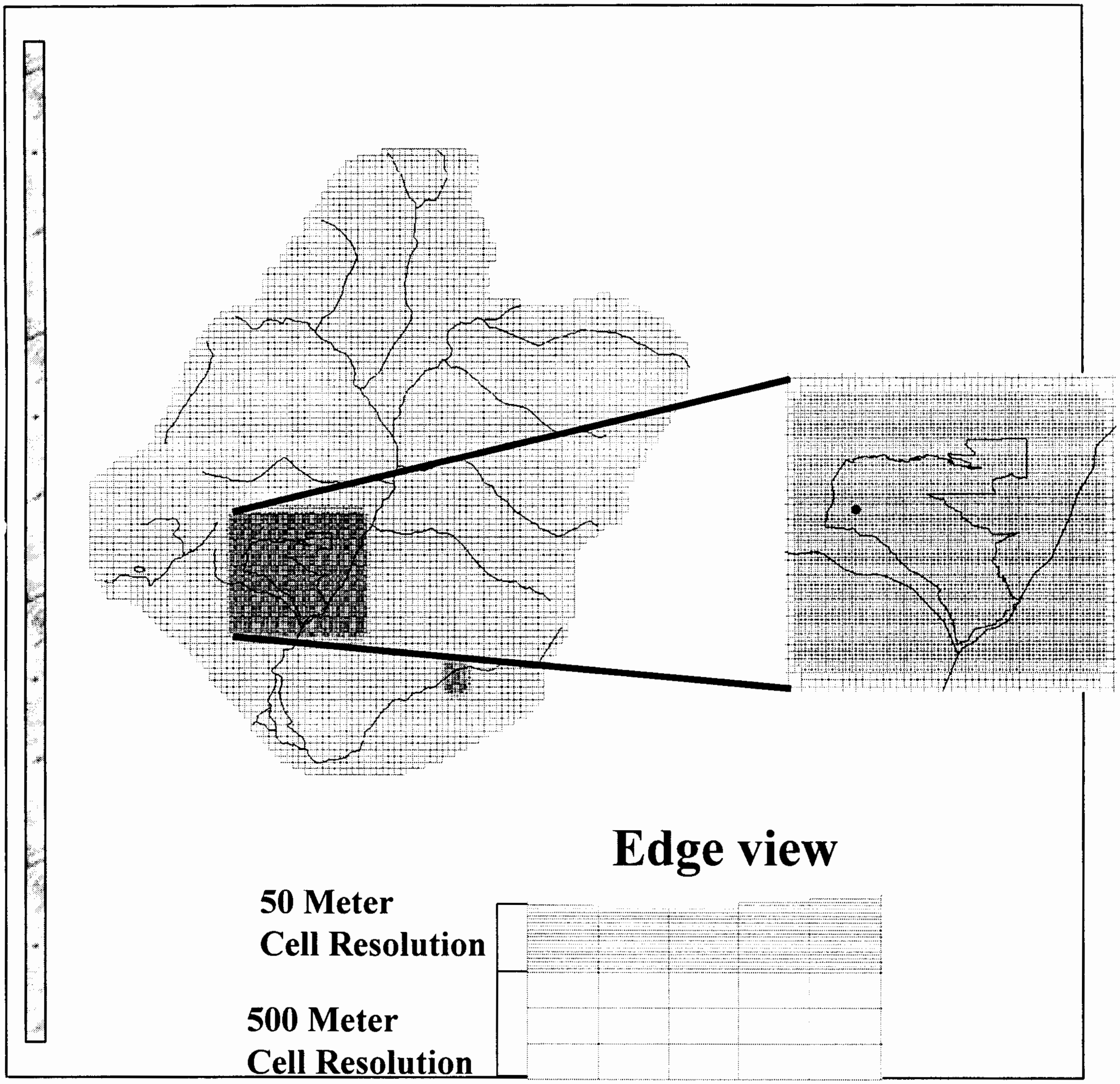


Wells completed in both Santa Fe Group rocks and "Chaquehui"





Inserting high resolution mesh within coarser basin model



Summary

- We have a working system for integrating hydrologic and geologic data via a high-resolution 3-D mesh for flow and transport computations
- Through the process of model calibration, we are evaluating the adequacy of our conceptual and numerical framework model and identifying data gaps

Our modeling approach

Relies heavily on independent data for model parameterization

Examples:

- independent evaluation of total recharge
- data-based hydrostratigraphic framework model

Benefit:

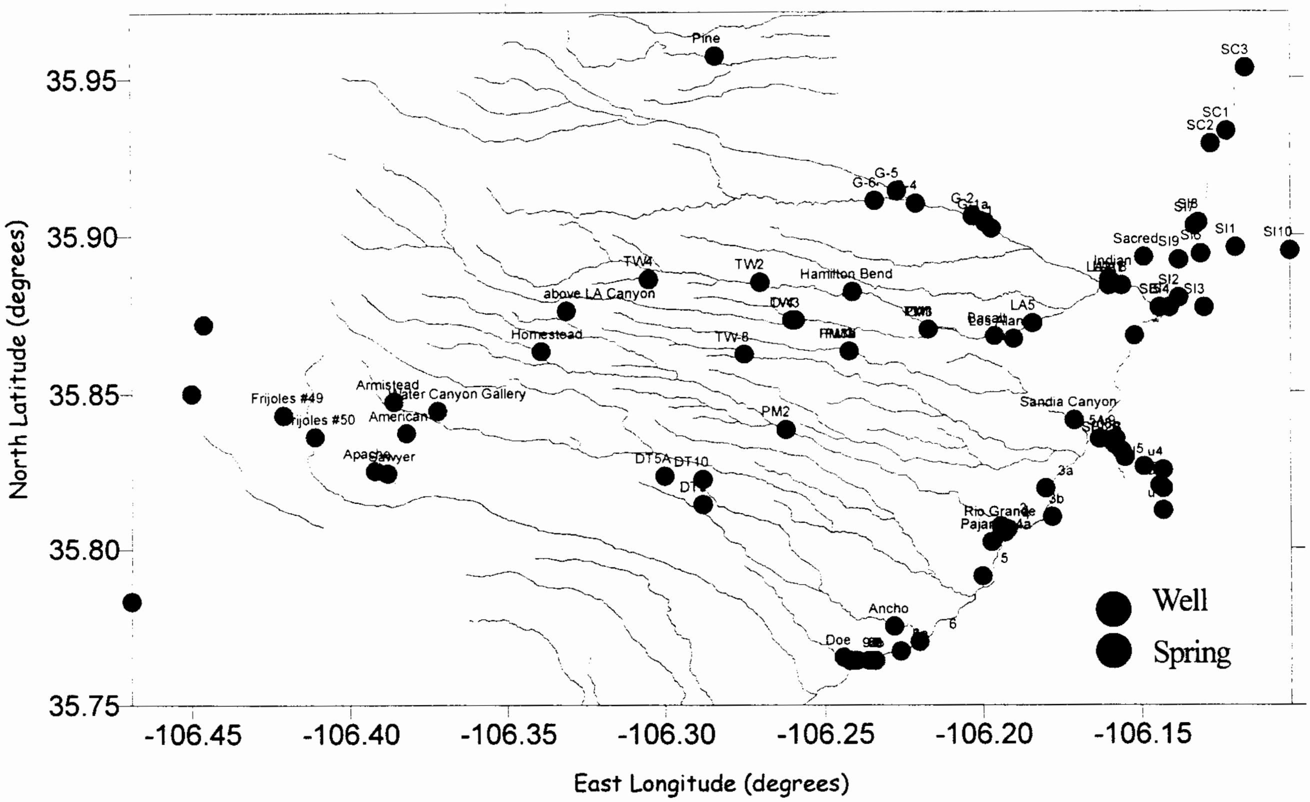
- Model can be used to improve our understanding of the aquifer
- Model can be used to evaluate data gaps

Geochemistry of the regional aquifer

- **Identify trends in major ion chemistry in regional aquifer water**
- **Understand reactions that are controlling major ion chemistry**

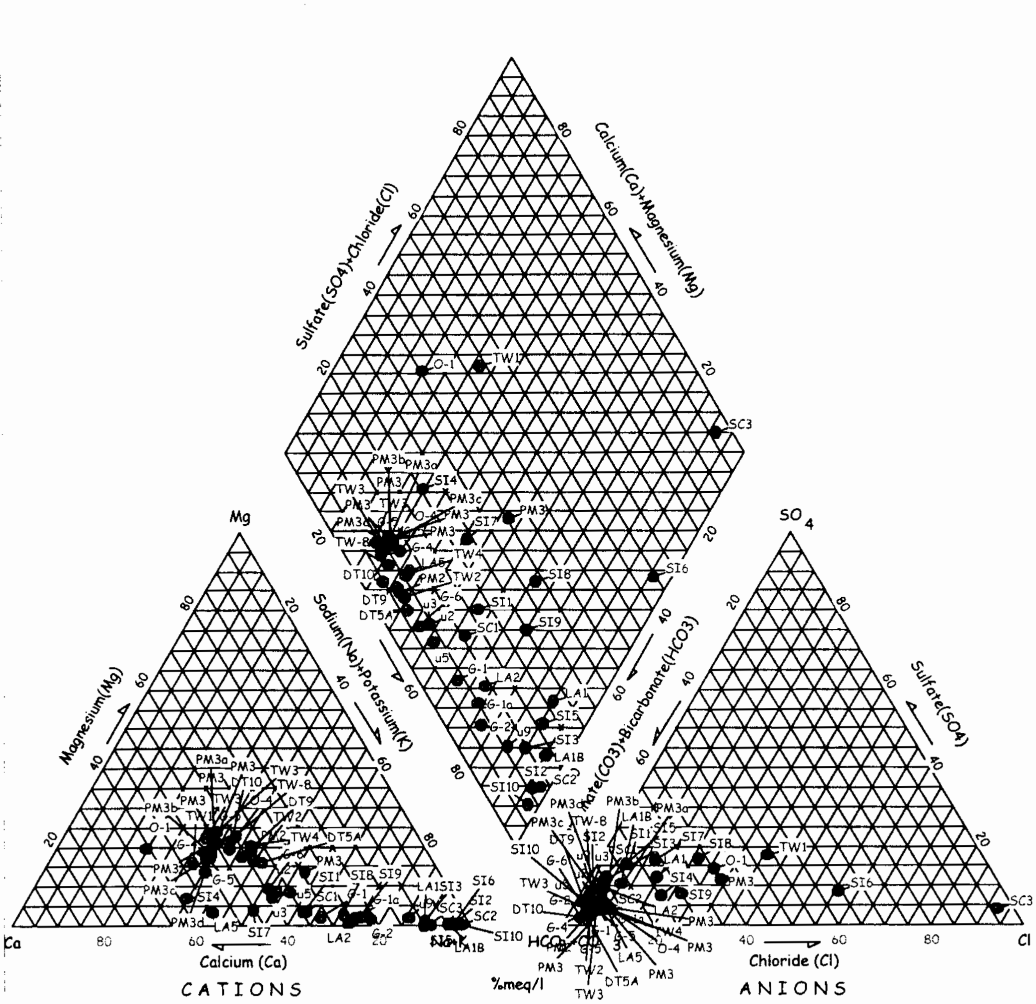
Modeling trends in water chemistry

- ✦Collection of petrographic and water chemistry data
- ✦Examination of spatial trends
- ✦Mineral/water equilibrium calculations
- ✦1-D Reaction-path models, assuming uniform mineralogy and no mixing of waters
- ✦3-D Reactive transport modeling, incorporating spatially explicit mineralogy data and hydrodynamic mixing

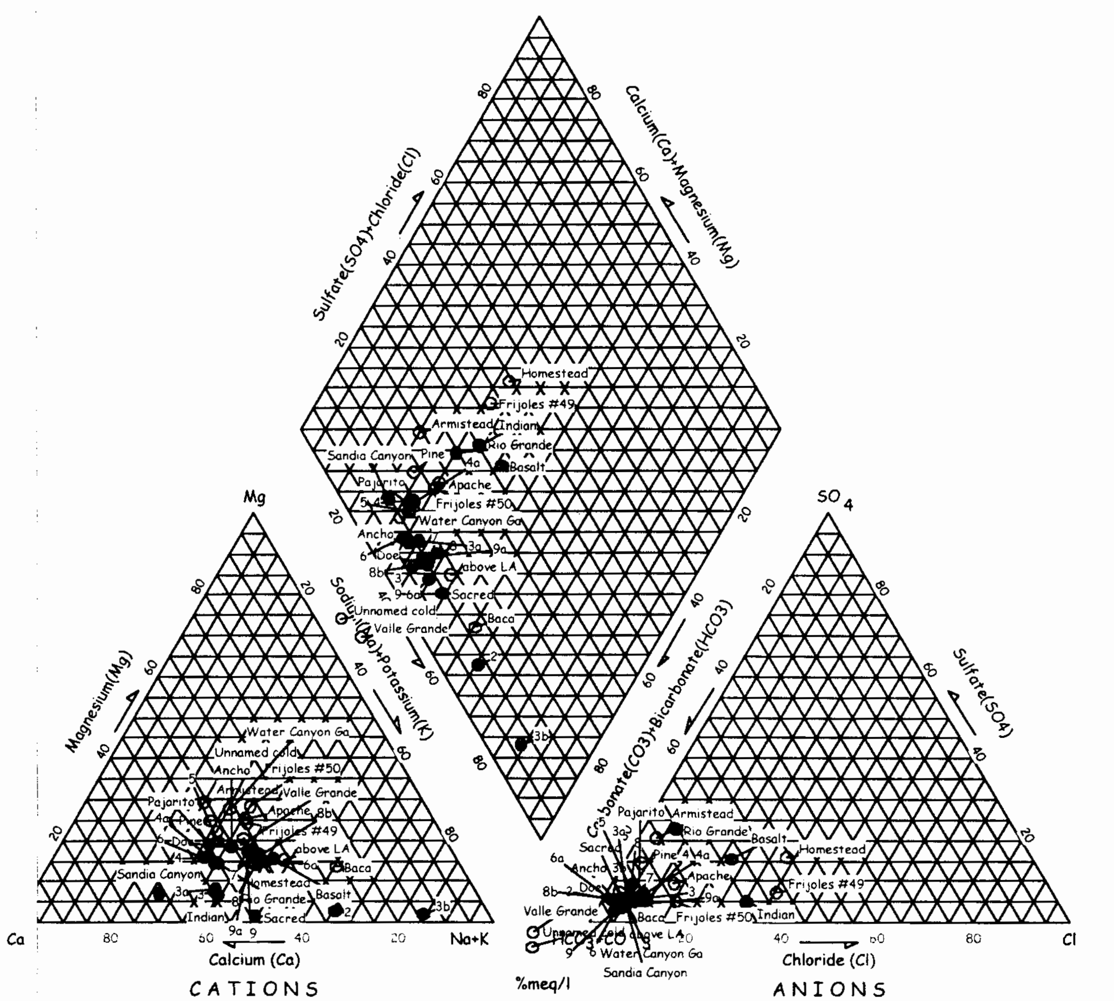


Pine
SC3
SC1
SC2
G-5
G-6
G-2
TW4
TW2
Hamilton Bend
above LA Canyon
Homestead
TW-8
LA5
Sacred
SI9
SI1
SI10
SI2
SI3
Indian
Sandia Canyon
PM2
DT5A
DT10
Frijoles #49
Armistead
American
Apache
Sawyer
Rio Grande
3a
3b
5
6
u4
Ancho
Doe
Well
Spring
35.95
35.90
35.85
35.80
35.75
-106.45
-106.40
-106.35
-106.30
-106.25
-106.20
-106.15
North Latitude (degrees)
East Longitude (degrees)

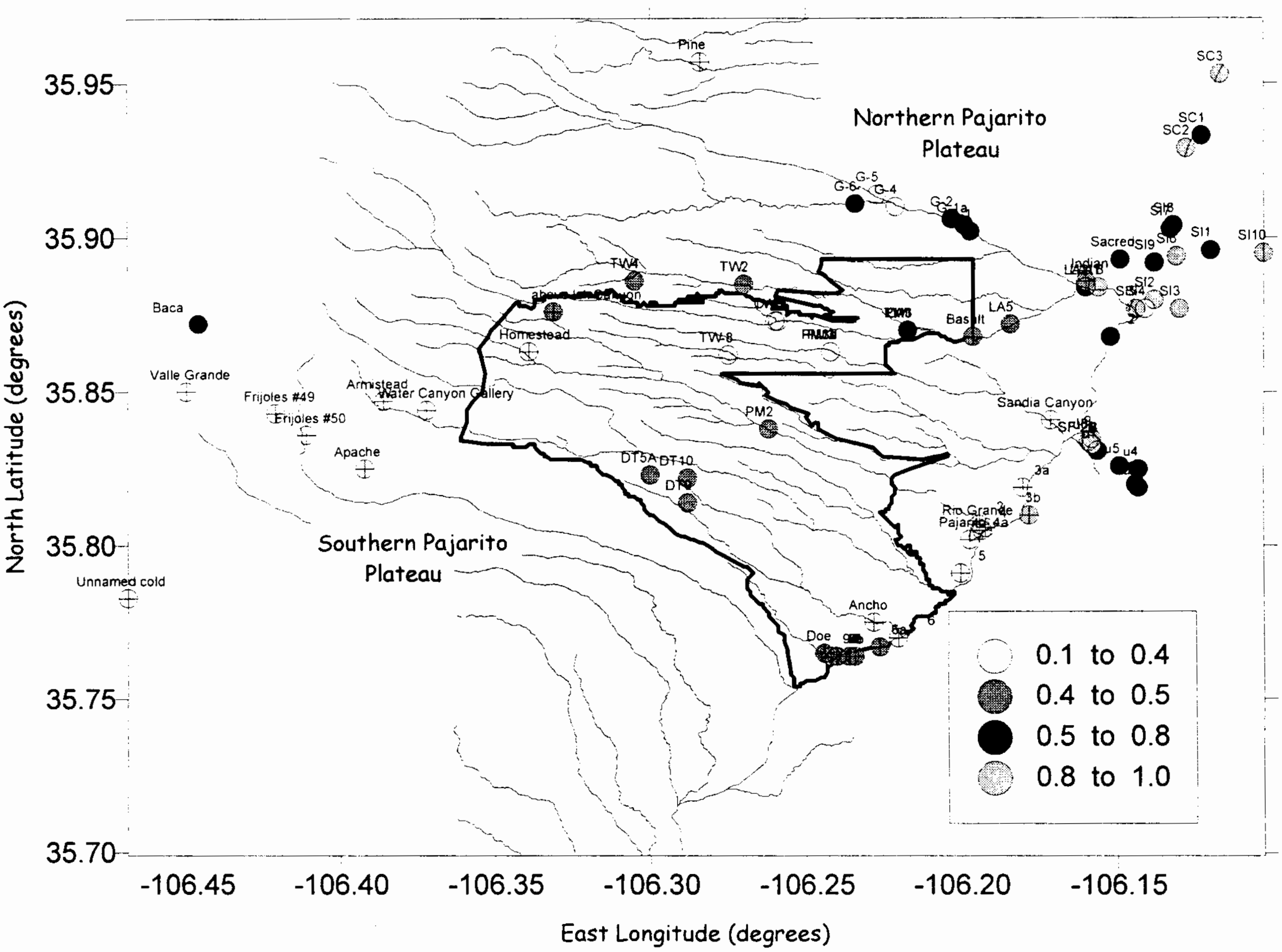
Piper plot of groundwater chemistry for wells



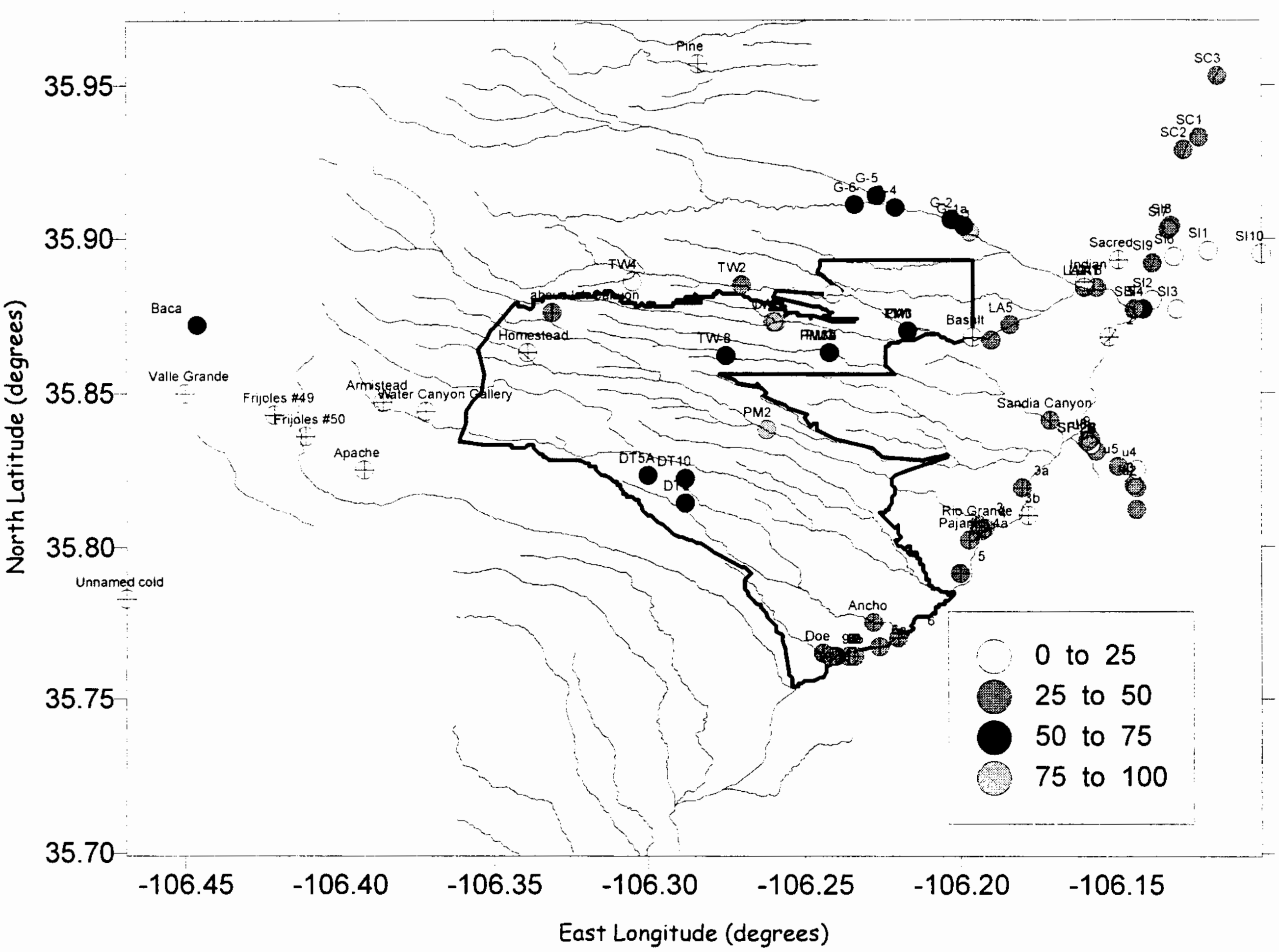
Piper plot of groundwater chemistry for springs



[Na]/[Na+Ca+Mg+K]


Northern Pajarito Plateau
Southern Pajarito Plateau
North Latitude (degrees)
East Longitude (degrees)
35.95
35.90
35.85
35.80
35.75
35.70
-106.45
-106.40
-106.35
-106.30
-106.25
-106.20
-106.15
0.1 to 0.4
0.4 to 0.5
0.5 to 0.8
0.8 to 1.0
Pine
SC3
SC1
SC2
G-5
G-6
G-4
G-2
Sacred
SI9
SI1
SI10
TW4
TW2
Baca
Homestead
TW-8
Basalt
LA5
Valle Grande
Frijoles #49
Frijoles #50
Armstead
Water Canyon Gallery
Apache
Sandia Canyon
PM2
DT5A
DT10
u4
3a
3b
Rio Grande
5
Unnamed cold
Ancho
Doe
6

SiO_2 (mg/l)

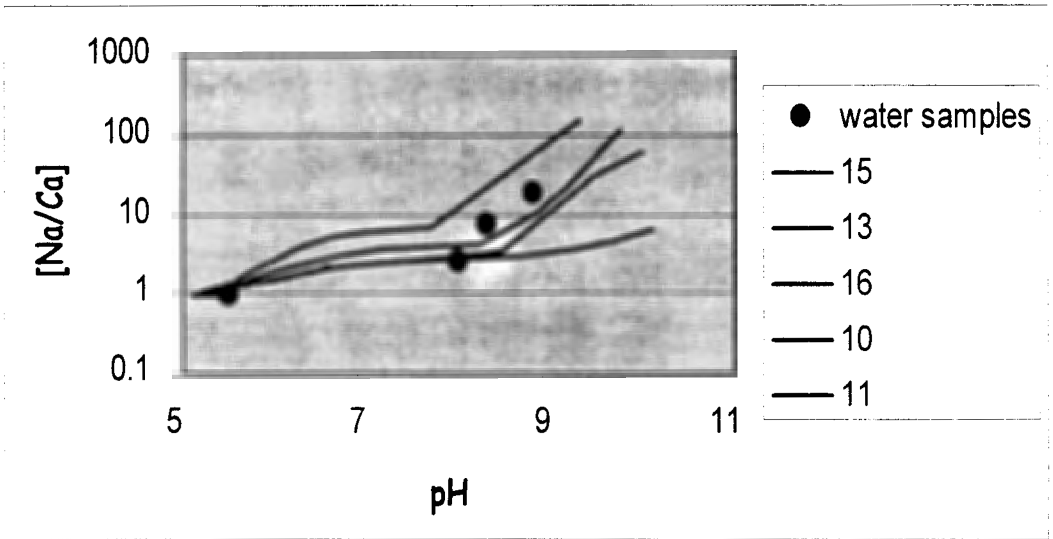


North Latitude (degrees)
East Longitude (degrees)
35.95
35.90
35.85
35.80
35.75
35.70
-106.45
-106.40
-106.35
-106.30
-106.25
-106.20
-106.15
0 to 25
25 to 50
50 to 75
75 to 100
Baca
Valle Grande
Frijoles #49
Frijoles #50
Armstead
Water Canyon Gallery
Apache
Unnamed cold
Homestead
Pine
TW4
TW2
TW-8
PM2
DT5A
DT10
Sandia Canyon
Rio Grande
Ancho
Doe
Basalt
LA5
SC3
SC1
SC2
SI1
SI10
SI2
SI3
Sacred
Indian
G-6
G-5
G-2

Table 4. Saturation indices for four representative waters. Blue indicates undersaturation (SI<-0.5), red indicates equilibrium (-0.5<SI<0.5), and green indicates supersaturation (SI>0.5).

Mineral	Pine Spring	G-6	G-2	SI 2
Chlorite7A	-25.6	-6.5	-6.7	-4.6
Chlorite14A	-22.2	-3.2	-3.3	-1.3
Anorthite	-3.8	-3.6	-3.5	-4.7
Al(OH)3(a)	0.3	-2.6	-2.9	-3.4
Albite	-3.2	-1.8	-1.0	-2.3
Calcite	-3.8	-0.3	-0.1	0.3
SiO2(a)	-1.1	-0.7	-0.6	-1.0
Silica glass	-0.8	-0.4	-0.3	-0.7
Chalcedony	-0.3	0.2	0.3	-0.2
Cristobalite	-0.3	0.2	0.3	-0.2
Illite	2.7	0.3	0.3	-2.3
Montmorillonite-Ca	5.1	0.9	0.8	-2.1
Kaolinite	7.0	2.2	1.9	-0.1
Mont-Aberdeen	2.7	3.5	3.7	1.6
Mont-BelleFche	4.7	4.2	4.3	1.9
Goethite	4.3	5.7	5.7	5.6
K-mica	10.3	5.5	5.4	2.4

1-D Reaction path models using PHREEQC



Kinetic reactions

Plagioclase dissolution

Equilibrium phases

Ca-montmorillonite
Illite
Calcite

Summary

- Preliminary reaction path models confirm importance of plagioclase dissolution, montmorillinite and calcite equilibrium in some waters

- To generalize to all waters beneath the Pajarito Plateau, we need to
  - integrate more petrographic data
  - explore other reactions such as cation exchange
  - import reactions into 3-D flow and transport model

Modeling of Groundwater Flow and Transport on the Pajarito Plateau

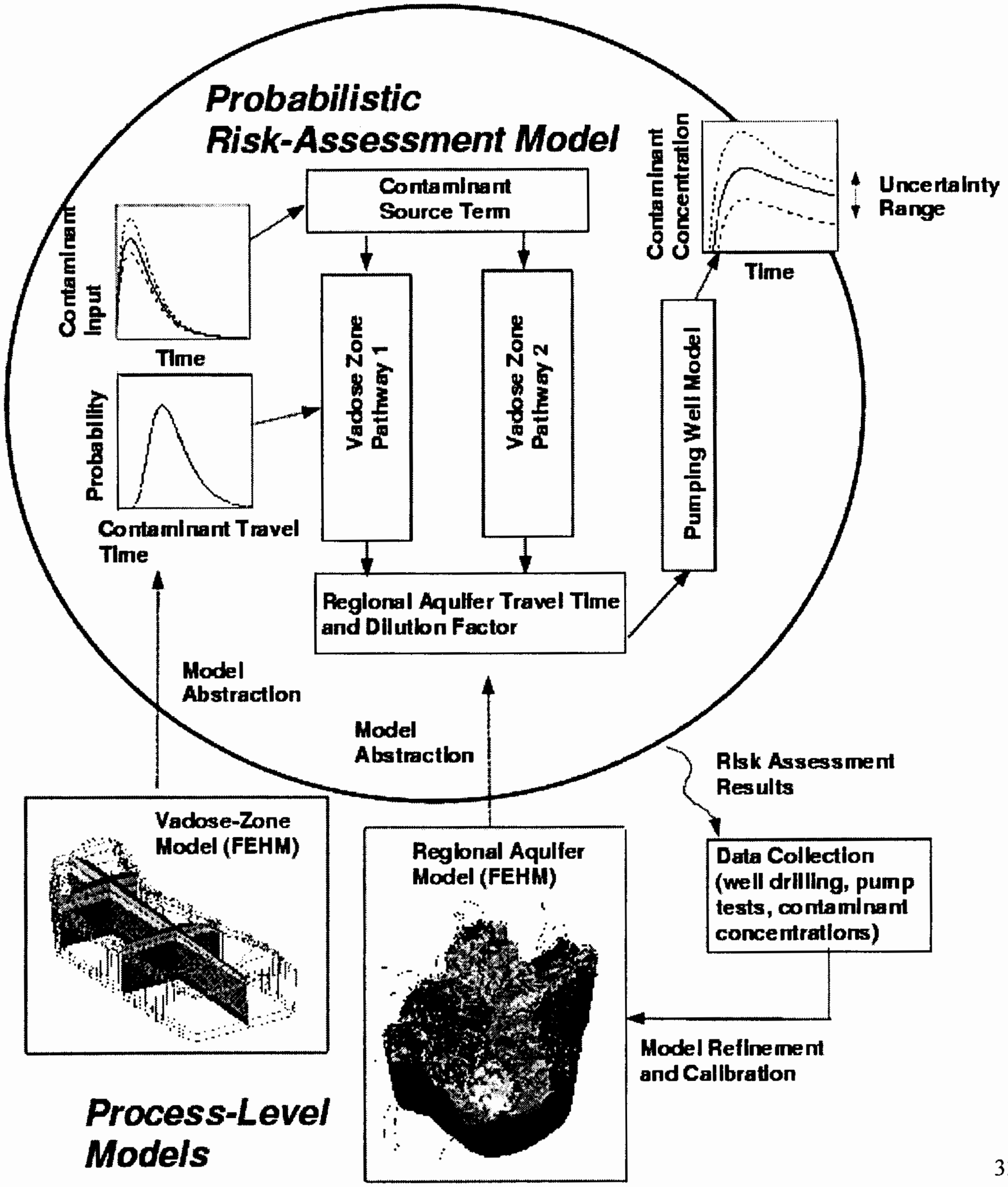
Presentation to External Advisory Group
October 13, 1999

Bruce Robinson and Elizabeth Keating
Earth and Environmental Sciences Division
Los Alamos National Laboratory
(505) 667-1910, robinson@lanl.gov

Goals of Pajarito Plateau Modeling Project

- Develop a methodology for groundwater flow and transport model development at potentially contaminated sites at the Laboratory
- Use methodology to guide data collection, site characterization, and modeling activities
- Define and address groundwater issues that are common to many sites on the Plateau
- Address a site that is currently in need of comprehensive treatment: TA-16

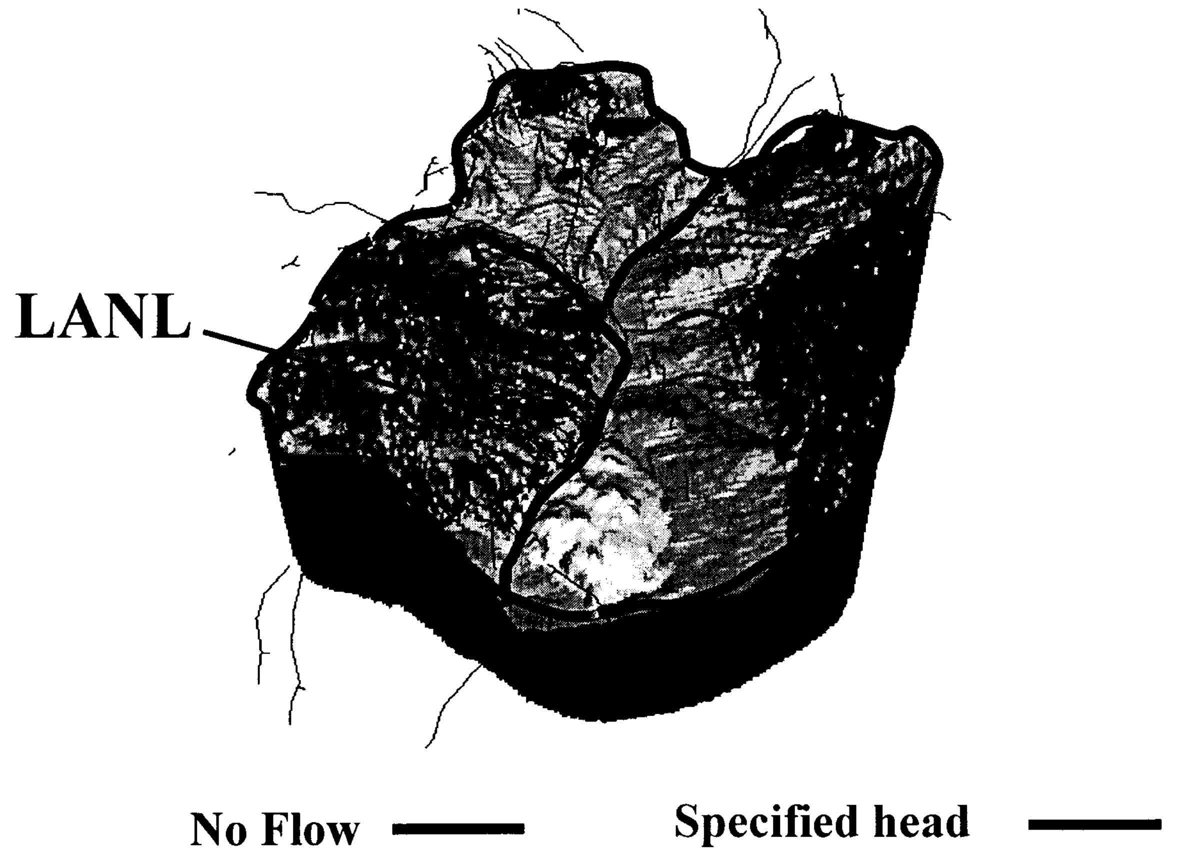
Groundwater Risk Assessment Methodology



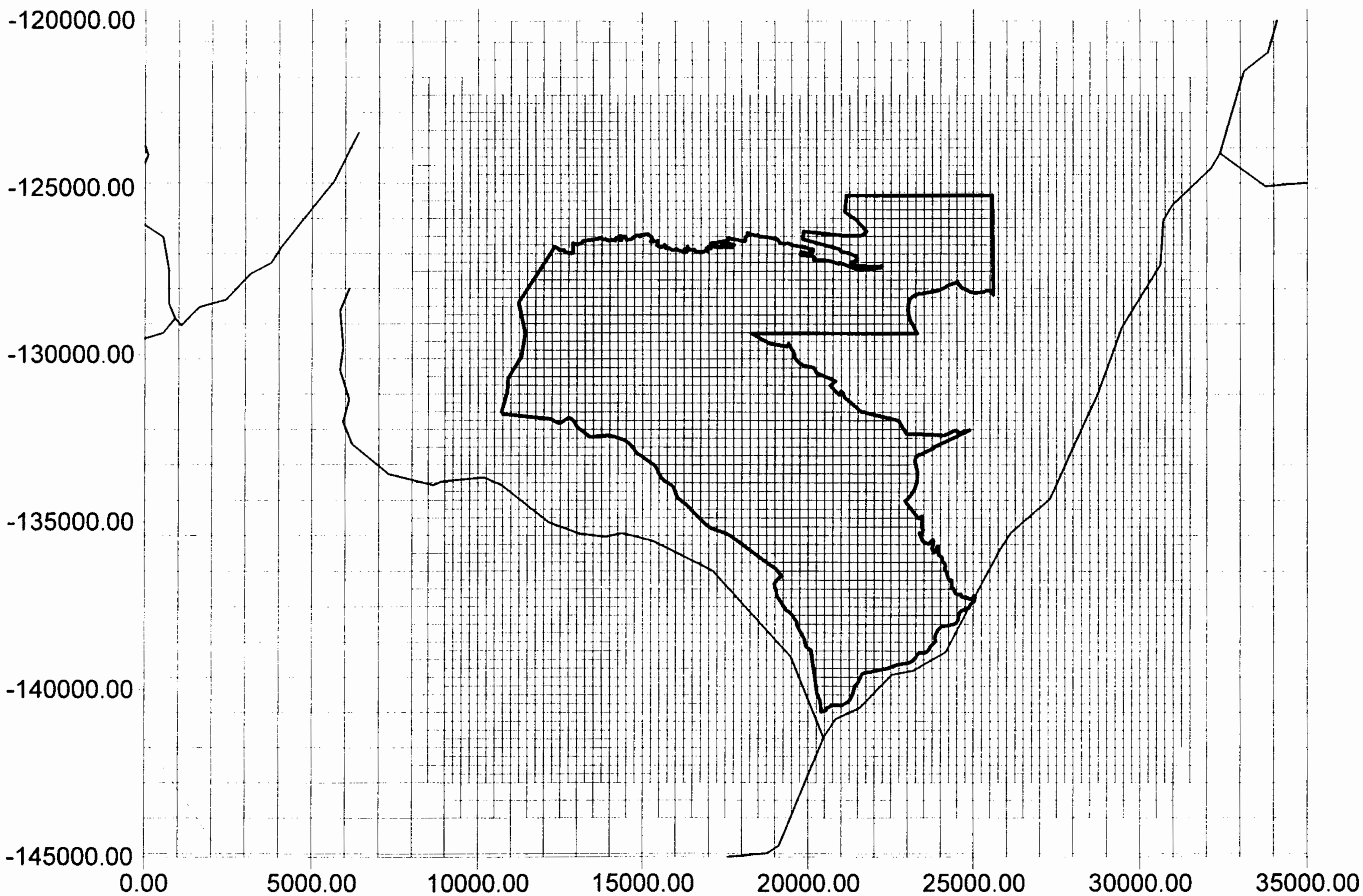
Components of the TA-16 HE Transport Model

- Source Terms
  - 260 Outfall
  - 90's Line pond
- Vadose Zone: one or more vadose zone transport models describing the pathways from the surface to the regional aquifer
- Regional aquifer flow and transport with supply well pumping

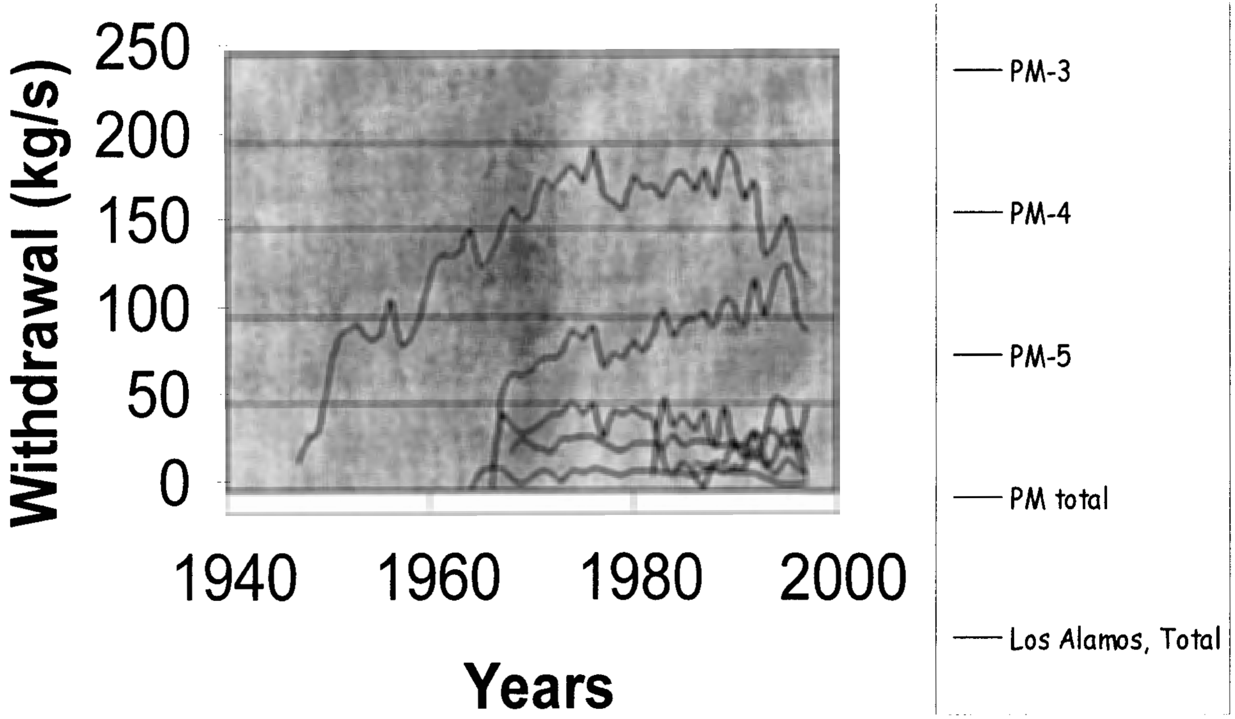
Regional Aquifer Flow and Transport Model



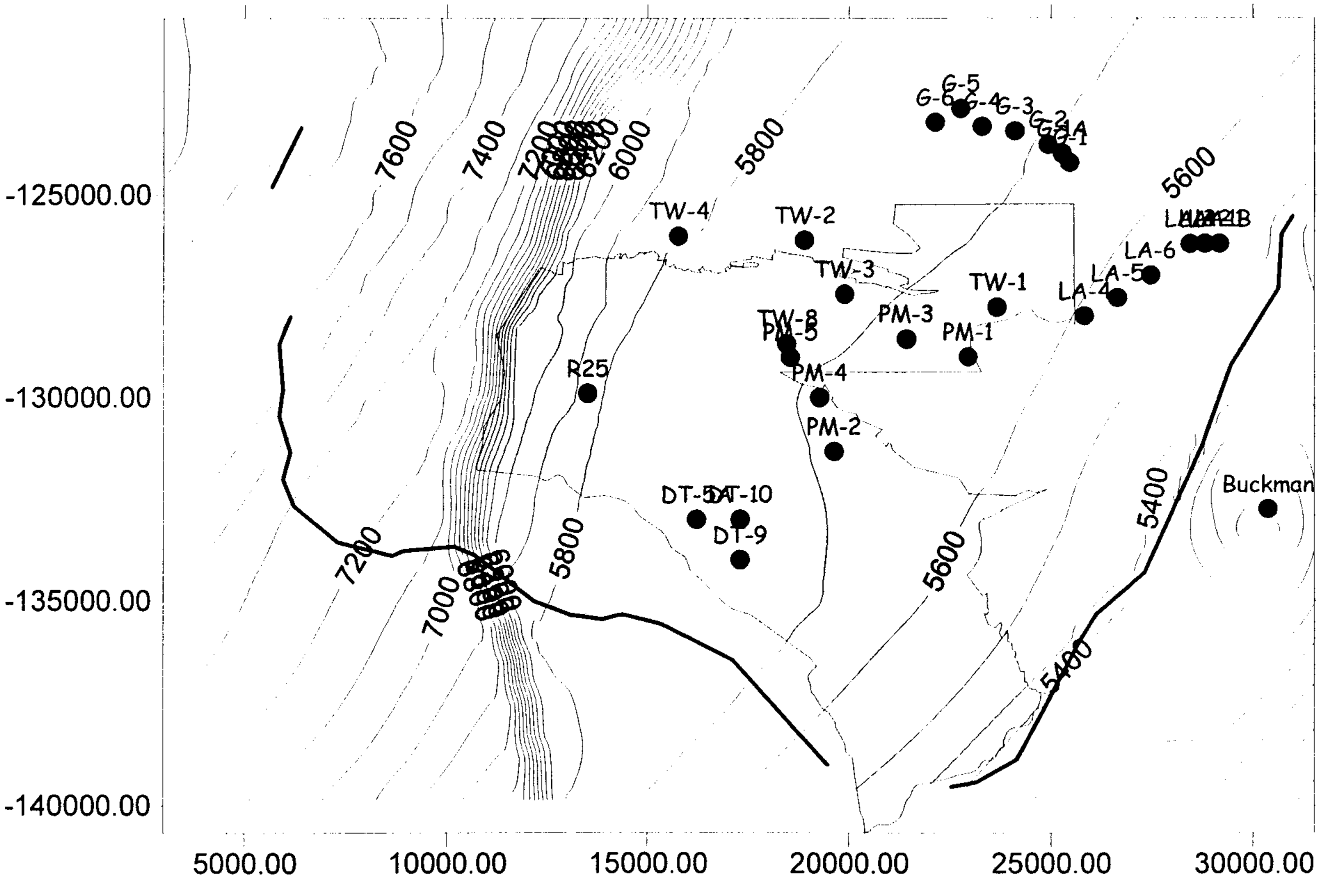
Computational Mesh Near the Laboratory



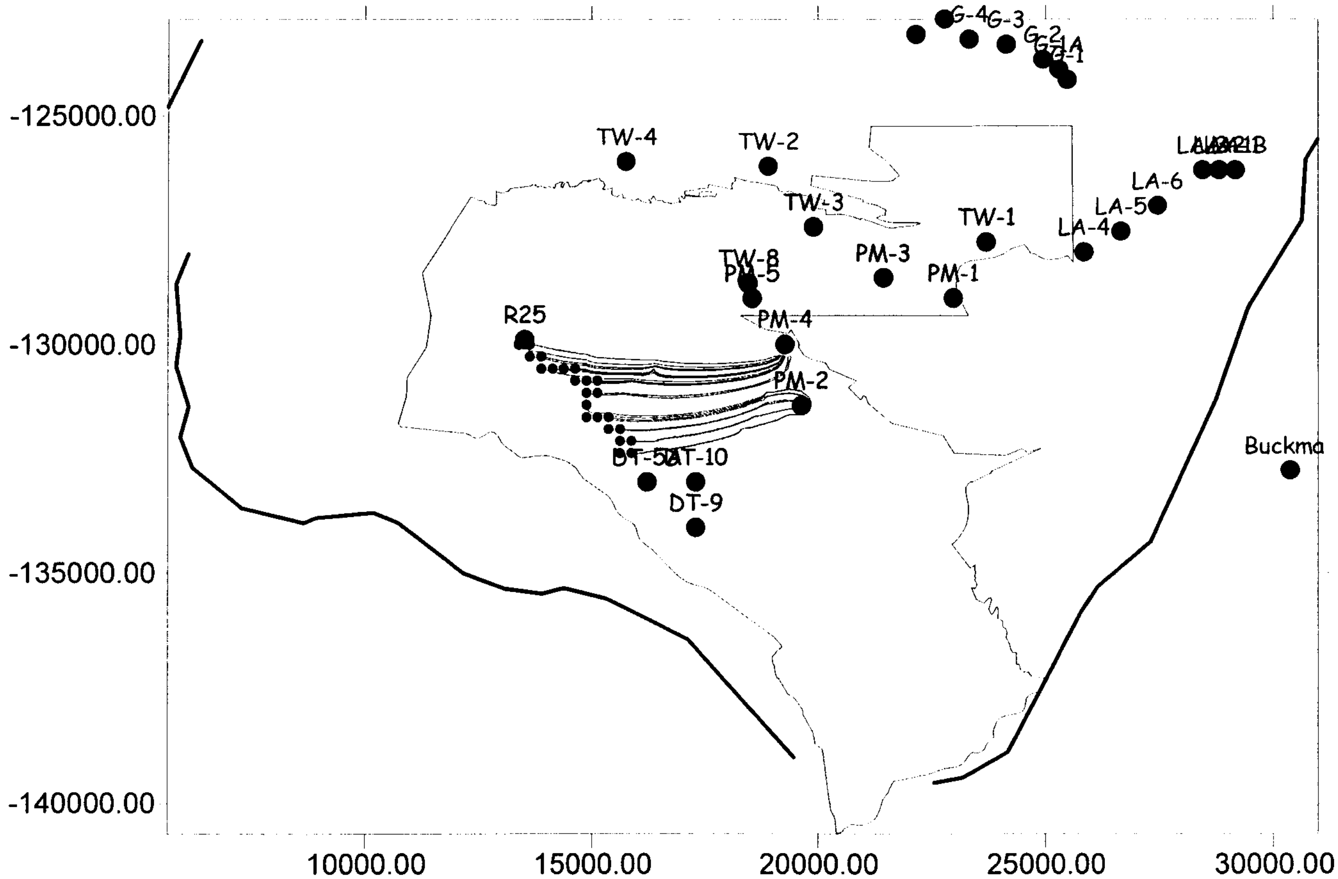
Pumping rates for the PM wellfield



Predicted 1995 Water Levels with Aquifer Pumping



Predicted Pathways from Various Locations Beneath Canon de Valle



Los Alamos National Laboratory Science Serving Society

Travel Times to Pumping Wells

	Porosity		Travel time (years) for 50% of particles to breakthrough at PM 2 or PM 4	
	Sedimentary rocks	Crystalline rocks	Source at TA-16	Source beneath Canon de Valle
Case 1	0.1	0.1	1428	PM2: 899 PM4: 719
Case 2	0.1	1.E-3	759	PM2: 899 PM4: 709
Case 3	0.1	1.E-5	749	PM2: 899 PM4: 709
Case 4	0.01	1.E-5	90	PM2: 100 PM4: 80

Confirmation of these travel times must be obtained through passive monitoring of plumes or through tracer testing in the regional aquifer.

Future Activities: TA-16 Modeling

- Expand the range of parameters in the regional aquifer transport simulations
- Incorporate information on biodegradation of HE
- Include vadose zone simulations
- Integrate the results of source term and groundwater models using groundwater risk assessment methodology

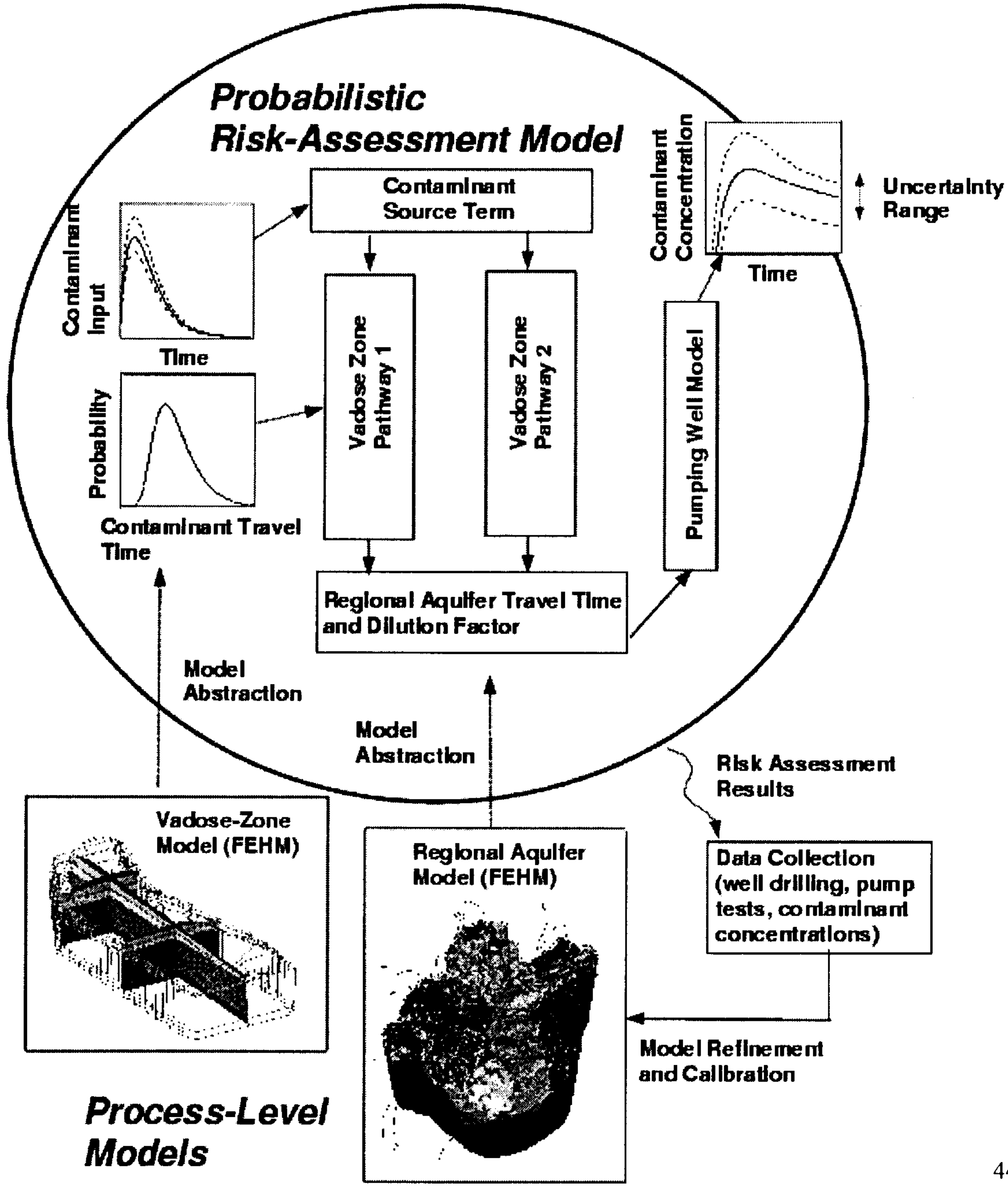
Modeling Presentations

- TA-49 Modeling: Kay Birdsell
- Los Alamos Canyon: Bruce Robinson
- Geochemical Modeling: Pat Longmire
- Regional Aquifer: Elizabeth Keating
- Pajarito Plateau Project: Bruce Robinson

Other Modeling Activities

- Geologic modeling
- Area L vapor plume
- Surface water modeling studies
- Area G risk assessment model development

Groundwater Risk Assessment Methodology



Data Quality Objectives for the Groundwater Protection Program

Charlie Nylander

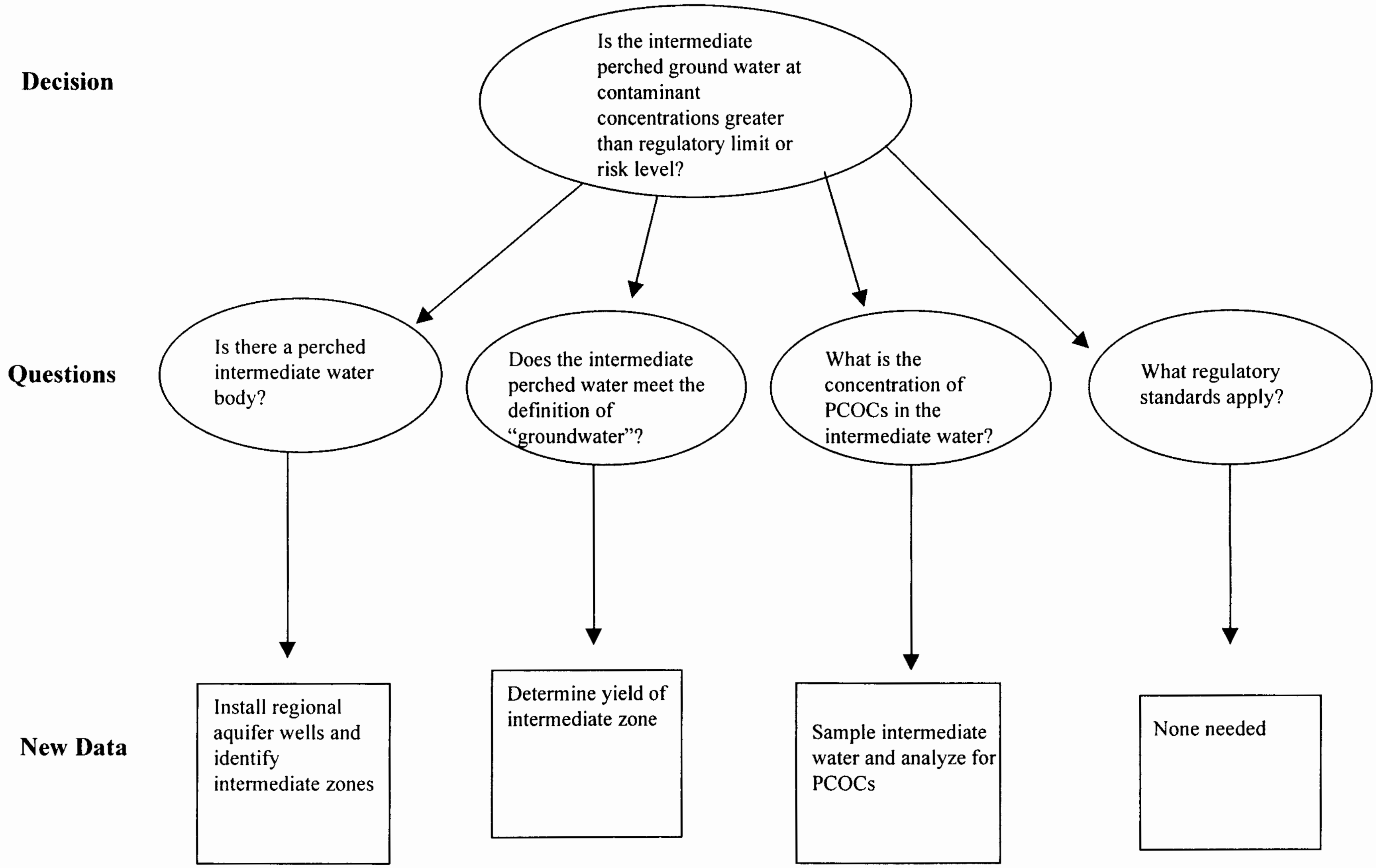
Presentation Overview

- Original development of the DQOs
- How DQOs translate into drilling method
- Data collection DQO Review Results

Original Hydrogeologic Workplan DQOs

- ***Decisions*** were formulated based on the conceptual model - how contaminants would move from surface and subsurface release points to groundwater
- ***Questions*** were the information needed to resolve the decisions
- ***Data needs*** were developed from the questions

Original DQO Example



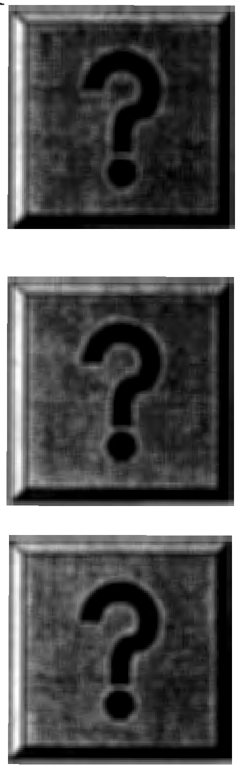
Development of DQO Decisions

- Conceptual model used to identify how contaminants would move and where they could be detected.
- Special consideration given to issues previously identified:
  - GWPMP - Identified groundwater issues
  - NMED - 1995 letters highlighted areas of inadequate understanding (e.g. recharge, faults)

DQO to Drilling Methods

Decisions

Questions



Data Needs
e.g.
- Water level
- Water quality
- permeability

Data Collection Methods
e.g.
- Probe
- Water samples
- Slug test

Drilling Method

Allows for reliable and representative data

Data Collection DQO Review

- Joint working session with NMED and GIT on September 13, 1999
- Reviewed original DQO decisions and made no substantive changes
- Reviewed questions and made no changes
- Reviewed data needed and made clarification to extent of fracture data

Data Collection DQO Review (cont)

- Listed possible data collection methods applicable to data needed
- Determined the character of borehole needed to apply the data collection methods

Example of DQO Review Results

Data Type	Data Collection Method	Advantages	Limitations	Relative Data Quality[1]	Relative Cost[2]	Drilling Method Requirements
	Data Collection Methods					
Hydraulic Properties	Recovery/slug test during drilling	Inexpensive, does not significantly slow drilling	Need an open hole, and a clean hole	3	A	Open hole, dry or fluid-filled[3]
	Single packer test during drilling	Inexpensive, does not significantly slow drilling	Need an open hole, and a clean hole	3	A	Open hole, dry or fluid-filled[3]
	Core Analysis	Easily done on intervals where core is available	Produces measurements of hydraulic properties on a small-scale	3	B	Open hole, dry or fluid-filled[3]
	Slug test – completed well	Standard method of measuring hydraulic properties	Limited to the screened interval of the completed well	4	B	Conducted in completed well so drilling method does not matter
	Geophysical Logs	Vertically continuous	Requires an open hole; some logs are limited to fluid-filled hole	4	B	Open hole, dry or fluid-filled[3]
	Air permeability by rig balance	Continuous during drilling, large scale	Less quantitative, requires dry, open hole	2	A	Open hole, air drilling only
	Air permeability by packer test	More quantitative	Requires dry open hole	3	A	Open hole, dry or fluid-filled[3]
	Pumping test in completed well	Large scale, provides best estimate of hydraulic properties	Need monitoring well nearby as an observation well	5	B	Conducted in completed well so drilling method does not matter
Water Level	Transducer	Continuous data, good resolution	Requires open hole with no tools downhole; reliability is an issue	5	A	Open hole, dry or fluid-filled[3]
	Probe/tape	Fast, can be used with tools in the hole	Single point measurements; resolution is an issue	3	A	Open hole, dry or fluid-filled[3]
Measurements on Rock (porosity, lithology, stratigraphy, bulk density, fracture characteristics)	Core analysis in a lab	Direct measurement	Requires core	5	B	Dry or fluid-filled, coring advances in front of the mud, so core is not affected by mud

[1] Rating is relative between collection methods for the same data type. The scale is 1 = low to 5=high.
[2] Rating is relative between collection methods for the same data type. The scale is A=inexpensive and B=expensive
[3] In fluid filled holes, the interval of interest must be isolated with packers and the mud circulated out of the interval before a test can be conducted.

DQO Review Results

- Concluded that:
  - Data needed will be determined for individual boreholes
  - Nearly all data needed can be collected in boreholes drilled dry or with mud
  - Mud holes require more complicated sampling preparation
  - Based on that, the drilling method will be selected on a borehole-by-borehole basis

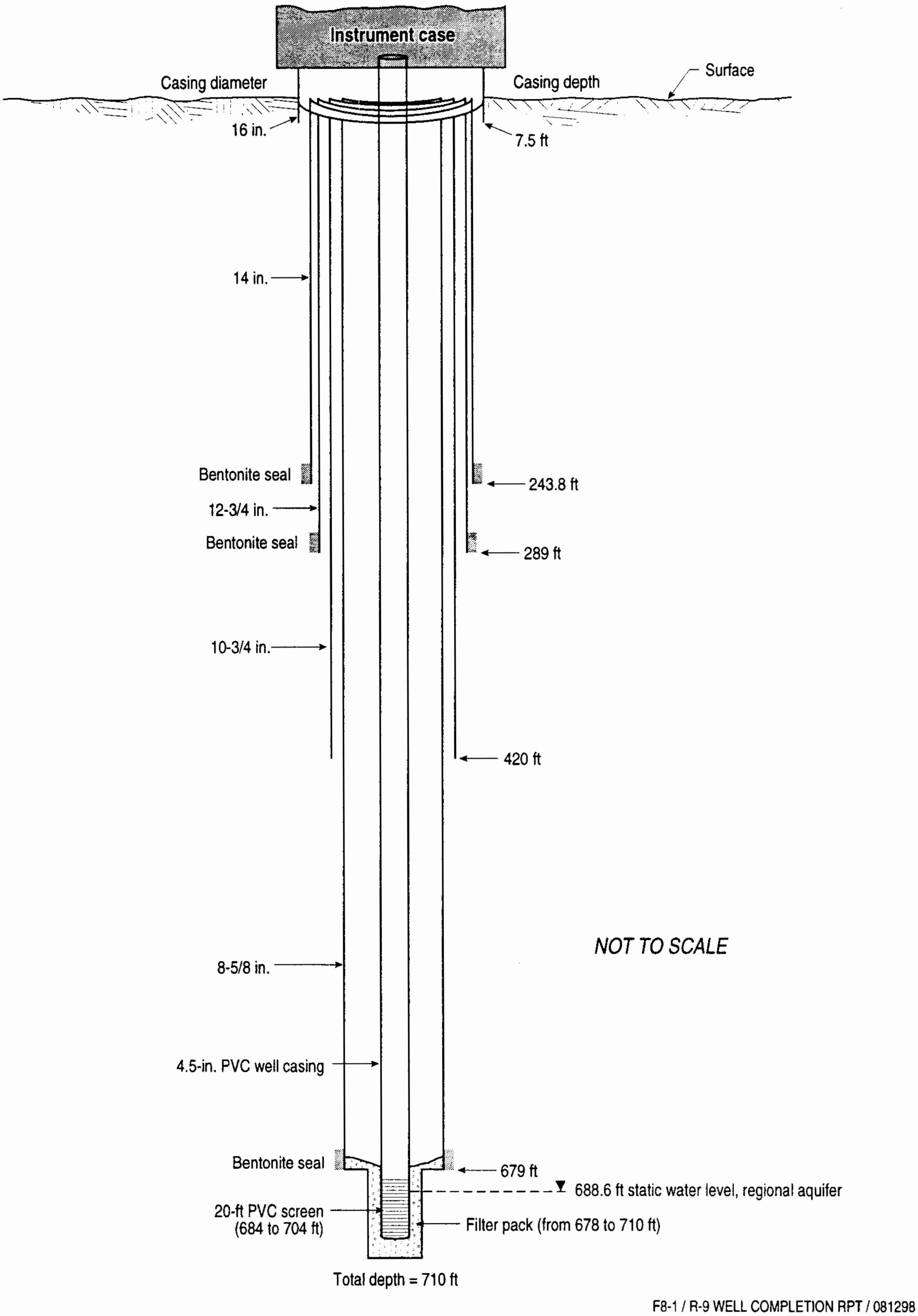


Figure 8-1. Configuration of the temporary well for R-9.