UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON NUCLEAR WASTE
WASHINGTON, D C. 20555-0001

Revised: September 19, 2002

AGENDA
137th ACNW MEETING
SEPTEMBER 25-26, 2002

WEDNESDAY, SEPTEMBER 25, 2002, TEXAS STATION HOTEL, AMARYLLIS ROOM, 2101 TEXAS STAR LANE, NORTH LAS VEGAS, NEVADA

1)	8:30 - 8:40 A.M.	Opening Statement (Open) (GMH/JTL) The Chairman will make opening remarks regarding the conduct of today's sessions.
2)	8:40 - 9:40 A.M.	Status of KTI Issue Resolution (Open) (GMH/ACC) The Committee will receive an information briefing by NRC staff on the status of DOE/NRC issue resolution.
	9:40 - 10:00 A.M.	*****BREAK*****
3)	10:00 - 11:30 A.M.	Discussion of Integrated Issue Resolution Status Report (Open) (GMH/ACC) The Committee will receive a status briefing from NRC staff on the forthcoming NUREG-1762 and staff analyses to support pre-licensing interactions and issue resolution.
4)	11:30 - 12:30 P.M.	NRC Review of Public Comments Received on the Yucca Mountain Review Plan (Open) (GMH/RKM) The Committee will receive a briefing by NRC staff on public comments received on the Yucca Mountain Review Plan (NUREG-1804).
	12:30 - 1:30 P.M.	*****LUNCH*****
5)	1:30 - 2:30 P. M.	Overview of Well Drilling in the Amargosa Desert Area (Open) (GMH/MPL) The Committee will receive an information briefing by an NRC staff on the analysis of well drilling activity in the Amargosa Desert Area covering the last 100 years.
6)	2:30 - 5:30 P.M.	DOE Scientific Update (Continued) (Open) 6.1) 2:30 - 3:30 P. M. - Proposed Resolution of Anomalous Chlorine-36 Indications (RGW/ACC)
	3:30 - 3:45 P.M.	*****BREAK*****

6.2) 3:45 - 4:45 P.M. - Microbial-Induced Corrosion Considerations (ML/ACC)
6.3) 4:45 - 5:00 P. M. - Questions and discussion

7) 5:00 - 6:00 P.M. Stakeholder Interactions
The Committee will reserve this time for interactions with stakeholders and meeting participants.

THURSDAY, SEPTEMBER 26, 2002, TEXAS STATION HOTEL, AMARYLLIS ROOM, 2101 TEXAS STAR LANE, NORTH LAS VEGAS, NEVADA

8) 8:30 - 8:35 A.M. Opening Statement (Open)(GMH/JTL)
The Chairman will make opening remarks regarding the conduct of today's sessions.

9) 8:35 - 12:00 Noon U.S. Department of Energy (DOE) Scientific Update for Selected Activities of the Geologic Repository Program at Yucca Mountain (Open)
The Committee will hear updates from DOE representatives on the following topics:
9.1) 8:35 - 9:00 A.M. - DOE Opening Remarks
9.2) 9:00 - 10:00 A.M. - Rebaselining of DOE Yucca Mountain Program (BJG/MPL)
9.3) 10:00 - 11:00 A.M. - Final Environmental Impact Statement for Yucca Mountain (BJG/RKM)
9.4) 11:00 - 12:00 NOON - Repository Design Update (ML/MPL)
9.5) 12:00 - 12:30 P.M. - Questions and discussion

12:30 - 1:30 P. M. *****LUNCH**

10) 1:30 - 4:00 P.M. **(3:00-3:15 P.M. - BREAK)** Preparation of ACNW Reports (Open)
The Committee will discuss proposed reports on the following topics:
10.1) Orphan Sources (MTR/RGW/HJL)
10.2) KTI Status Report (GMH/ACC)
10.3) Integrated IRSR (GMH/ACC)
10.4) Public Outreach (GMH/MPL)
10.5) DOE Scientific Update (tentative) (ML/MPL)

4:00 - 4:15 P. M. *****BREAK*****

11) 4:15 - 5:15 P.M. Stakeholder Interaction (Open) (GMH)
The Committee will reserve this time for interactions with stakeholders and meeting participants.

12) 5:15 - 6:45 P.M.		Preparation of ACNW Reports (Continued) (Open) The Committee will continue discussion of its proposed reports.
13) 6:45 - 7:00 P.M.		Miscellaneous (Open) The Committee will discuss matters related to the conduct of Committee activities and matters and specific issues that were not completed during previous meetings, as time and availability of information permit.
7:00 P.M.		Adjourn 137th Meeting

NOTE:

- Presentation time should not exceed 50 percent of the total time allocated for a specific item. The remaining 50 percent of the time is reserved for discussion.
- Thirty-Five (35) copies of the presentation materials should be provided to the ACNW.
- ACNW meeting schedules are subject to change. Presentations may be canceled or rescheduled to another day. If such a change would result in significant inconvenience or hardship, be sure to verify the schedule with Mr. Howard Larson at 301-415-6805 between 8:00 a.m. and 4:00 p.m., several days prior to the meeting.

YUCCA MOUNTAIN PROJECT

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

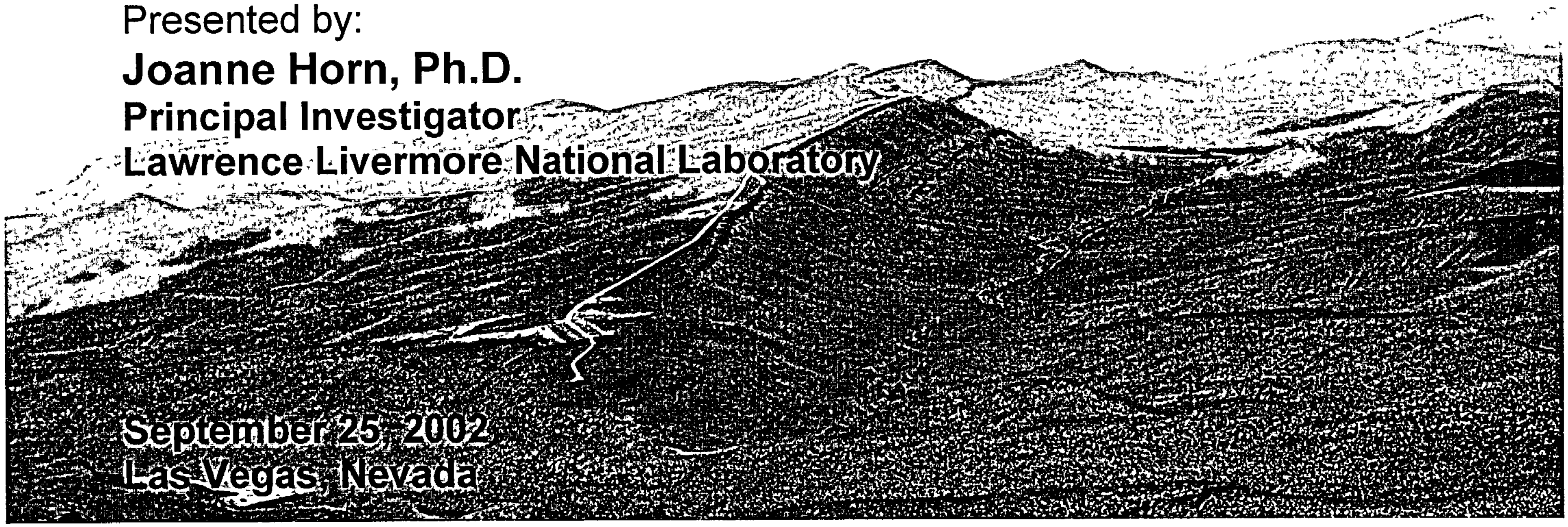
Assessing the Impact of Microorganisms on Long Term Nuclear Waste Containment

Presented to:
Advisory Committee on Nuclear Waste

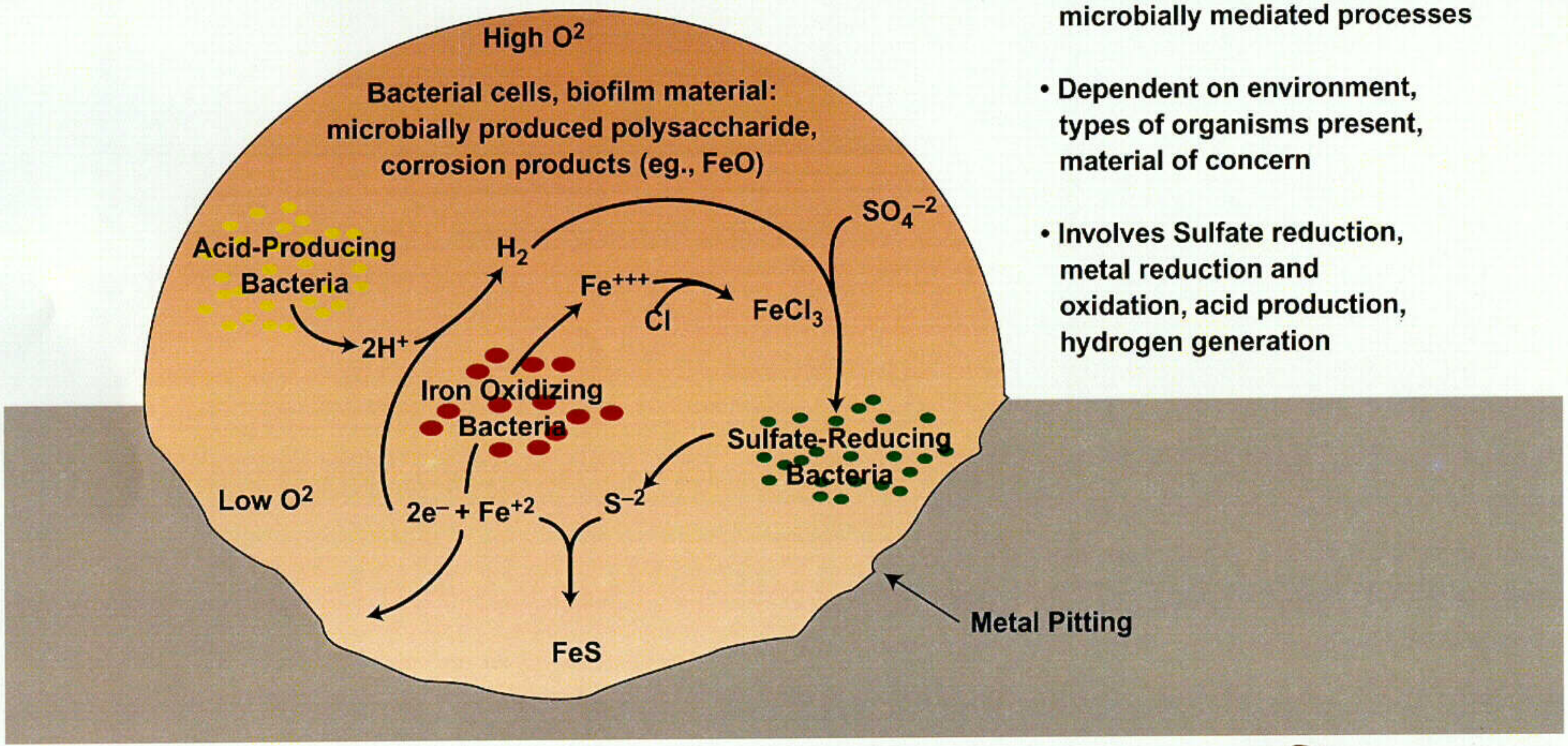
Presented by:

Joanne Horn, Ph.D.
Principal Investigator
Lawrence Livermore National Laboratory

September 25, 2002
Las Vegas, Nevada



Mechanics of Microbiologically Influenced Corrosion (MIC)



- Complex set of interacting microbially mediated processes
- Dependent on environment, types of organisms present, material of concern
- Involves Sulfate reduction, metal reduction and oxidation, acid production, hydrogen generation

C01-

Goals of the Microbiologically Influenced Corrosion (MIC) Program

- Determine the potential for MIC in the YM repository

- Determine the conditions for MIC to occur
  - Boundary conditions for microbial growth
  - Conditions for corrosive microbial activities

- Quantify the rates of MIC on waste package materials
  - production of deleterious metabolic end products
  - effect on candidate waste package materials

Multiple Approaches to Assessing Microbial Contributions to Corrosion of Waste Package

- Ecological Studies
  - Types organisms present/expected: potential for MIC
  - Conditions for growth; over repository evolution: time of MIC initiation
  - Effect of microbial activity on water composition: indirect microbial effects
- Electrochemical Studies
  - Quantify overall changes in corrosion rates due to MIC
  - Can indicate mode of corrosion
- Accelerated Testing: Mixed/Pure Cultures
  - Surfacial effects on materials
  - Biochemical effects on water chemistry
  - Pure Cultures - boundary conditions

Ecological Studies

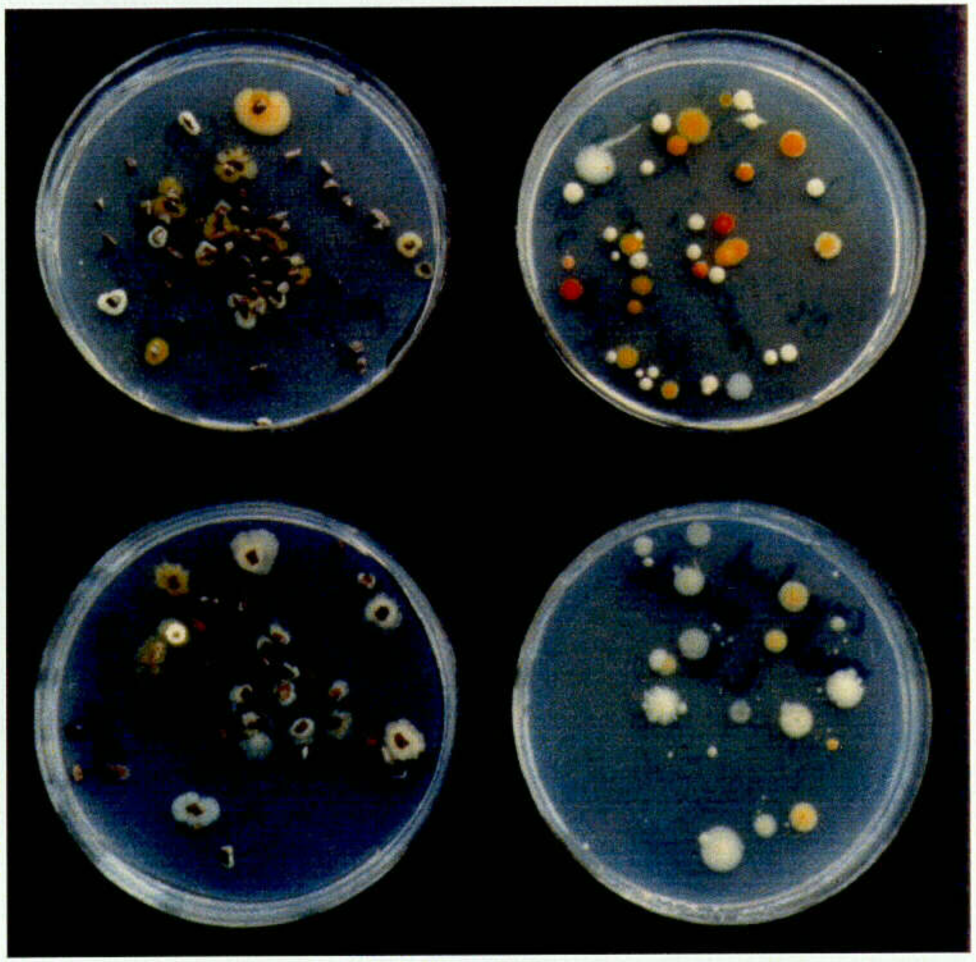
- Characterization of Yucca Mountain microbial and fungal communities
  - –Culturing, Screening, Molecular Diagnostics

- Determination of microbial densities and growth limiting factors

Bacteria Derived from Yucca Mountain Excavated Rock

Crushed Rock ESF

Crushed Rock Large Block



Crushed Rock Wash ESF - Washed with APW 0.2 ml. [IX]

Crushed Rock Wash Large Block - Washed with APW 0.2 ml. [IX]

C02

Yucca Mountain Bacterial Isolates Displaying Corrosion-Related Activities

Strain#[a]	Species Identification[b]	Acid Production[c]	Sulfide Production[d]	Slime Production[e]
*ESF-C1	*Cellulomonas flavigena*	X	X (oxic)	
LB-71h-RT-13	*Pseudomonas stutzeri*	X		
*ESF-71h-RT-4	*Flavobacterium esteroaromaticum*	X	X (oxic)	
*LBan-U7	uncharacterized	X		
LBan-UW2	*Cellulomonas turbata*	X		
*LB-71h-50-3	probably *Bacillus sp*	X		
ESFan-U4	*Bacillus circulans*	X		
LBan-C1	*Arachnia propionica* (poor match	X	X (oxic/anoxic)	
LBan-UW2	*Cellulomonas turbata*	X		
LBan-U1	*Cellulomonas galida*	X		
LBan-U2	*Bacillus pabuli*	X	X (anoxic)	
*LBan-U3	*Bacillus pantothenticus*		X (anoxic)	X
LB-71h-50-2	*Bacillus pumilus* subgroup B		X (anoxic)	
*LB-71h-50-4	*Bacillus subtilus*		X (anoxic)	X
*LB-71h-50-6	probably *Bacillus sp*		X (anoxic)	X
ESF-71h-RT-1	*Flavobacterium esteroaromaticum*		X (oxic)	
*LB-C1	uncharacterized		X (oxic)	X
LB-C2	uncharacterized		X (oxic)	
LB-C7	*Pseudomonas stutzeri*		X (oxic)	
*LB-71h-RT-15	*Pseudomonas pseudoflava*			X
LB-71h-RT-4	*Pseudomonas pseudoflava*			X
LB-CW-6	*Arthrobacter oxydans*			X

*Used as inoculum for electrochemical determination of corrosion rates with iron oxidizing and sulfate reducing enrichment cultures

[a]ESF=Exploratory Study Facility, LB=Large Block; an=isolated under anaerobic conditions; C=crushed rock isolate, U=uncrushed rock isolate; W=isolated from after washing rock; 71h=isolated after 71 hours of growth, RT=room temperature isolate; 50=50oC. isolate

[b]Determined by fatty acid analysis using the MIDI/Hewlett Packard microbial identification system (MIS, Analytical Services, Inc , VT), identification of given isolates may be tentative due to a lesser degree of similarity with type organisms contained in the MIS database

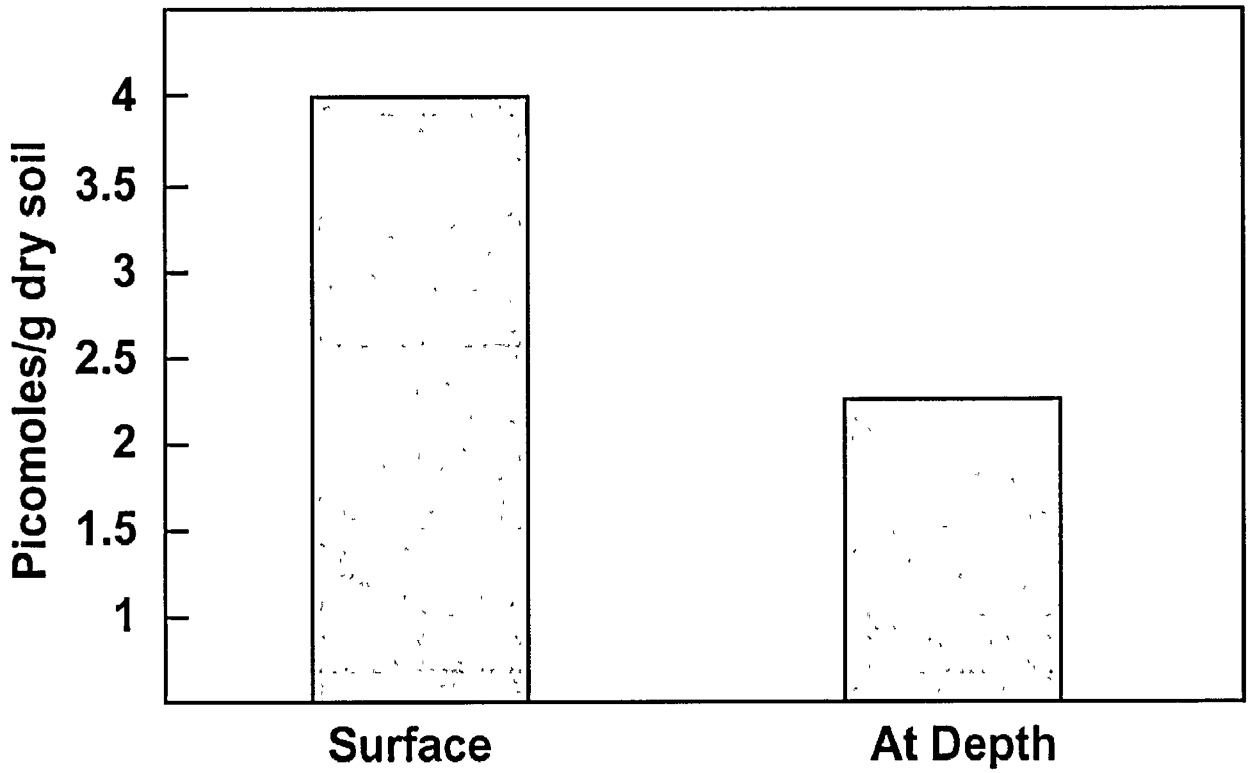
[c]Determined after growth in R2 media with or without 0 5% glucose and pH indicators bromocresol purple and methyl red .

[d]Determined after growth in R2 agar media (Difco) containing 0.75% proteose peptone #3 (Difco) and lead acetate

[e]Determined after growth on R2 agar (Difco) .

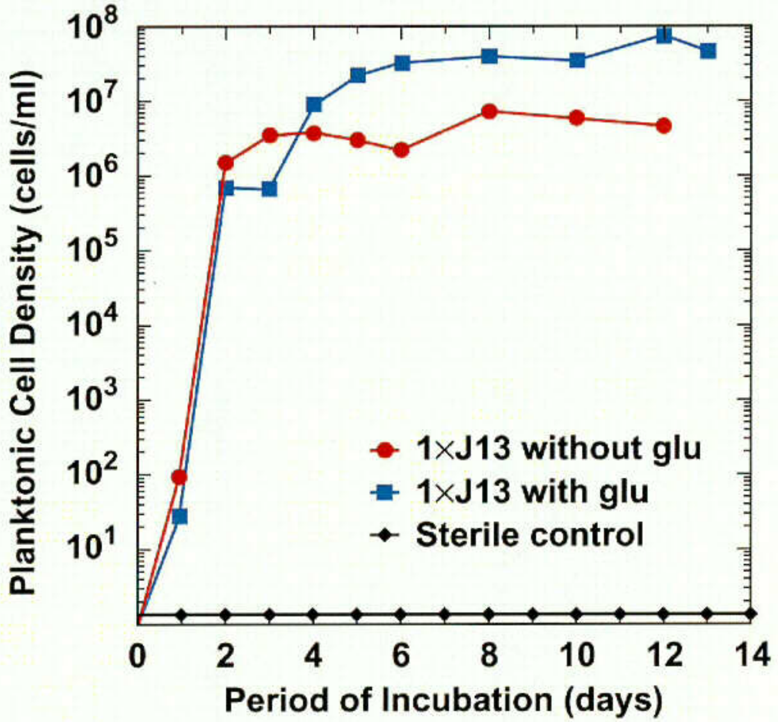
YUCCA MOUNTAIN PROJECT

Bacterial Density Determination in YM Rock Samples Using Direct Extraction of Phospholipids



Proximity to drift wall corresponds to 4-7 $\times$ 10^4 cells/g dry rock

Microbial Growth from YM Rock is Dependent on Water Availability

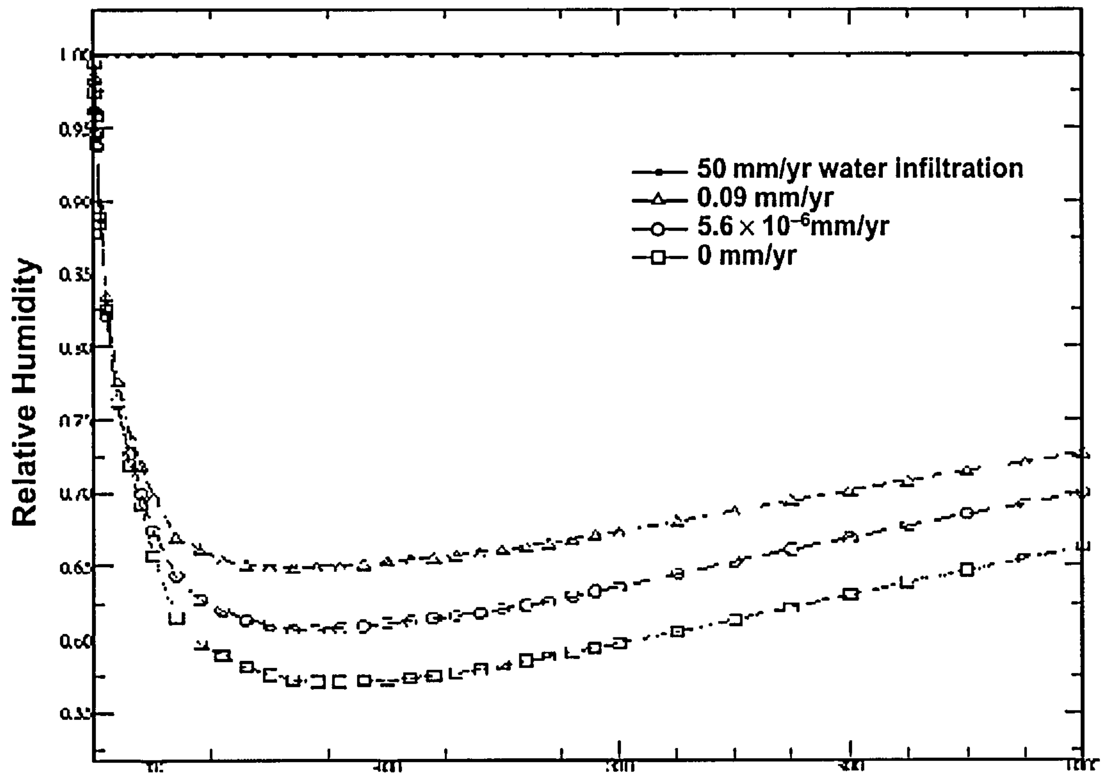


- **Major limiting factor to growth is water availability**
  when simulated 1×J13 water is added, cell densities increase by at least 2-3 orders of magnitude

- **Secondary limiting factors are phosphate and carbon**
  when either phosphate or organic carbon is added, densities increase 1-2 orders of magnitude

C03

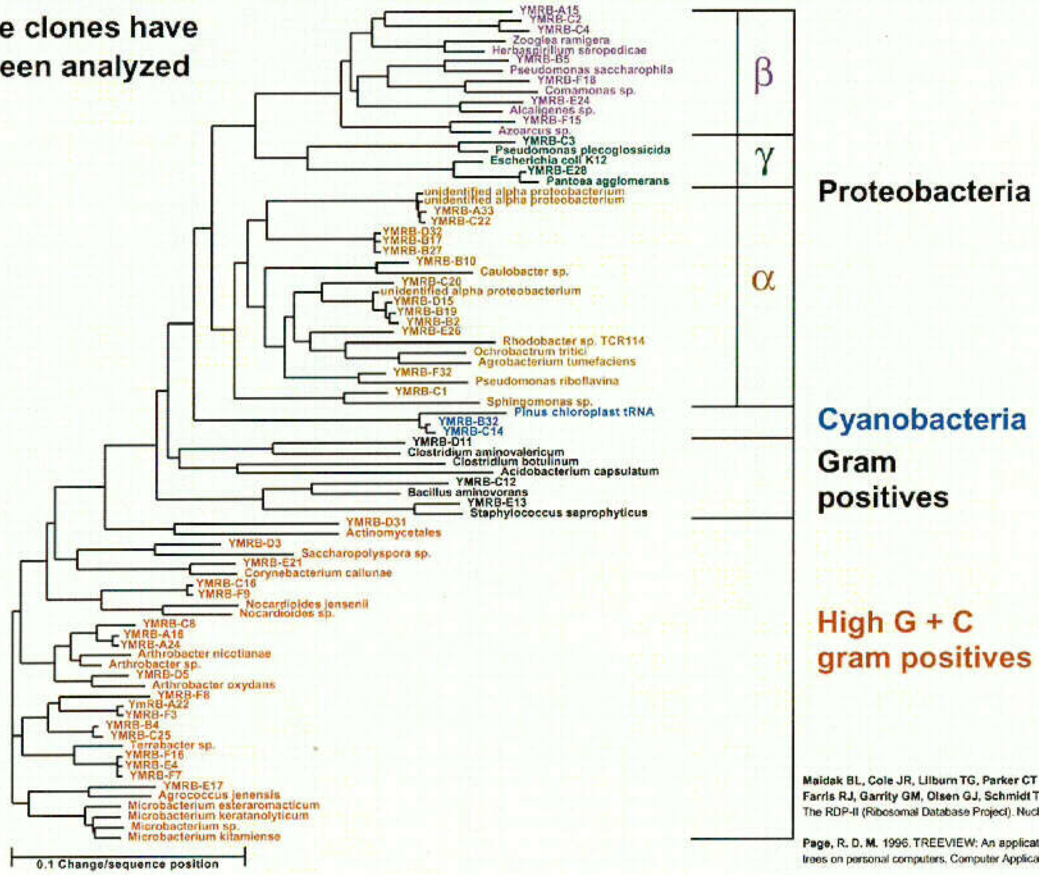
Expected Relative Humidity as a Function of Infiltration Rate on Drift Walls Over Time in the Post-Closure LTOM Repository Design



Time (years)
50 mm/yr

Phylogenetic Tree of Bacterial rDNA Clones Extracted Directly from Yucca Mountain Rock

21 unique clones have not yet been analyzed



Maidak BL, Cole JR, Lilburn TG, Parker CT Jr, Saxman PR, Farris RJ, Garrity GM, Olsen GJ, Schmidt TM, Tiedje JM. The RDP-II (Ribosomal Database Project). Nucleic Acids Res 2001 Jan 1;29(1):173-4

Page, R. D. M. 1996. TREEVIEW: An application to display phylogenetic trees on personal computers. Computer Applications in the Biosciences 12: 357-358.

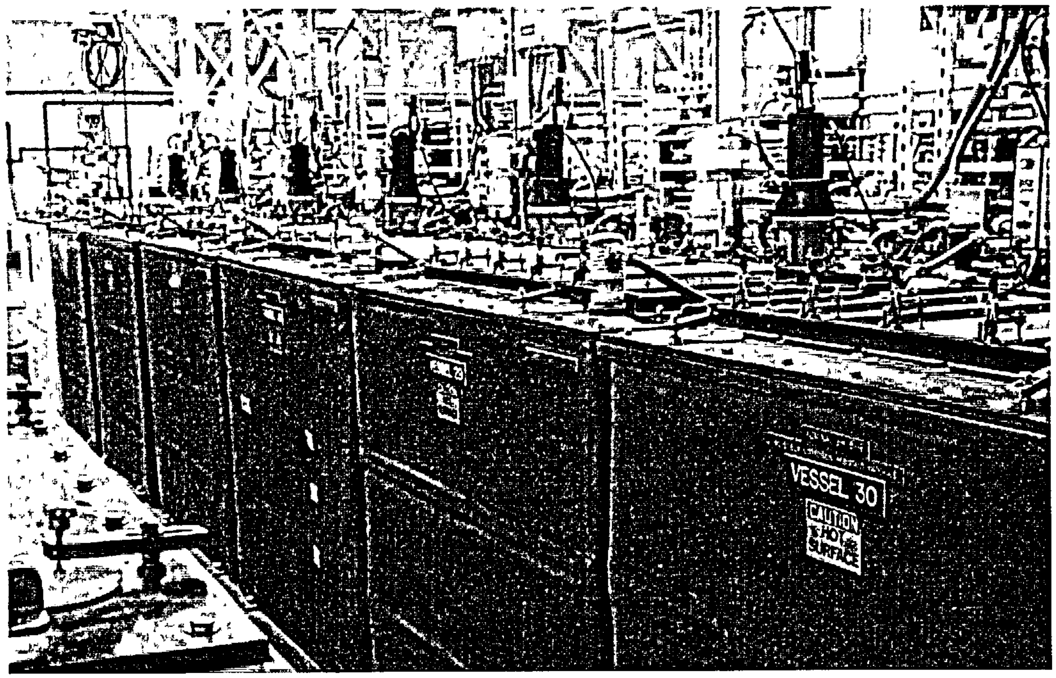
C04

Fungi Identified from ESF/YM using Different Analytical Methods and their Relative Occurrence

Fungi Identified by rDNA (MIDI Labs[1])	Fungi Identified by Morphology (Armstrong[2])	Median Number of Organisms per Swab Sample (Armstrong[2])	Number of Swab Samples Showing Presence of Organism (Armstrong[2])
**Aspergillus awamori*			
**/*Aspergillus ochraceus*		125	5
**/*Aspergillus ustus*	**Aspergillus*		
**/*Aspergillus versicolor*			
†*Acremonium sclerotigenum*			
Aphanocladium album			
Beauveria felina			
Blastobotrys arbuscula			
Blastobotrys proliferasns			
	†/**Cladosporium*	25	6
Doratomyces microsporus			
**Emericellopsis terricola*			
†*Exophiala jeanselmei*			
Hapsidiospora irregularis			
Microascus trigonosporus			
Nectria inventa			
Nectria mauritiicola			
Neosartorya quadricincta			
Ovadendron sulphureoochraceum			
†/**Paecilomyces lilacinus*			
†/*/**Penicillium chrysogenum*	**Penicillium*	3715	16
†/*/**Penicillium decumbens*			
**Penicillium hordei*			
**Penicillium implicatum*			
**Penicillium peonense*			
*/**Penicillium glabrum*	†/**Rhizopus*	100	3
**Penicillium quadricincta*	†/**Rhizomucor*	35	2
**Penicillium resedanum*			
Syncephalastrum racemosum			
Talaromyces flavus			
Zygorhynchus moelleri			

1 MIDI Labs, Inc , Newark, DE
2 Armstrong Forensic Laboratories; Arlington, TX
* mycotoxin-producers
** allergens; associated with immune-related disease
† invasive, infects and grows in afflicted tissues

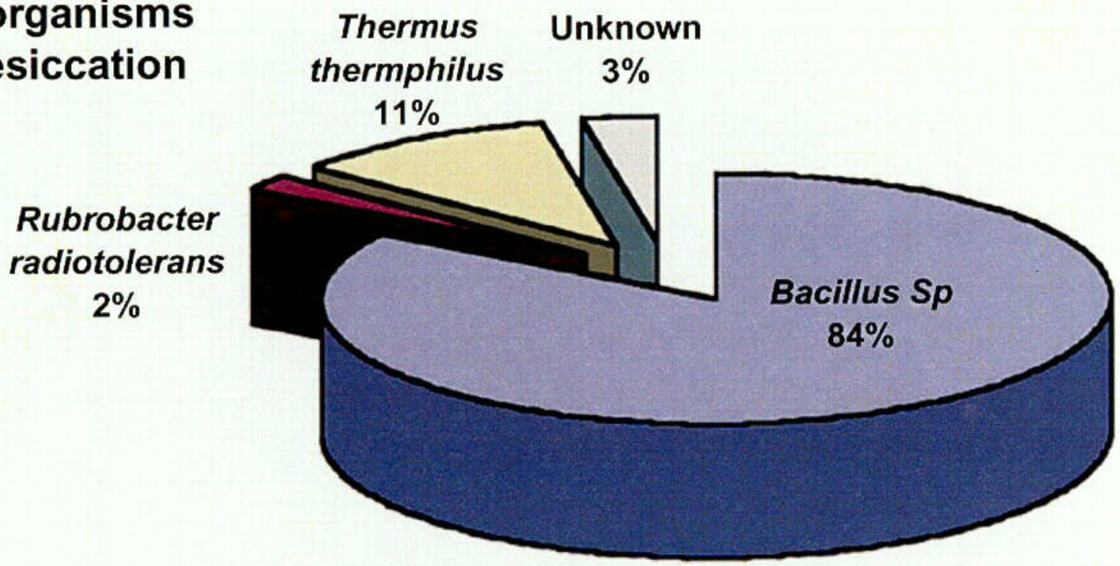
Molecular Microbial Community Analysis of Long Term Corrosion Experiment



- Tank environments mimic expected repository environments, vary in ionic strength, pH, T°
- No bacteria introduced intentionally, but evidence that they have become colonized
- Reflects repository evolution: initially sterile, then becomes colonized

Community Characterization of Tank 29: SDW/60°C/Corrosion Resistant Materials

- *R. radiotolerans* is a radiation-resistant organism
- *T. thermophilus* is a heat-tolerant organism
- Bacilli are sporulating organisms that can endure both desiccation and high temperature



Now analyzing Tank 25 (SAW, 60°C./Corrosion Resistant Materials); observed a very strong DNA signal, have cloned amplified 16S rDNA genes, now screening

C05

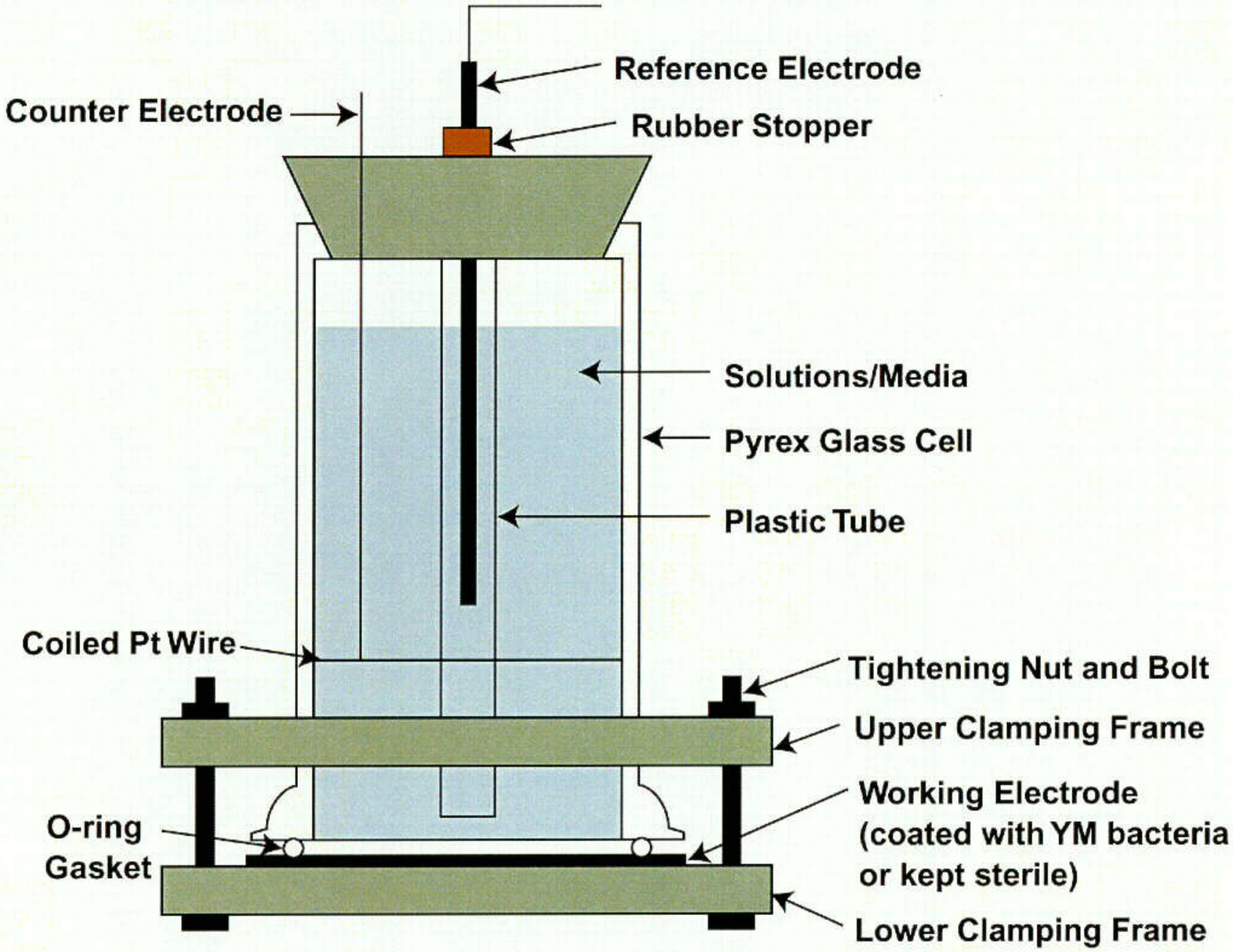
Summary of Ecological and Growth Studies

- Microorganisms are extant in YM Rock (10^4-10^5 bacteria/gm rock)
- A wide variety of fungi also inhabit YM rock
- Major growth limiting factor is water; when water becomes available, microbial growth will ensue
- Infiltrating water will also likely transport organisms into the repository
- Cultured YM bacteria have activities associated with MIC; establishes the potential for MIC in the repository
- Uncultured identified organisms span a wide phylogenetic range; their activities are being investigated for MIC activities
- Investigations of the Corrosion Test Tanks show that organisms adapted to repository environments will become established

Electrochemical Studies

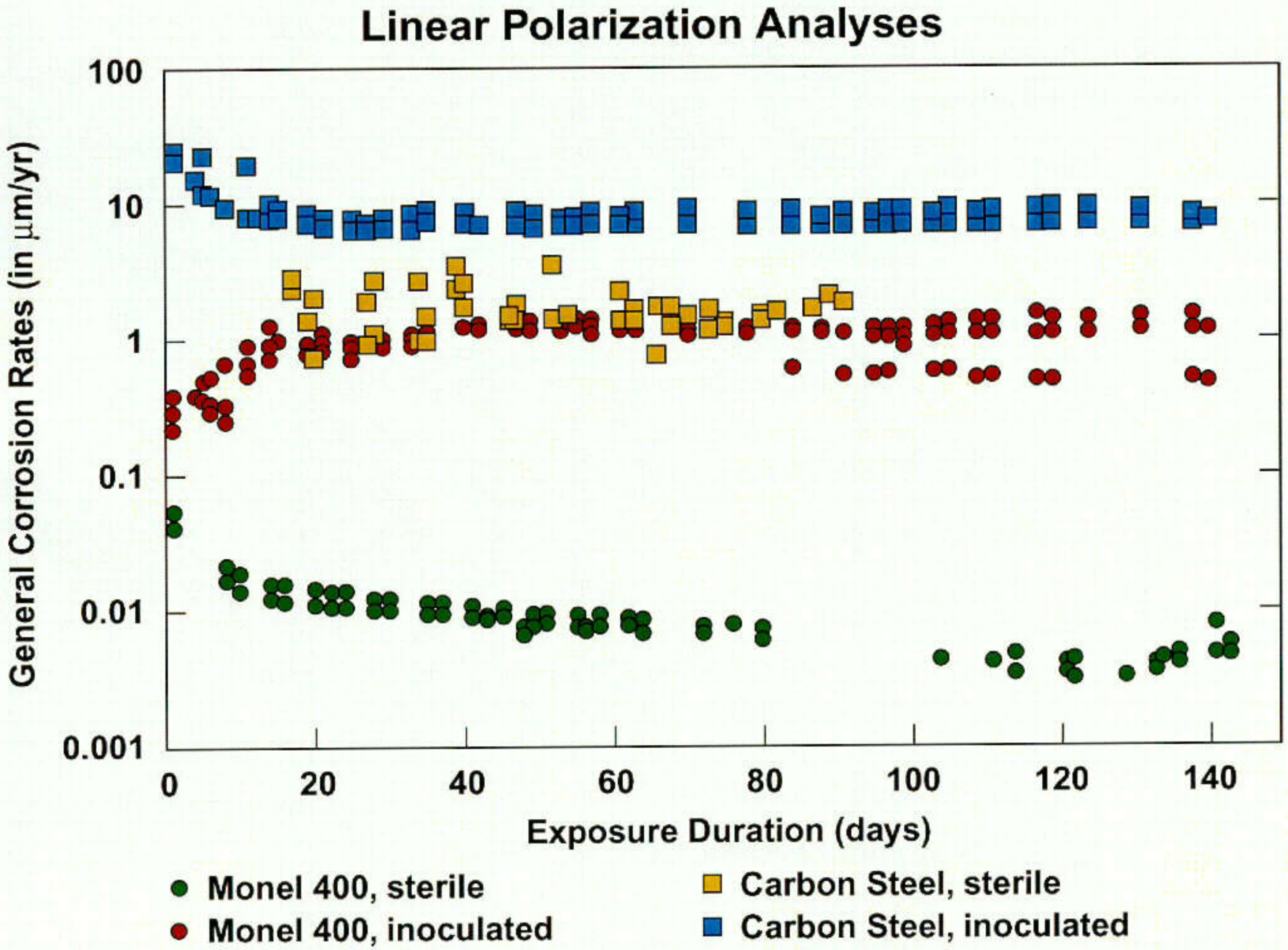
- Quantify overall contribution of microorganisms to corrosion
- Offers indication of mode of biogenic alterations to corrosion rates

Apparatus used for Electrochemical and Dissolution Experiments



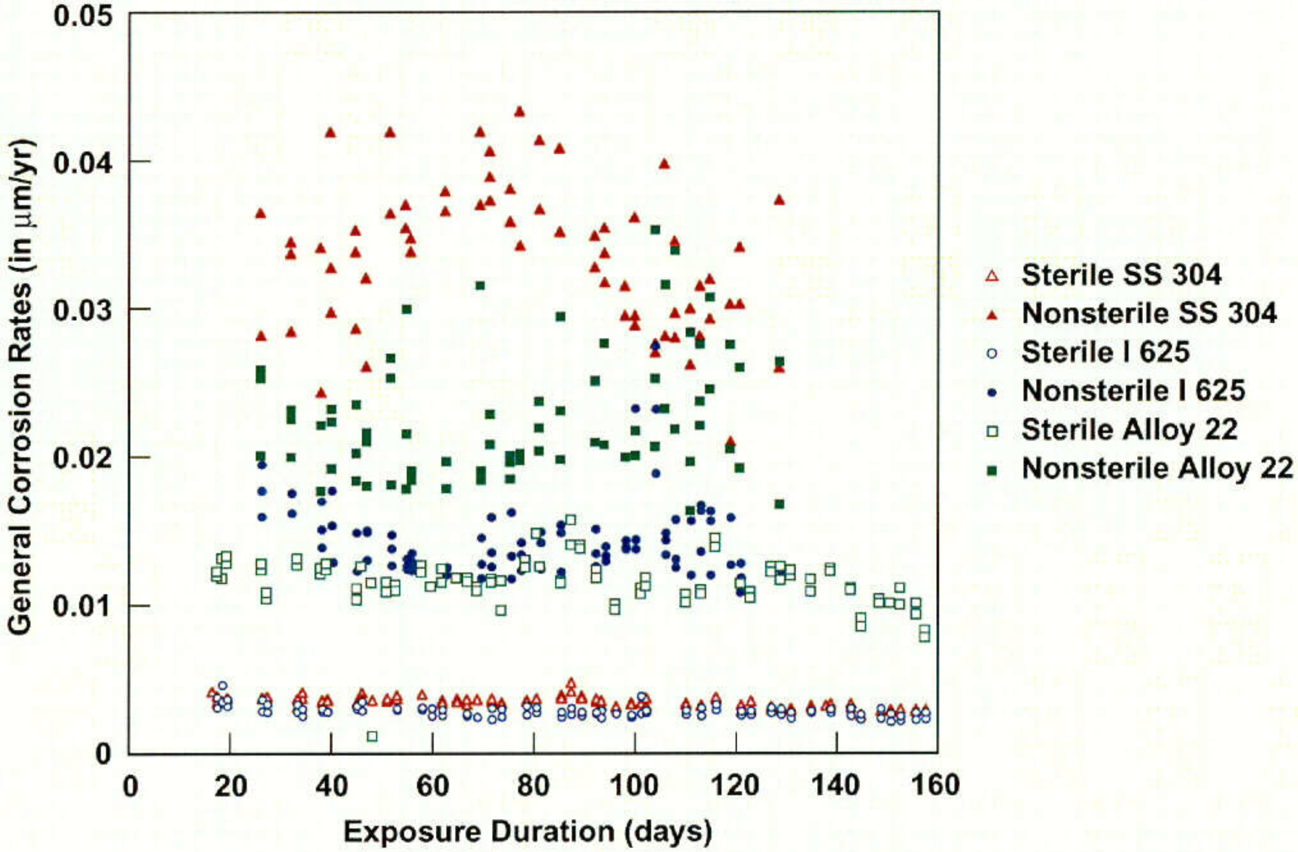
C06

Inoculated YM Bacteria Increase Corrosion Rates of Carbon Steel and Monel 400



C07

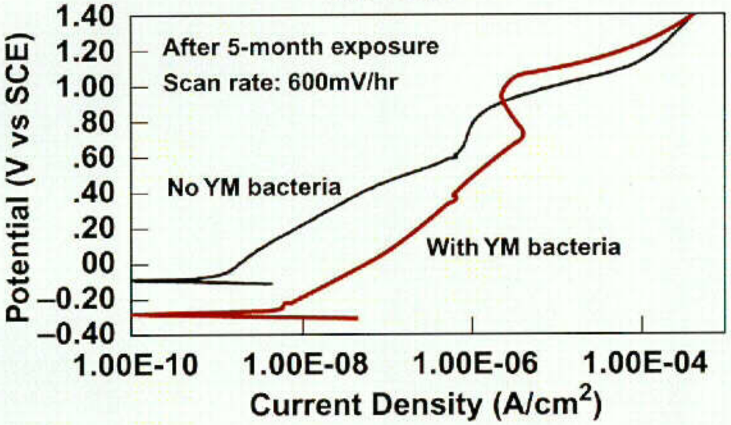
General Corrosion Rates of SS 304, and Alloys 625 and 22: Sterile vs. Inoculated YM Bacteria



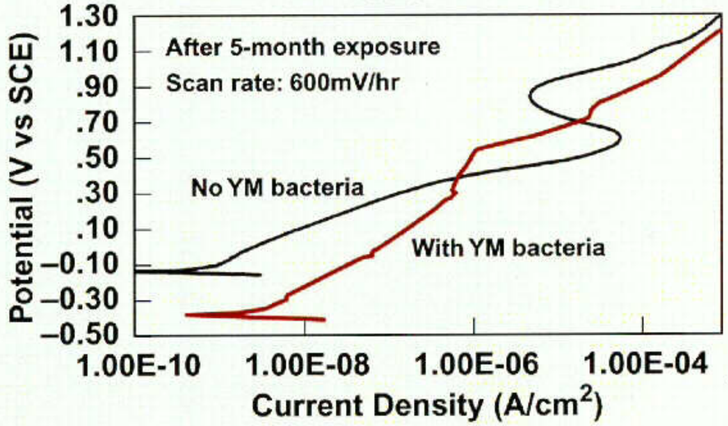
C08

Anodic Polarization of Behavior of 304SS, I625 and Alloy 22, Exposed to Amended J-13 Groundwater with and without the Presence of YM Microorganisms

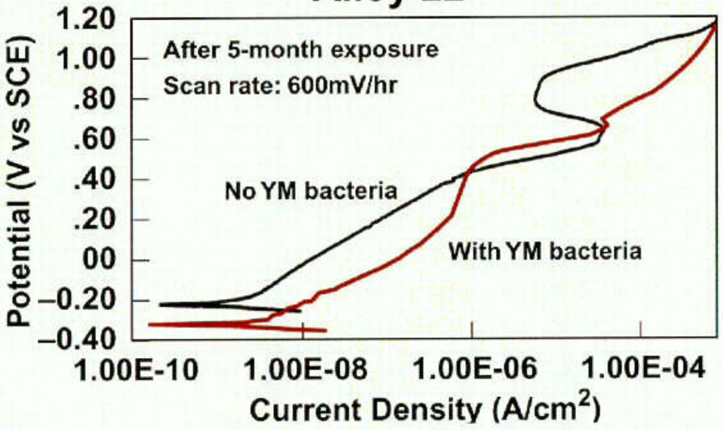
304SS



I625



Alloy 22



Alterations in Average Corrosion Rates and E_{corr}, due to Inoculated YM Bacteria in Polarization Resistance Experiments

Tested Sample Initial Condition	Average Corrosion Rate (in µm/yr)	Corrosion Potential E_{corr} (V vs SCE)	
		Initial	Endpoint
CS1020 + YM Microbes	8.8	-0.660	-0.685
Sterile CS1020	1.4	-0.500	-0.550
M400 + YM Microbes	1.02	-0.415	-0.315
Sterile M400	0.005	-0.135	-0.070
Alloy 22 + YM Microbes	0.022	-0.440	-0.252
Sterile C-22	0.011	-0.260	-0.200
I625 + YM Microbes	0.013	-0.440	-0.285
Sterile I625	0.003	-0.160	-0.130
304SS + YM Microbes	0.035	-0.540	-0.280
Sterile 304SS	0.003	-0.145	-0.065

Concentration of Material Components in Solution at Termination of LP Experiments

Tested Sample Initial Condition	Metal Concentration in the Solution at the End of Exposure (in ppm)			
	Ni	Cr	Cu	Fe
CS1020 + YM Microbes				
Sterile CS1020				16.5
M400 + YM Microbes	18.5		1.00	0.40
Sterile M400	0.09		0.06	0.25
Alloy 22 + YM Microbes	0.10	1.15		0.3
Sterile C-22	n.d. <0.02	n.d.<0.01		0.42
I625 + YM Microbes	0.14	1.03		0.32
Sterile I625	n.d. <0.02	n.d.<0.01		0.31
304SS + YM Microbes	0.04	1.02		0.55
Sterile 304SS	n.d. <0.02	n.d.<0.01		0.31

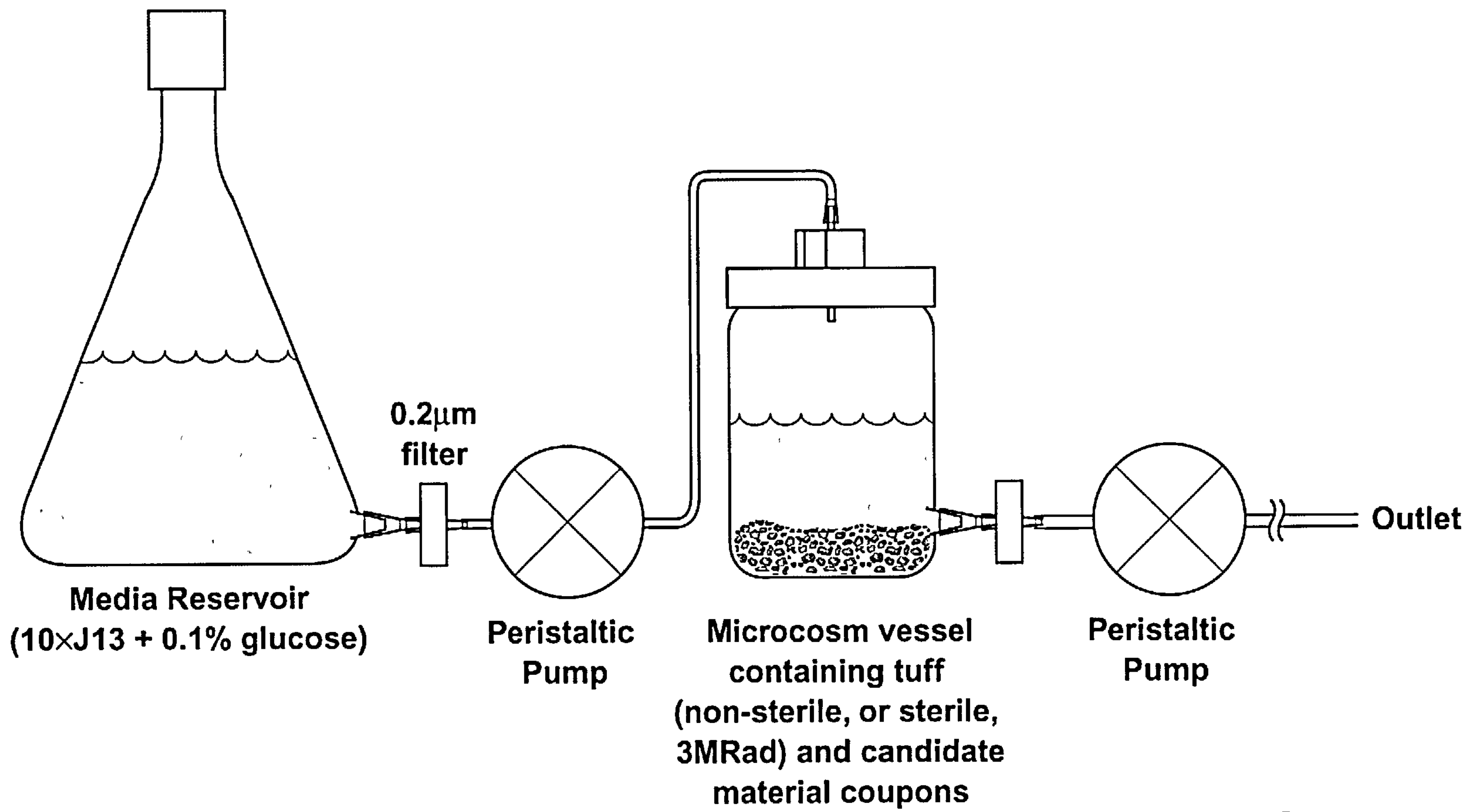
Summary of Electrochemical and Dissolution Studies

- Carbon Steel shows an increase in corrosion rate due to YM bacteria, Monel shows a greater "MIC Factor"
- Alloy 22 shows a lower increase in MIC factor (2-fold)
- Delineated MIC factors require further investigation under more representative conditions
- Cyclic polarization testing is planned to better estimate localized corrosion rates
- To date, anodic polarization analyses demonstrate that microbes are causing an increase in anodic activity (metal dissolution)
- MIC factors thus far determined have been incorporated into overall modeling

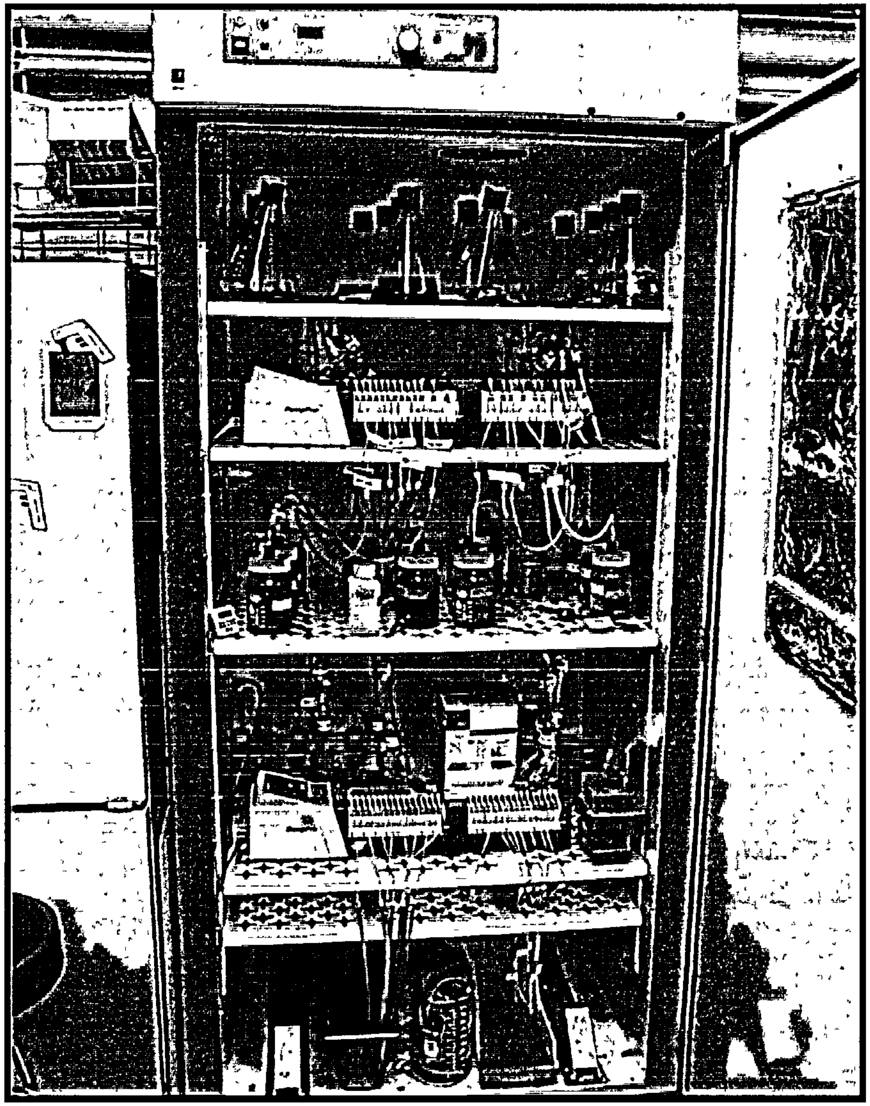
Accelerated Materials Testing

- Simulated Saturated Repository Microcosms
- Pure Culture Studies
- Batch Chemical Testing

Simulated Saturated Repository Microcosms to Assess the Contribution of YM Bacteria to Corrosion of WP Materials



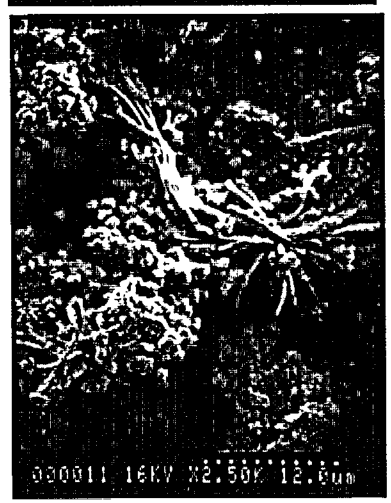
Microcosm Experiments Performed at 30°C



SEM Images of Microcosm-Incubated C1020 Carbon Steel Corrosion Products

"Honeycomb-like" particles composed of Fe, Si, and O_2

Rhombohedrons, and "honeycombs"

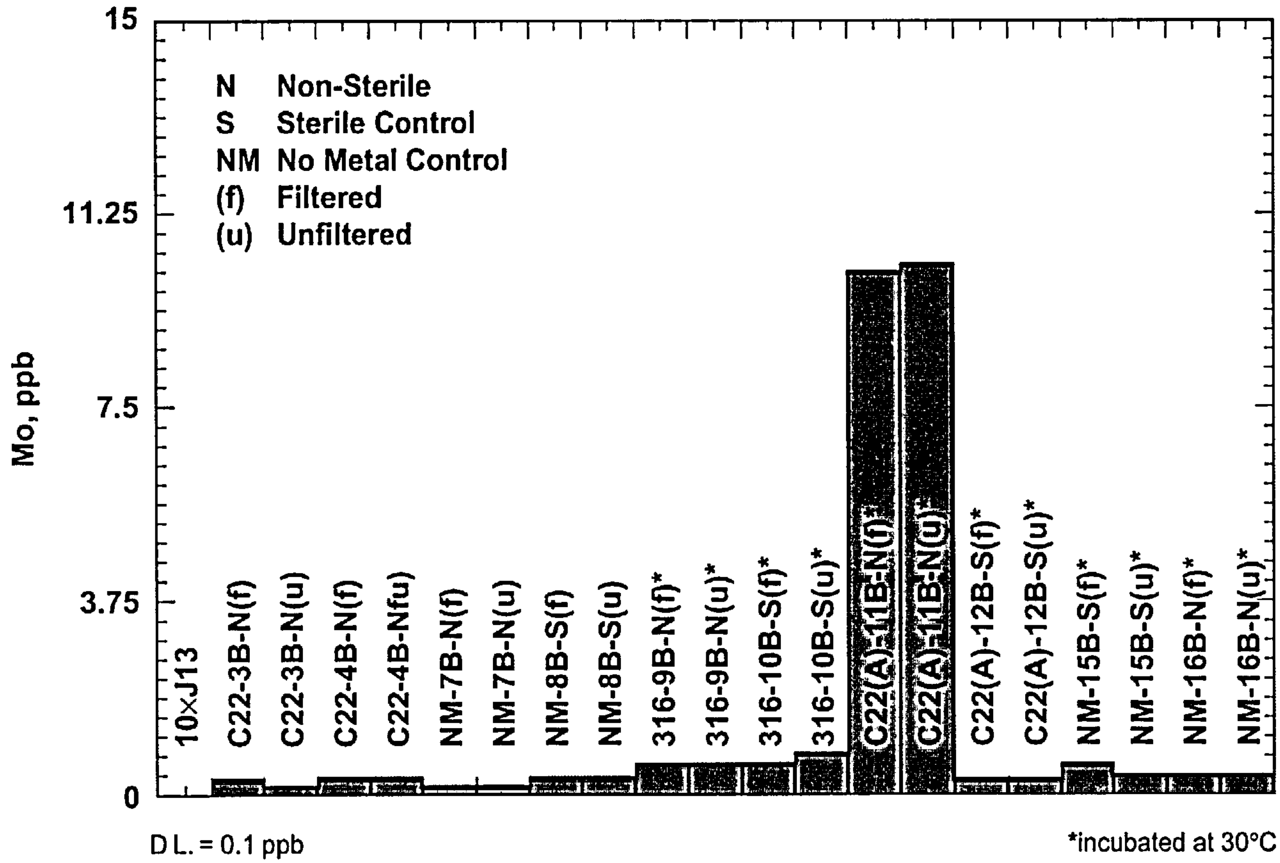


Cable-like bundles composed of Ca, Si, and O_2

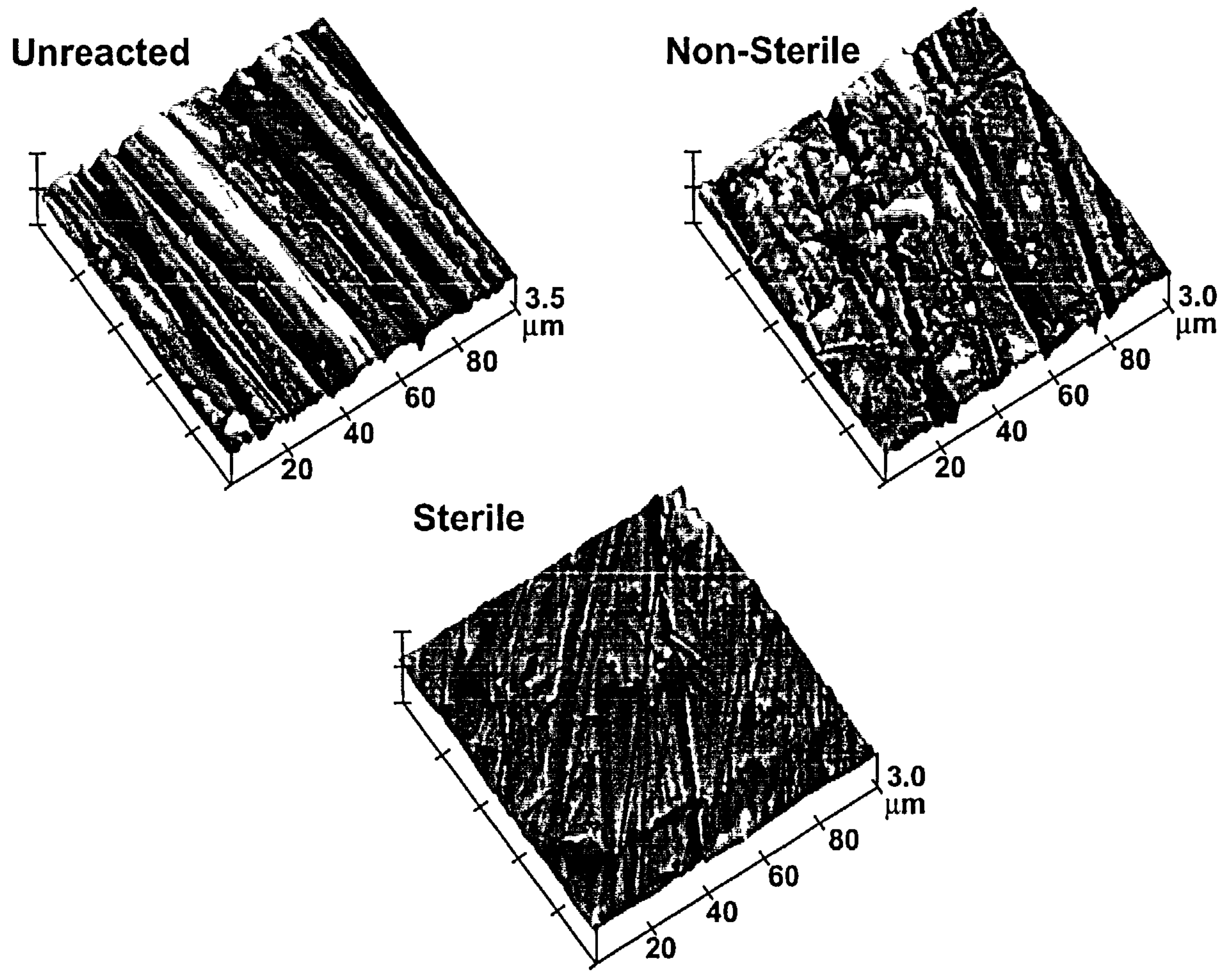
Solid-Phase Chemical Analyses of Corrosion Products from Microcosm-Exposed Carbon Steel

Gluteraldehyde-dried SEM	 EDS	N_2-dried *in situ* XRD	 Scraped XRD
Pyramidal-shaped	Fe, Mn	Cohenite (Fe_3C)	Substrate
Rhombohedrons	Ca, O	Calcite ($CaCO_3$)	Calcite
Honeycombs	Ca, Si, O	Greenalite ($Fe_3Si_2O_5(OH)_4$)	Greenalite
Cables	Si, O, Fe (Al)	–	–
–	–	Rancieite ($(Ca,Mn)Mn_4O_9 \cdot 3H_2O$)	–

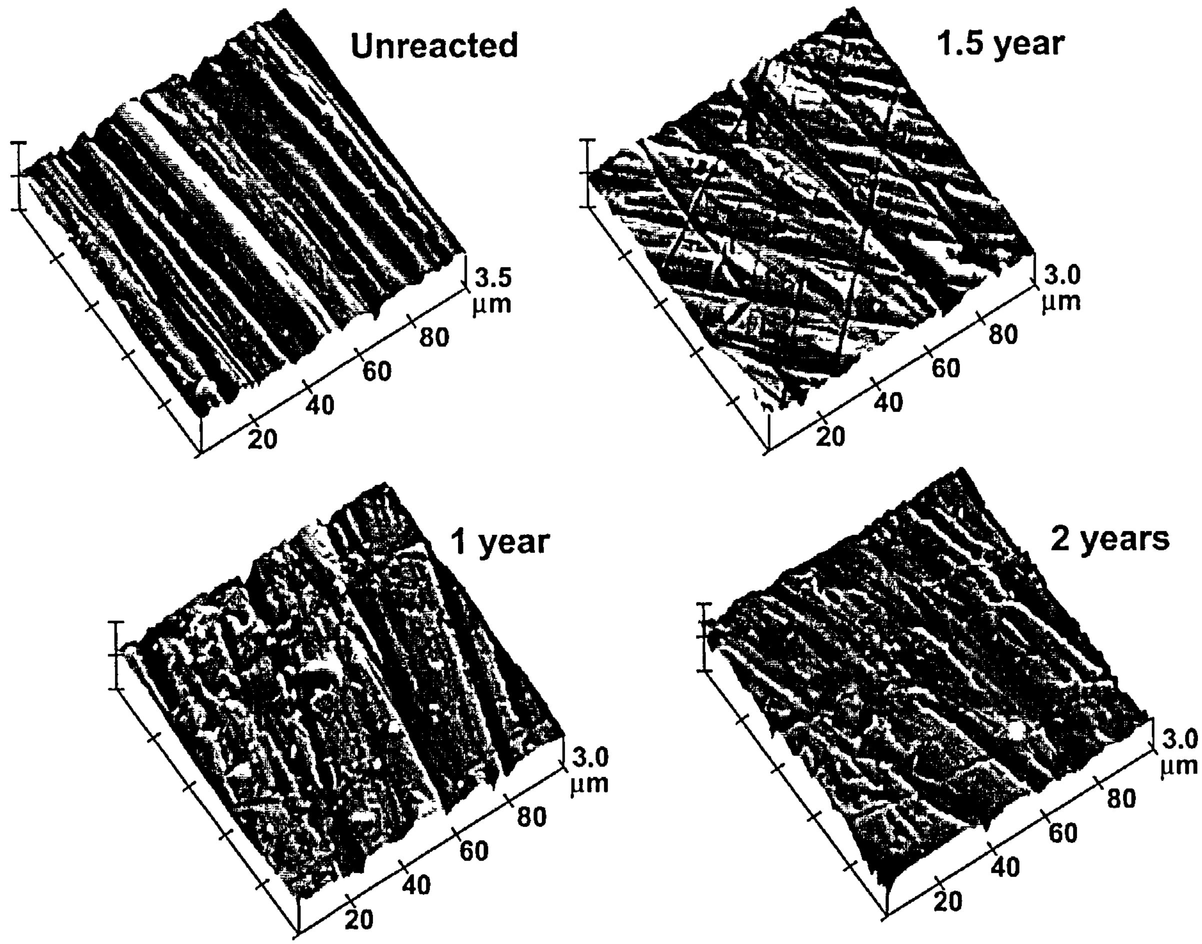
Elevated Soluble Molybdenum Concentration in Non-Sterile Microcosm Efflux at 30°C



AFM Images of Alloy 22 Incubated in Non-Sterile Microcosms Show More Accelerated Corrosion than those Exposed in Sterile Microcosms



AFM Images of Alloy 22 Incubated 2 Years in Non-Sterile Microcosms: Roughness Redistribution and Smoothing



Summary of Simulated Saturated Repository Microcosms

- System allows analysis of material effects in an environment that includes central elements of repository: rock, ground water, materials

- Effects of microorgansims can be discerned by comparison with abiotic, sterile controls, effects of rock tuff can be discerned by comparison with no-material controls

- Combined chemical analytical and imaging techniques allows quantification and speciation of corrosion products

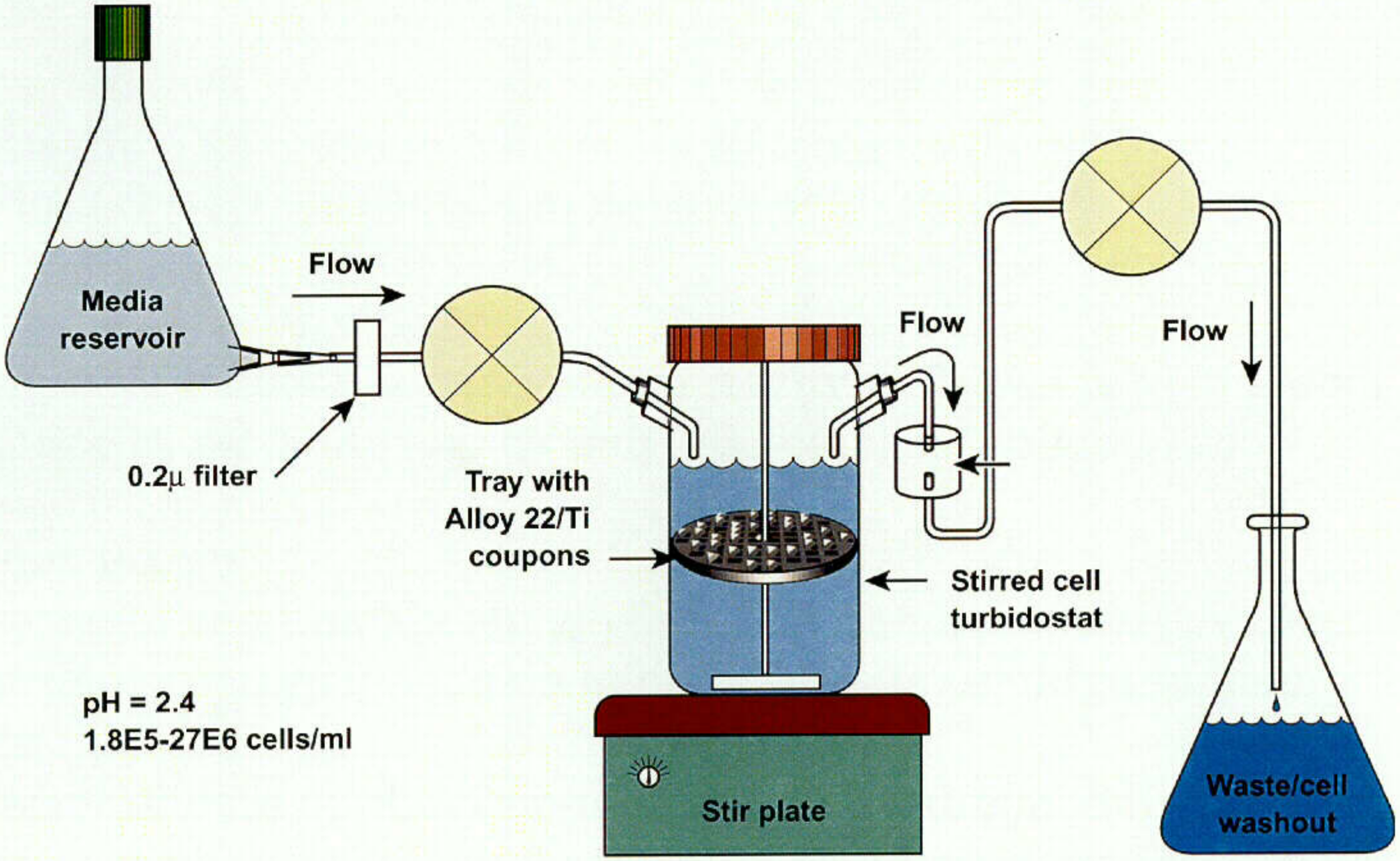
- Imaging and gravimetric analysis of materials permits estimation of corrosion rates/effects

- There appears to be some nano effects of microbial activity on Alloy 22 but quantification and distribution of corrosion needs to be analyzed with mirror finish coupons (in progress), then results can incorporated into corrosion models

Pure Culture Studies Analyze Materials Performance after Exposure to Most Likely Means of MIC Failure

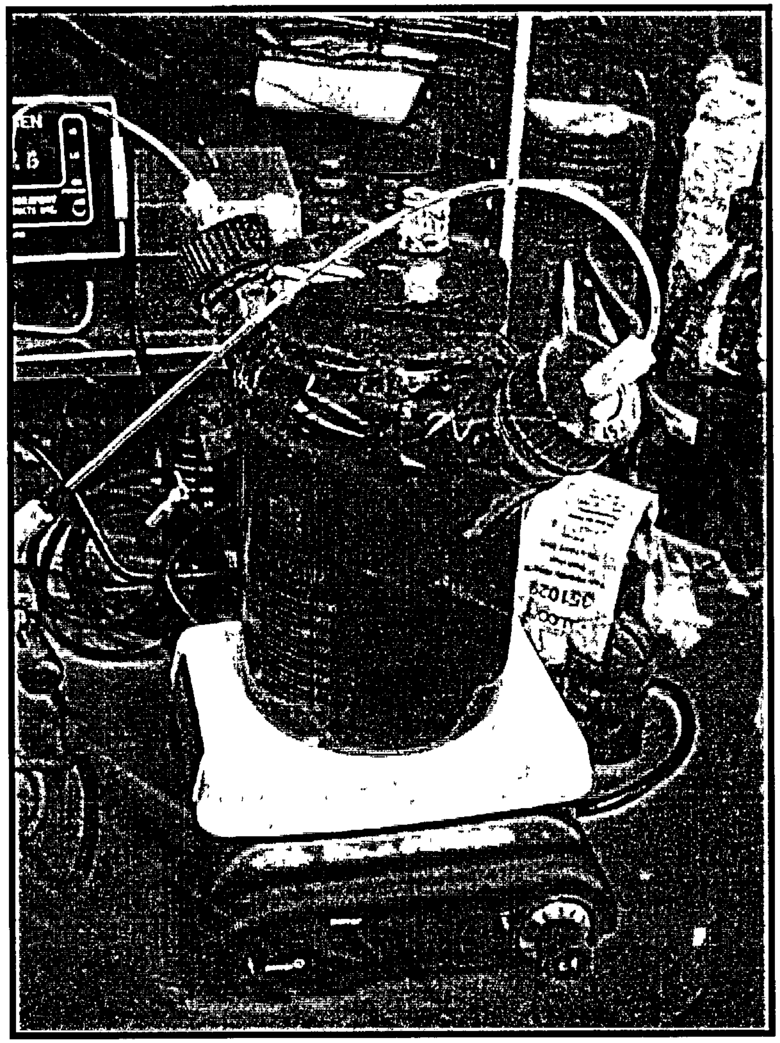
- Exposure under optimal growth conditions, continual feed. Also permits measurement of upper boundary of end-product generation.
  - Hydrogen embrittlement by a defined H_2-generating organism *Clostridium acetobutylicum* M5 grown in peptone, yeast extract, glucose media
  - Presence of biogenic sulfide and high chloride concentration *Desulfovibrio desulfuricans subsp. aestuarii* grown in SRB media without Fe(II), +2.5% NaCl
  - Low pH (<pH4.5), presence of mineral acid (sulfuric) *Thiobacillus ferrooxidans* grown in thiosulfate media (0.5%), oxidizes to sulfuric acid
  - Production of organic acids (e.g., oxalic) mixture of YM fungi grown in rich mycological broth

Configuration of Bioreactor/Stirred Cell used for Pure Culture Growth and Incubation



pH = 2.4
1.8E5-27E6 cells/ml

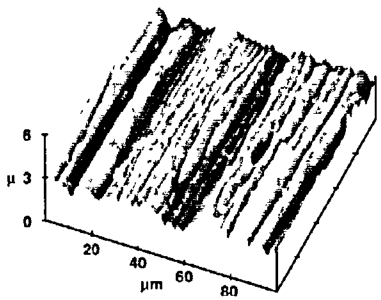
C. acetobutylicum Pure Culture Stirred Cell (contained in anaerobic glove box)

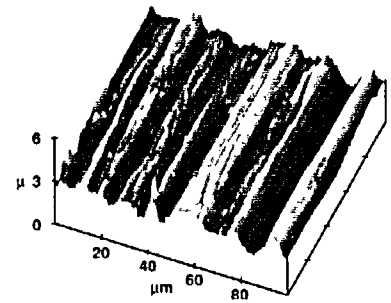


Biofilm Formation on Titanium gr7 Coupons after Incubation in Sulfate Reducing Bacterial Culture

Thiobacillus ferrooxidans Corrosion of Titanium after 7 Months Exposure to Continuous Culture Grown on Thiosulfate Medium

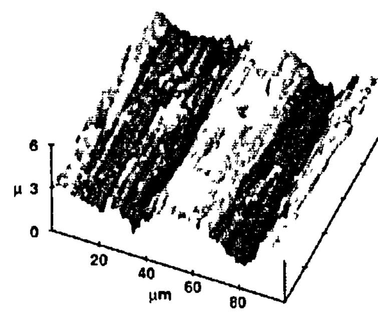
Unexposed





Sterile Control

Re-precipitated Ti was found on reactor surfaces



T. ferrooxidans - Exposed

Averaged Root Mean Square (RMS) Indices of AFM-Interrogated Material Coupons After Incubation with *T. ferrooxidans**

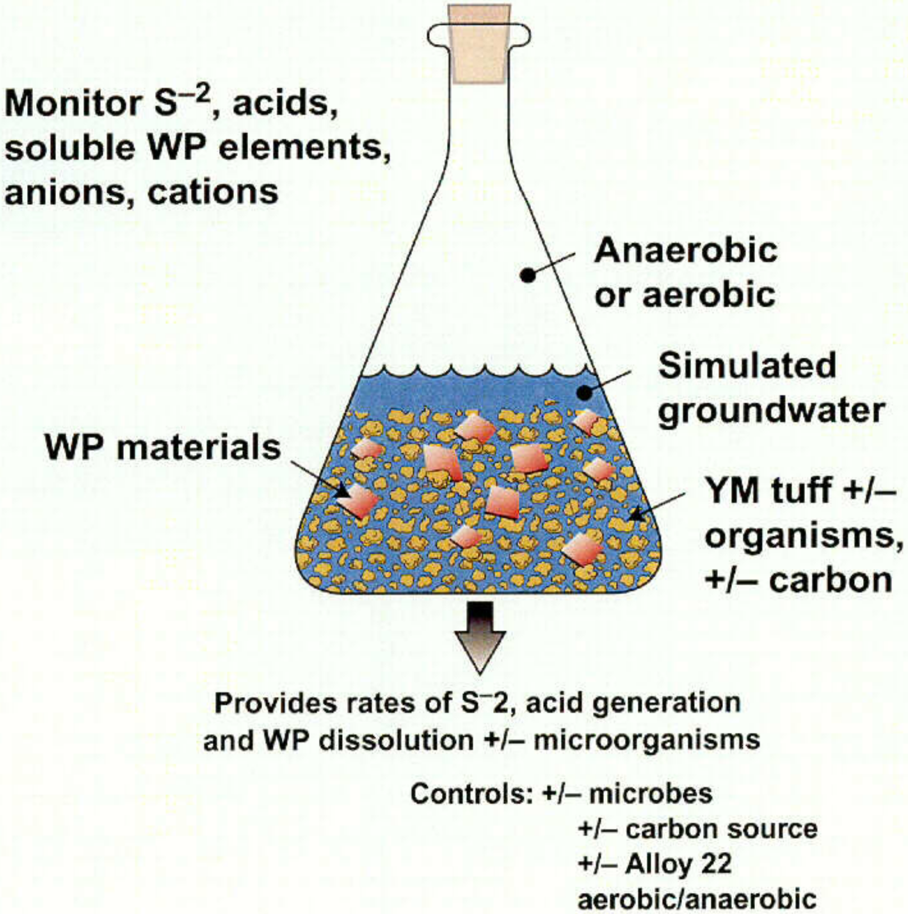
Material	Unexposed	Sterile/Media Only Exposed	*T. ferrooxidans* Exposed
Alloy 22	254	189	172
Ti gr7	361	409	519

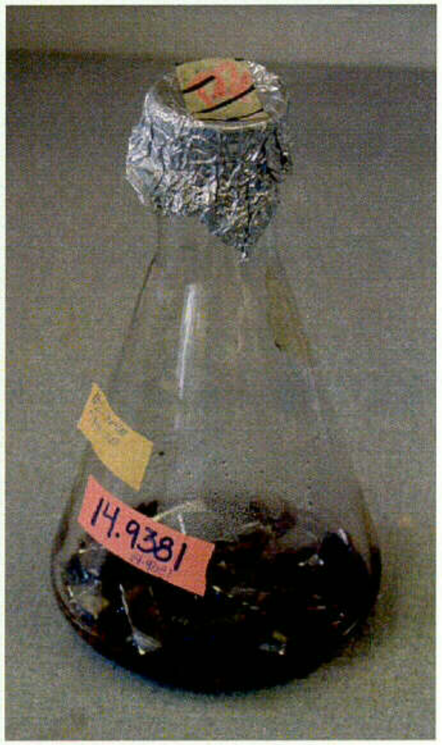
*RMS data were all collected on 100μm x 100μm area of coupon surface

Summary of Pure Culture Studies

- Analyzes the effects of specific deleterious metabolic products on material performance
- Permits determination of upper limits of generation of these end-products under optimal conditions for their production; upper boundaries can be incorporated into environmental models
- Despite the fact that there is a continual input/output into the system, a steady state is gained and some material components (e.g., Ti) have been detected
- Surfacial analysis of material coupons is ongoing

Batch Chemical Experiments to Determine Microbial Effects on Groundwater Composition and WP Material Degradation





Overall Summary of Microbiologically Influenced Corrosion (MIC) Studies to Date

- Potential for MIC to occur has been affirmatively determined
- Conditions for microbial growth established, when coupled with thermohydrological modeling, this establishes when MIC may become a factor for WP corrosion
- A roster of organisms extant at the YM site has been delineated, also organisms which may colonize the repository is being determined. Coupled with their associated metabolic activities this information allows what MIC activities may be relevant to WP corrosion
- Initial MIC factors determined, establishes overall contribution of microorganisms to WP corrosion. Further testing underway.
- Dissolution rates and corrosion modes of EBS materials are being determined
- Upper limits of deleterious bacterial end products and their effects on EBS materials are being established
- Effects on YM groundwater are currently under investigation

Integrated Issue Resolution Status Report

Advisory Committee on Nuclear Waste
137th Meeting
September 25, 2002

James Andersen
301-415-5717 - jwa@nrc.gov
Division of Waste Management
High-Level Waste Branch

Presentation Outline

- Integrated Issue Resolution Status Report (Integrated IRSR)
  - Purpose
  - Status and Structure of Integrated IRSR
  - Content
  - How it fits into the issue resolution process
  - Summary

2

Integrated IRSR - Purpose

- Provides background information on the status of NRC/DOE pre-licensing interactions
- Provides technical bases for the NRC staff's views presented at meetings
- Transitions from the Key Technical Issue (KTI) framework to the Yucca Mountain Review Plan (YMRP) framework

3

Integrated IRSR -Status

- Published in July 2002 as NUREG-1762
- Electronic version on NRC web site
- Hardcopies mailed to high-level waste distribution list

4

Integrated IRSR - Structure

- Follows the draft YMRP format
  - Uses same section headings
  - Sections broken down by acceptance criteria
- Report discusses Pre-Closure, Post-Closure, and several other areas outlined in the draft YMRP
- Some sections are not addressed since NRC/DOE interactions have not taken place or review of DOE documents has not been completed
- Cutoff date for technical information was October 2001

5

Integrated IRSR - Content

- Captures results of the first round of issue resolution meetings
- Incorporates 10 CFR Part 63 and the draft YMRP
- Discusses information the NRC staff will need to conduct a licensing review
- Does not include information from the Risk Insights Initiative

6

Integrated IRSR – Content Cont.

- Pre-Closure Safety
  - Discussion broken into 10 sections
  - Much of the discussion is based on NRC review of DOE documents
  - Only one Technical Exchange held to date
  - Additional NRC/DOE public meetings are needed

7

Integrated IRSR – Content Cont.

- Post-Closure Safety
  - Discussion broken into 4 areas:
    - Multiple Barriers
    - Features, Events, and Processes
    - Model Abstractions
    - Demonstration of Compliance

8

Integrated IRSR – Content Cont.

- Post-Closure Safety – Cont.
- Model Abstraction
  - Section divided into the 14 model abstractions
  - Sections identify which KTI subissues impact the model abstractions
  - Sections illustrate the overall relationship to the other model abstractions

9

Integrated IRSR – Content Cont.

- Post-Closure Safety – Cont.
- Model Abstraction – Cont.
  - Sections address the five acceptance criteria
  - KTI agreements which impact the model abstraction are identified

10

Integrated IRSR – Issue Resolution Process

- How the Integrated IRSR fits into the issue resolution process
  - Puts into writing the integration of the KTI subissues
  - Application of the YMRP to pre-licensing documents

11

Integrated IRSR – Issue Resolution Process – Cont.

- How the Integrated IRSR supports the review of the KTI agreements
  - Documents the technical bases and intent for the agreements
  - Provides stakeholders with background information on the agreements
  - Pre-closure area will assist in focusing discussions at future NRC/DOE public interactions

12

Summary

- The Integrated IRSR:
  - Provides an issue resolution status report as of October 2001
  - Documents the technical bases and intent for the agreements
  - Is an aid for transitioning from the KTI subissues to draft YMRP framework

13

- Backup Slides

14

Pre-Closure Safety Areas

- Site Description
- Description of Structures, Systems, Components, Equipment, and Operational Process
- Identification of Hazards and Initiating Events
- Identification of Event Sequences
- Consequence Analyses
- Identification of Structures, Systems, and Components Important to Safety; Safety Controls; and Measures to Ensure Availability of the Safety Systems

15

Pre-Closure Safety Areas – Cont.

- Design of Structures, Systems, and Components Important to Safety and Safety Controls
- Meeting the 10 CFR Part 20 as Low as is Reasonably Achievable Requirements for Normal Operations and Category 1 Event Sequences
- Plans for Retrieval and Alternate Storage or Radioactive Waste
- Plans for Permanent Closure and Decontamination, or Decontamination and Dismantlement of Surface Facilities

16

Model Abstractions

- Degradation of Engineered Barriers
- Mechanical Disruption of Engineered Barriers
- Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms
- Radionuclide Release Rates and Solubility Limits
- Climate and Infiltration
- Flow Paths in the Unsaturated Zone
- Radionuclide Transport in the Unsaturated Zone

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Model Abstractions- Cont.

- Flow Paths in the Saturated Zone
- Radionuclide Transport in the Saturated Zone
- Volcanic Disruption of Waste Packages
- Airborne Transport of Radionuclides
- Representative Volume
- Redistribution of Radionuclides in Soil
- Biosphere Characteristics

18

Key Technical Issue - Issue Resolution Status

Advisory Committee on Nuclear Waste
137th Meeting
September 25, 2002

James Andersen
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Division of Waste Management
High-Level Waste Branch

Presentation Outline

- Status of Key Technical Issue (KTI) Agreements
- FY02 Issue Resolution Activities
  - DOE KTI Item Planning Strategy
  - NRC Risk Insights Initiative
  - Integrated Issue Resolution Status Report
- FY03 – FY05 Issue Resolution Activities
  - DOE FY03 – FY05 Plan
  - NRC Staff Concerns
  - FY03-05 Path Forward
- Summary

2

Status of KTI Agreements

- Technical exchanges with DOE have resulted in 293 NRC/DOE agreements
- The agreements cover all nine KTIs and Pre-Closure
- Two Pre-Closure meetings have been conducted, additional meetings are needed

3

Status of KTI Agreements

- As of September 18, 2002, 61 of the agreements are complete
  - Complete meaning the NRC staff has no further questions at this time, not that a licensing decision has been made
- Of the remaining 232 agreements:
  - 33 are under NRC review
  - 199 have not been fully addressed by DOE

4

FY 2002 Issue Resolution Activities

- DOE FY02 Schedule and Binning of Agreements
- NRC Risk Insights Review
- Integrated Issue Resolution Status Report

5

FY2002 Issue Resolution Activities – Cont.

- April 2002 Technical Exchange
  - Discussed the DOE KTI Agreement Planning Strategy
  - DOE discussed the agreements it planned to address in FY02
  - Discussed specific agreements

6

FY2002 Issue Resolution Activities – Cont.

- DOE Binning of Agreements
  - Bin 1 – Literal agreement scope to be accomplished
  - Bin 2 – Revised agreement scope – will achieve the original intent
  - Bin 3 – Risk-informed, performance-based basis to support resolution of the agreement
  - Bin 4 - Other

7

FY2002 Issue Resolution Activities – Cont.

- DOE Schedule for FY 2002 Agreements
  - 61 agreements were discussed at the April 2002 meeting
  - Most have been delivered on time
- Status of NRC Review of the 61 Agreements
  - 30 under review
  - 13 complete
  - 4 need additional information
  - 9 remain to be submitted
  - 5 other

8

FY2002 Issue Resolution Activities – Cont.

- NRC Risk Insights Initiative
  - Document existing risk information and tie the information to KTI resolution
  - Enhance communication of risk information
  - Incorporate risk information into the agreement/issue resolution process
  - Identify additional risk information necessary to support issue resolution

9

FY2002 Issue Resolution Activities – Cont.

- Summary of Preliminary Results
  - All the agreements are not alike
  - 16 agreements NRC rated as high
    - 8 are complex, may require large effort
    - 5 are less complex, may require moderate effort
  - 25 agreements NRC rated as medium-high
    - 4 are complex, may require large effort
    - 12 are less complex, may require moderate effort

10

FY2002 Issue Resolution Activities – Cont.

- Implementing the Preliminary Results
  - NRC staff is documenting existing risk information
  - NRC staff plans to focus more attention on issues considered more risk significant from preliminary results
  - NRC staff will continue to enhance its understanding of the risk significance of issues

11

FY2002 Issue Resolution Activities – Cont.

- Integrated Issue Resolution Status Report
  - Issued July 2002
  - Provides a status report on the issue resolution process
  - Documents the technical bases and intent for the agreements
  - Is an aid for transitioning from the KTI to Yucca Mountain Review Plan framework

12

FY2003-2005 Issue Resolution Activities

- July 2002 Technical Exchange
  - DOE Preliminary FY03-05 Plan
  - DOE Binning of Remaining Agreements
  - NRC Staff Concerns
  - FY03-05 Path Forward

13

FY2003-2005 Issue Resolution Activities – Cont.

- DOE FY03-05 Schedule and Binning of Agreements
- Schedule
  - 60 in FY03
  - 92 in FY04
  - 13 in FY05
- Binning
  - 54 in Bin 1
  - 63 in Bin 2
  - 45 in Bin 3
  - 03 in Bin 4

14

FY2003-2005 Issue Resolution Activities – Cont.

- NRC Staff Concerns
  - Based on the NRC risk initiative, 41 agreements were determined to be high or medium-high
  - Some of 41 agreements were listed as Bin 3 by DOE
  - DOE schedule had some agreements being addressed two months prior to the license application target date
  - Some agreements listed as Bin 3 by DOE relate to uncertainty issues

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FY2003-2005 Issue Resolution Activities – Cont.

- FY03-05 Path Forward
  - Need final DOE plan
  - Have calls on all agreements
  - Increased discussion on Bin 3 items
- Next phase of NRC Risk Insights Review
  - Incorporate information into issue resolution process

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Summary

- The issue resolution process is progressing
- NRC staff is actively monitoring the agreements
- NRC/DOE need to continue discussions on agreements
- NRC staff will continue to refine use of risk-information

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Backup Slides

18

Key Technical Issue Definitions

- **Unsaturated and Saturated Zone Flow Under Isothermal Conditions** – How does water move above and below a potential repository at Yucca Mountain?
- **Thermal Effects on Flow** – How does temperature affect the timing and mechanisms whereby water reaches the waste containers?
- **Container Life and Source Term** – How long do we expect the containers and waste forms to last and what will happen to the waste as the containers and waste forms degrade over time?
- **Evolution of the Near Field Environment** – How do water and heat affect the chemical environment of the containers, waste forms and the immediate area around the repository?
- **Radionuclide Transport** – How do radionuclides released from degraded waste move away from the repository?

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Key Technical Issue Definitions – Cont.

- **Repository Design and Thermal Mechanical Effects** – How do engineering design, construction, and operation of a repository affect short- and long-term repository safety?
- **Structural Deformation and Seismicity** – How do the physical characteristics of the rock in the repository and the likelihood of earthquakes affect repository safety?
- **Igneous Activity** – How likely is it that volcanic eruptions or intrusion will disrupt the repository and what would be the potential consequences to people and the environment?
- **Total System Performance Assessment and Integration** – How can we best describe how well the entire system of engineered and natural barriers will work together to retain waste, so we can decide whether DOE's proposed repository at Yucca Mountain will comply with safety and environmental standards?
- **Activities Related to Development of the U.S. Environmental Protection Agency Yucca Mountain Standard**

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Issue Resolution Terminology

- Closed – Issues are designated as closed if the DOE approach and available information acceptably address NRC staff questions such that no information beyond what is currently available will likely be required for regulatory decision making at the time of initial license application
- Closed-Pending – Issues are designated as closed-pending if the NRC staff has confidence that DOE's proposed approach, together with DOE's agreements to provide the NRC with additional information (through specified testing, analysis, etc.) acceptably address the NRC's questions such that no information beyond that provided, or agreed to, will likely be required at the time of initial license application.
- Open - Issues are designated as open if the NRC staff has identified questions regarding the DOE approach or information, and the DOE has not yet acceptably addressed the questions or agreed to provide the necessary additional information in the license application.

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Status of KTI Subissues

KTI	Subissue 1	Subissue 2	Subissue 3	Subissue 4	Subissue 5	Subissue 6
USFIC	Closed	Closed	Closed-Pending	Closed-Pending	Closed-Pending	Closed-Pending
IA	Closed-Pending	Closed Pending	N/A	N/A	N/A	N/A
CLST	Closed-Pending	Closed-Pending	Closed-Pending	Closed	Closed-Pending	Closed-Pending
SDS	Closed-Pending	Closed-Pending	Closed-Pending	Closed	N/A	N/A
RT	Closed-Pending	Closed-Pending	Closed-Pending	Closed-Pending	N/A	N/A
TEF	Closed-Pending	Closed-Pending	N/A	N/A	N/A	N/A
ENFE	Closed-Pending	Closed-Pending	Closed-Pending	Closed-Pending	Closed-Pending	N/A
RDTME	Closed	Closed-Pending	Closed-Pending	Closed	N/A	N/A
TSPAI	Closed-Pending	Closed Pending	Closed-Pending	Closed-Pending	N/A	N/A

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Status of KTI Agreements

- KTI Agreement Tracking Categories

  1) Not Received - NRC has not received any information pertaining to the agreement

  2) Partly Received - NRC has received some of the information pertaining to the agreement

  3) Received - NRC has received all the information pertaining to the agreement and the material is under consideration

  4) Complete - NRC has reviewed the information and the issue is resolved

  5) Need Additional Information - NRC has reviewed the information and needs additional information

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Status of KTI Agreements – Cont.

KTI Title	Agreements Reached	Documentation Received for Agreement	Documentation Partly Received for Agreement	Documentation Not Received for Agreement	Need Additional Information	Agreement Complete
USFIC	27	6	1	14	0	6
IA	22	4	0	8	0	10
CLST	58	6	3	25	8	16
SDS	10	2	2	0	2	4
RT	29	3	2	17	4	3
ENFE	41	1	7	19	2	12
TEF	15	0	3	5	1	6
RDTME	23	1	2	20	0	0
TSPAI	58	9	0	44	2	3
General	1	0	0	1	0	0
Pre-Closure	9	1	0	6	1	1
Totals	293	33	20	159	20	61

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Summary of Preliminary Risk Initiative Results

	High Importance (16)	Medium-High Importance (25)
Complex, Large Effort	**Container Life and Source Term** Chemical environment of drip shield and waste package, stability of passive oxide film on waste package, and corrosion rates of welded and non-welded samples (CLST 1 01, 1 08, 1 10, 1 15) **Near Field Environment** Data used in calibrations and assessment of model uncertainties (ENFE 2 17) **Igneous Activity** Air and water remobilization of volcanic ash, magma and repository interaction, and magma interaction with waste package (IA 2 17, 2 18, 2 19)	**Container Life and Source Term** Long term corrosion testing, and mitigation of stress corrosion cracking (CLST 1 04, 1 12) **Igneous Activity** Incorporation of waste into magma (IA 2 20) **Unsaturated and Saturated Zone Flow Under Isothermal Conditions** Model support for seepage (Alcove and Niche tests) (USFIC 4 01)
Less Complex, Less Effort	**Container Life and Source Term** Fabrication and phase instability of Alloy-22, and aging of Alloy-22 and extrapolation to repository conditions (CLST 2 04, 2 05) **Near Field Environment** Bounding chemical environment for waste package (trace elements and fluoride), and data and model uncertainties of geochemical models (ENFE 2 04, 2 05) **Total System Performance Assessment** Propagation of uncertainty in waste package and drip shield performance (TSPAI 3 01)	**Near Field Environment** (ENFE 2 06, 2 15) **Pre-closure** (PRE 7 02, 7 03, 7 04, 7 05) **Repository Design and Thermal Mechanical Effects** (RDTME 3 19) **Radionuclide Transport** (RT 2 06) **Thermal Effects on Flow** (TEF 2 05, 2 08) **Total System Performance Assessment** (TSPAI 3 10, 3.23)
Low Effort	CLST 1 09, ENFE 1 05, TSPAI 3 12	CLST 1 06, PRE 3 01, RDTME 3 17, RT 3 10, TEF 2 01, TSPAI 3 38, USFIC 4 04, 5 04, 6 03

25

Framework for Staff Analyses to Support Pre-Licensing Interactions and Issue Resolution

Presented to the
Advisory Committee on Nuclear Waste
September 25 , 2002
Las Vegas, Nevada

Tim McCartin 301-415-7285 tjm3@nrc.gov
Division of Waste Management
U S Nuclear Regulatory Commission

Outline

- Background
- Framework
- Example Calculation
- Summary

2

Background

- Staff conduct wide range of analyses
  - understand repository system behavior
  - evaluate factors affecting timing and magnitude of dose
  - assess effects of key assumptions and parameters

- Staff analyses reported via:
  - NUREG publications
  - ACNW presentations
  - conference proceedings

- Staff use these and future analyses to support pre-licensing interactions, including issue resolution process, as well as the risk insight initiative

3

Framework

- Variety of analyses are useful for
  - understanding repository behavior including barriers
  - examining risk significance of parameters and models
  - considering uncertainties

- Framework for staff analyses
  - comprehensive treatment of issues
  - appropriate context of analyses
  - improved communication of risk analyses

4

Analysis Types

- Overall performance of repository system
- Capabilities of engineered and natural barriers
- Effect of uncertainty in parameters and models
- Effect of potential limitations in technical basis

5

Capabilities of Engineered and Natural Barriers

- Evaluation of each barrier's capability, as represented in the performance assessment

Regulatory Context

- Repository to be comprised of engineered and natural barriers [63.113(a)]
- Description of each barrier's capability [63.115]
- Barrier defined as material, structure, or feature that substantially reduces flow of water or radionuclides, or release rate from the waste [63.2]

6

Capabilities of Engineered and Natural Barriers (cont.)

Rationale for Analysis

- Provides independent evaluation of DOE's description of barrier capabilities
- Assists interpretation of performance assessment results
- Identifies significant barriers to focus regulatory review and ensure technical basis is consistent with importance to safety

Release from Waste Package (years)

% = contribution of each radionuclide to total inventory of SNF

Barrier	Tc 99 0.7%	I 129 0.002%	Np 237 0 06%	Am 241 54%	Pu 240 25%	Pu 239 18%	U 238 0 02%
Waste Package (mean value)	50,000	50,000	50,000	50,000	50,000	50,000	50,000

Release from Single Waste Package (years)

[number of years to lead to a cumulative dose of 15 mrem from the specific barrier only – not an annual dose]

Barriers	Tc 99 0 7%	I 129 0 002%	Np 237 0 06%	Am 241 54%	Pu 240 25%	Pu 239 18%	U 238 0 02%
Release Rate (10^{-4} per year)	3,500	8,000	10	1	1	1	1,000
Solubility Limit (10 liters/yr or 1 mm/yr/1WP	1	1	100	5	100	300	>100K

9

Release from Geologic Units (years)

[Time for initial release into barrier to be released from barrier]

Barriers	Tc 99 0 7%	I 129 0 002%	Np 237 0 06%	Am 241 54%	Pu 240 25%	Pu 239 18%	U 238 0.02%
UZ total (CHnv, CHnz, & invert)	200	200	400	400	400	400	400
UZ (CHnv only)	400	400	20,000	>100K	>100K	>100K	10,000
SZ Rock	400	400	1,000	>100K	5,000	5,000	1,000
SZ Alluvium	200	200	20,000	>100K	>100K	>100K	50,000

10

Summary

- Flexibility in selection of analysis method (and use of diverse methods) necessary because of system complexity, long time frame, and uncertainties
- Each analysis provides specific information and/or answers a specific question
- Development of a framework ensures staff analyses are appropriately defined in terms of intended purpose and application of results

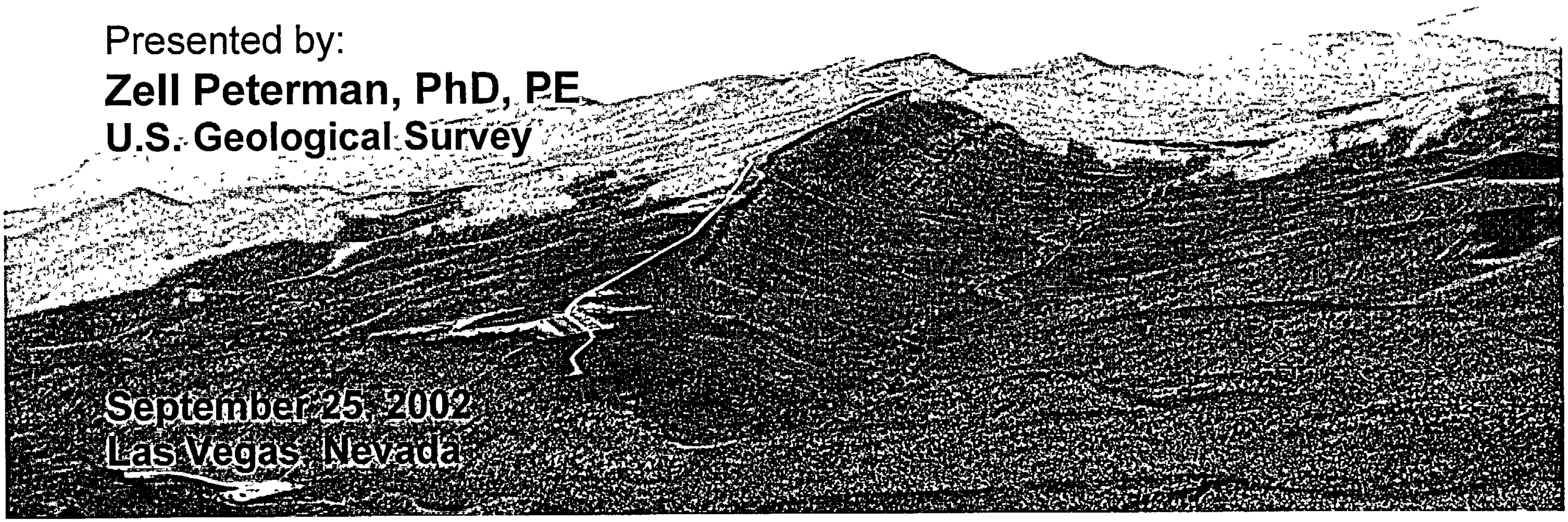
U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Current Status of ^{36}Cl Validation

Presented to:
Advisory Committee on Nuclear Waste

Presented by:
Zell Peterman, PhD, PE
U.S. Geological Survey



September 25, 2002
Las Vegas, Nevada

History of Project

- Early Fiscal Year 1996—Exploratory Studies Facility ^{36}Cl and fracture mineral studies were started
- Objective was to test the effect of the Paintbrush nonwelded unit (PTn) on percolation through Topopah Spring welded unit (TSw) (tin-roof concept)
- Los Alamos National Laboratory and U.S. Geological Survey coordinated their sample collections
- Sampling followed Tunnel Boring Machine through the Exploratory Studies Facility

History of Project
(Continued)

- Early results including bomb-pulse ^{36}Cl hits discussed at meeting in Denver
- General agreement that validation was needed including ^{3}H, ^{99}Tc, and ^{129}I
- Early attempt (Flint et al.) to determine tritium in tunnel-wall samples failed

History of Project
(Continued)

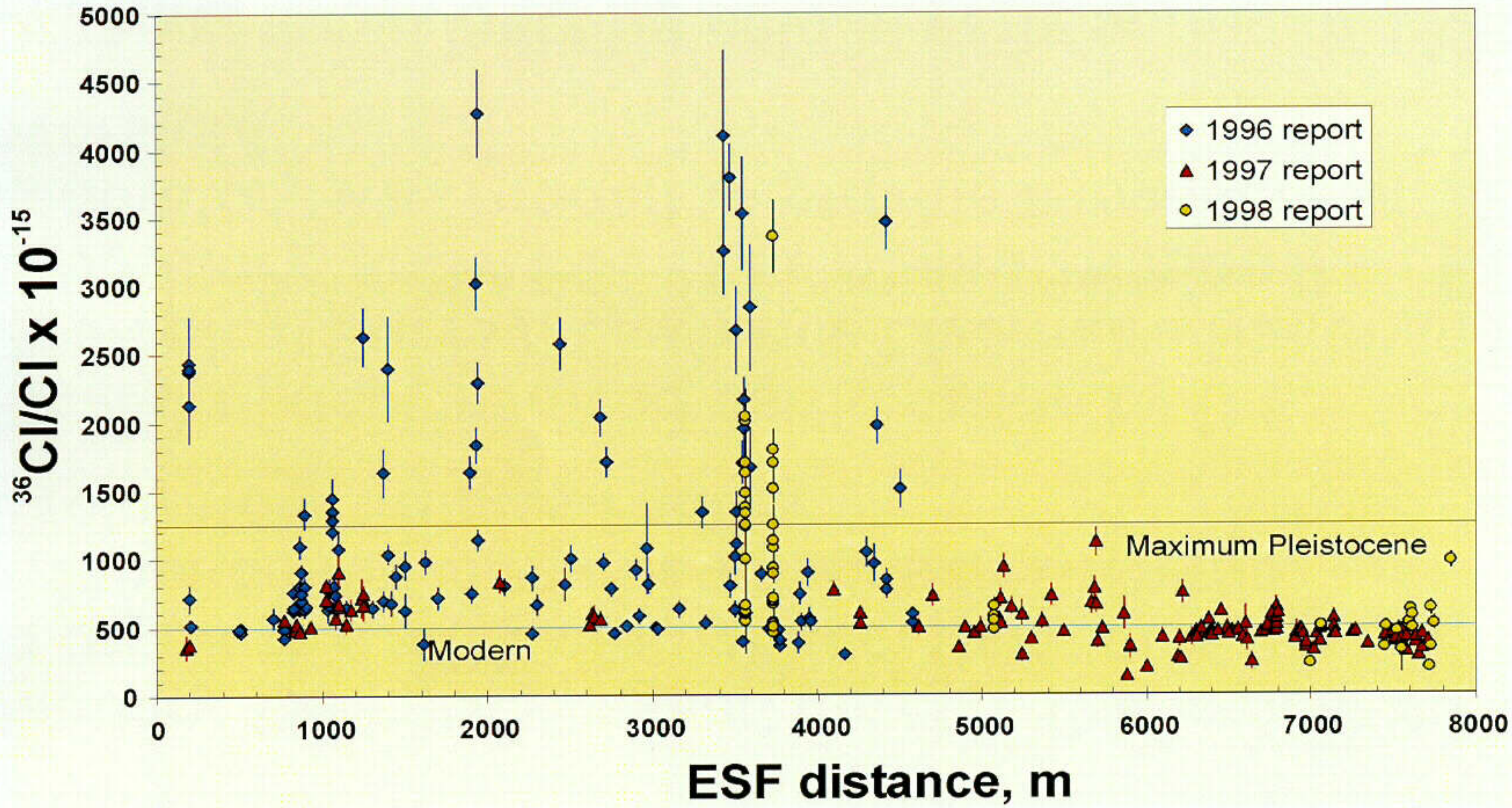
- ^{36}Cl and fracture mineral sampling and analyses continued through the Exploratory Studies Facility and into the Enhanced Characterization of the Repository Block
- Analyses of other bomb-pulse isotopes was not emphasized except for ^{99}Tc at two localities
- Dating of outermost opal and calcite produced ages from tens of thousands to >500,000 years
  - No differences in fracture mineral ages from within or outside of zones containing bomb pulse ^{36}Cl

History of Project

(Continued)

- January 1999: DOE asked the U.S. Geological Survey to organize a validation project that could independently verify bomb pulse ^{36}Cl in the Exploratory Studies Facility
- Final proposal involved participation by U.S. Geological Survey, Lawrence Livermore National Laboratory, and AECL. Los Alamos National Laboratory was funded to provide a measure of oversight
- Organizational meeting held in early spring of 1999

Los Alamos National Laboratory ^{36}Cl Data for the ESF



C12

History of Project
(Continued)

- U.S. Geological Survey designed a sampling protocol
  - Selected Sundance and Drill Hole Wash ^{36}Cl anomalies as focus of validation study
  - U.S. Geological Survey examined all Los Alamos National Laboratory sample sites within these anomalies
  - U.S. Geological Survey examined U.S. Bureau of Reclamation full periphery maps to assess fracture occurrences and spacing
  - Because of the unknown history of tunnel-wall washdowns since initial Los Alamos National Laboratory collections, U.S. Geological Survey decided not to collect samples from tunnel walls

History of Project
(Continued)

- U.S. Geological Survey designed sampling protocol (Continued)
  - Sampling consisted of 50 4-m-long boreholes on 5-m centers
    - 40 within and adjacent to Sundance anomaly
    - 10 within and adjacent to Drill Hole Wash anomaly
  - Advantages of drill sampling included
    - Elimination of construction water and dryout effects
    - Deeper intervals could be used for water extraction for tritium analyses (an independent bomb pulse verification)

History of Project

(Continued)

- Project was delayed because of
  - Safety stand down (several months)
  - Development of Quality Assurance procedures at Lawrence Livermore National Laboratory
- Validation core was subsampled for ^{36}Cl (to Lawrence Livermore National Laboratory), tritium (to Denver), and Uranium isotopes (to AECL)
  - Lawrence Livermore National Laboratory used an active leach method (7 hrs in a slowly rotating tumbler) versus Los Alamos National Laboratory passive leach method (24 to 48 hours)

History of Project
(Continued)

- First ^{36}Cl results presented by Lawrence Livermore National Laboratory at Spring Nuclear Waste Technical Review Board meeting in Pahrump (May 1, 2000)
  - Lawrence Livermore National Laboratory $^{36}Cl/Cl$ ratios were smaller than Los Alamos National Laboratory values and Cl concentrations were larger
  - Los Alamos National Laboratory completed analyses of a few validation core and results were within their normal background range

History of Project
(Continued)

- Concern was expressed that Lawrence Livermore National Laboratory dynamic leaching may have been too aggressive, thus releasing a large proportion of rock Cl
- Participants agreed that a test sample was needed for experimental leaching
- U.S. Geological Survey was charged with preparation and distribution of test sample

History of Project
(Continued)

- June 16, 2000, Nuclear Waste Technical Review Board wrote letter to OCRWM Director urging quick resolution to disagreement
- Path forward July 12, 2000 (Peterman, Caffee, and Fabryka-Martin)
  - Large muck sample obtained from Enhanced Characterization of the Repository Block Niche 5 (EVAL-1)
  - Crushed and sized (1/2 to 1/4 inch) in Denver
  - Aliquots sent to Lawrence Livermore National Laboratory and Los Alamos National Laboratory

History of Project
(Continued)

- **Path forward** (Continued)
  - Los Alamos National Laboratory and Lawrence Livermore National Laboratory conducted leaching experiments to determine optimum method of minimizing rock component and maximizing meteoric component
- **Preliminary results were discussed by participants and interested observers at the Geological Society of America meeting in Reno, November, 2000**

History of Project

(Continued)

- Two subsequent meetings were held in Las Vegas in the first half of 2001 to discuss results of leaching experiments
- Both Los Alamos National Laboratory and Lawrence Livermore National Laboratory results indicated that passive leaching for no more than one hour was desirable

History of Project
(Continued)

- **Path forward developed using accepted leaching protocol**
  - U.S. Geological Survey selected additional intervals from ^{36}Cl validation core
  - Crushing was done by the Sample Management Facility to maximize1/2-1/4 inch size range [crusher had only seen Topopah Spring welded unit (TSw)]
  - U.S. Geological Survey leached samples and distributed aliquots to Los Alamos National Laboratory and Lawrence Livermore National Laboratory

History of Project
(Continued)

- Los Alamos National Laboratory spiked samples with enriched ^{35}Cl spike, precipitated AgCl, and sent to Lawrence Livermore National Laboratory for analyses accelerated mass spectroscopy
- Lawrence Livermore National Laboratory spiked samples with enriched ^{37}Cl spike, precipitated AgCl, and analyzed by accelerated mass spectroscopy
- Results generally agreed with $^{36}Cl/Cl$ ratios between 200E-15 and 500E-15

Fiscal Year 2002
Path Forward

- **Status and path forward meeting in Denver on January 16, 2002**
  - Further work was to focus on Niche#1 core (no bomb pulse ^{36}Cl found on walls of niche but found in core)
  - Remaining Niche#1 core was not in Sample Management Facility —some located at hydrologic research facility and some at Los Alamos National Laboratory
  - Representative Niche#1 core transferred to U.S. Geological Survey

Fiscal Year 2002 Path Forward

(Continued)

- Leachates, following jointly accepted protocol, were prepared independently at Los Alamos National Laboratory and U.S. Geological Survey
- Los Alamos National Laboratory: $^{36}Cl/Cl$ 1140E-15 to 8580E-15
  - [Cl] 0.13 to 0.67 mg/kg
- U.S. Geological Survey: $^{36}Cl/Cl$ 244E-15 to 708E-15
  - [Cl] 0.17 to 0.26 mg/kg
- Both U.S. Geological Survey and Los Alamos National Laboratory leach blanks okay

Fiscal Year 2002 Path Forward

(Continued)

- U.S. Geological Survey
  - Conducted crushing blank using 99.9999% pure silicon (computer-chip Si)
  - Blanks were 0.01 and 0.03 mg/L of Cl
    - Crushing does not contribute significant Cl
  - Leached an aliquot of crushed Niche#1 core prepared by Los Alamos National Lab
    - $^{36}Cl/Cl$ value of 1130E-15 confirmed previous LANL value

Summary of ^{36}Cl/Cl

- "Bomb pulse" (^{36}Cl/Cl >1,250) observed in old Los Alamos National Laboratory data (samples from both Exploratory Studies Facility walls and drill core from Niche #1)
- "Bomb pulse" observed in recent Los Alamos National Laboratory data from Niche #1 core (randomly picked 6 samples, ^{36}Cl/Cl up to 8,500)
- No "bomb pulse" in old Los Alamos National Laboratory ^{36}Cl-validation drill core data (Nuclear Waste Technical Review Board meeting, May 2000)

Summary of $^{36}Cl/Cl$

(Continued)

- Lowest $^{36}Cl/Cl$ values are in Lawrence Livermore National Laboratory data for active leaches of ^{36}Cl-validation core (enriched in rock "dead" chloride)
- No "bomb pulse" in both U.S. Geological Survey/Lawrence Livermore National Laboratory and U.S. Geological Survey/Los Alamos National Laboratory/ Lawrence Livermore National Laboratory ^{36}Cl-validation core data
- No "bomb pulse" in recent U.S. Geological Survey/ Lawrence Livermore National Laboratory data from Niche #1 drill core (randomly picked 6 samples)

FY03 Path Forward

- Complete joint report on the status of the ^{36}Cl validation project (due December 2002)
- Establish a path forward as part of the report
- The Project may bring in one or more outside experts to review report and planned path forward

Backup

Current Status of ^{36}Cl Validation

Sampling and Analytical Techniques

Los Alamos National Laboratory/Purdue (old data)

- Sampling rocks mainly from the walls of the Exploratory Studies Facility (few drill core samples from niches)
- Mechanical crushing equipment at Los Alamos National Laboratory was found to be contaminated with ^{36}Cl
- Procedure changed to hammer and steel plate
- Passive leaching for ~ 48 hours
- Spiking and precipitation as AgCl
- Accelerated mass spectroscopy analyses at Purdue University

Sampling and Analytical Techniques
(Continued)

Los Alamos National Laboratory/Lawrence Livermore National Laboratory ^{36}Cl validation study (new data)

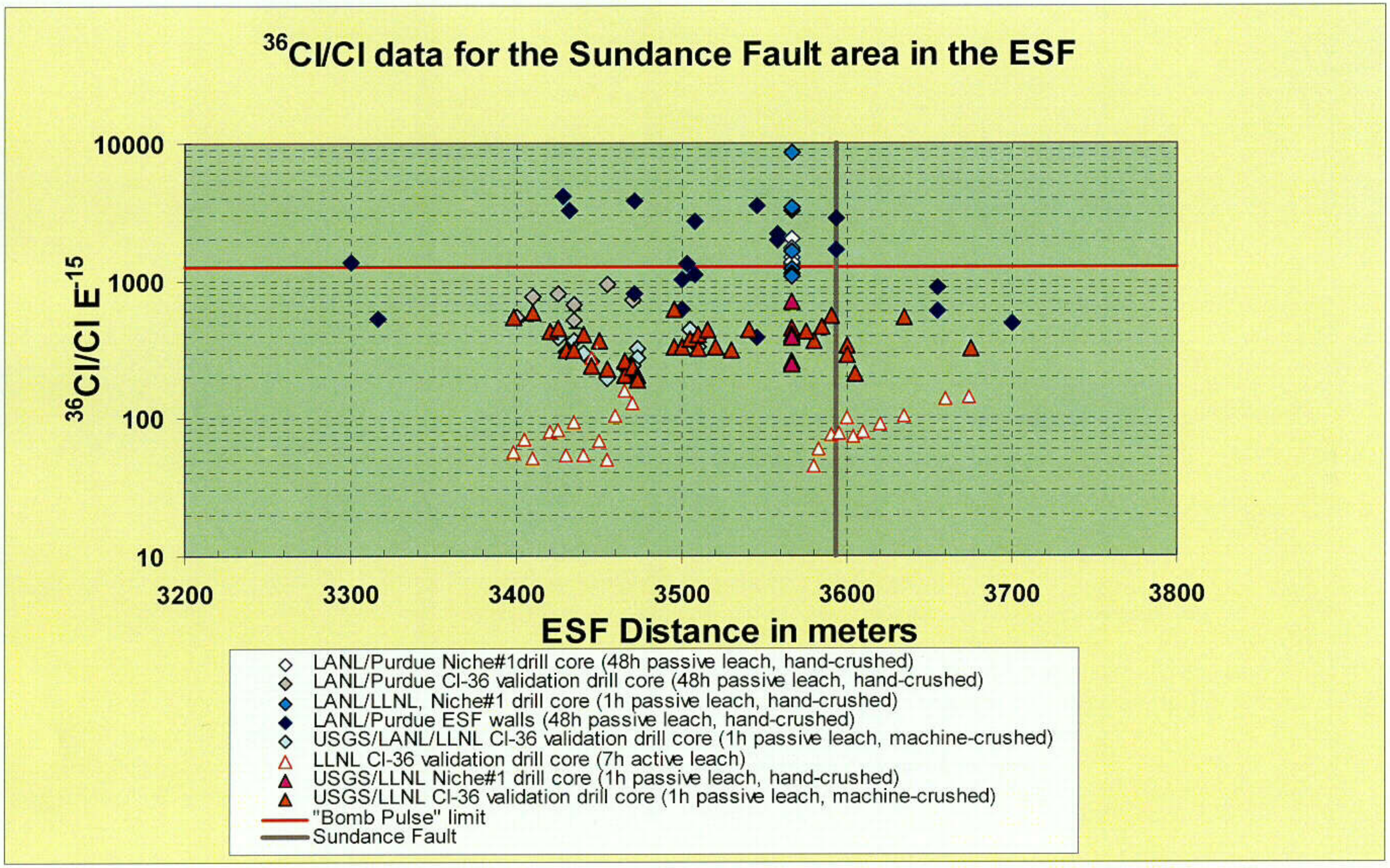
- Sampling from the drill core (several feet away from the tunnel walls)
- Crushing
  - Jaw crusher at U.S. Geological Survey (validation core)
  - With hammer at Los Alamos National Laboratory (Niche#1 core)
- Passive leaching by DI water for 1 hour
- Spiking with ^{35}Cl and precipitation as AgCl
- Accelerated mass spectroscopy analyses at Lawrence Livermore National Laboratory

Sampling and Analytical Techniques

(Continued)

U.S. Geological Survey/Lawrence Livermore National Laboratory ^{36}Cl validation study

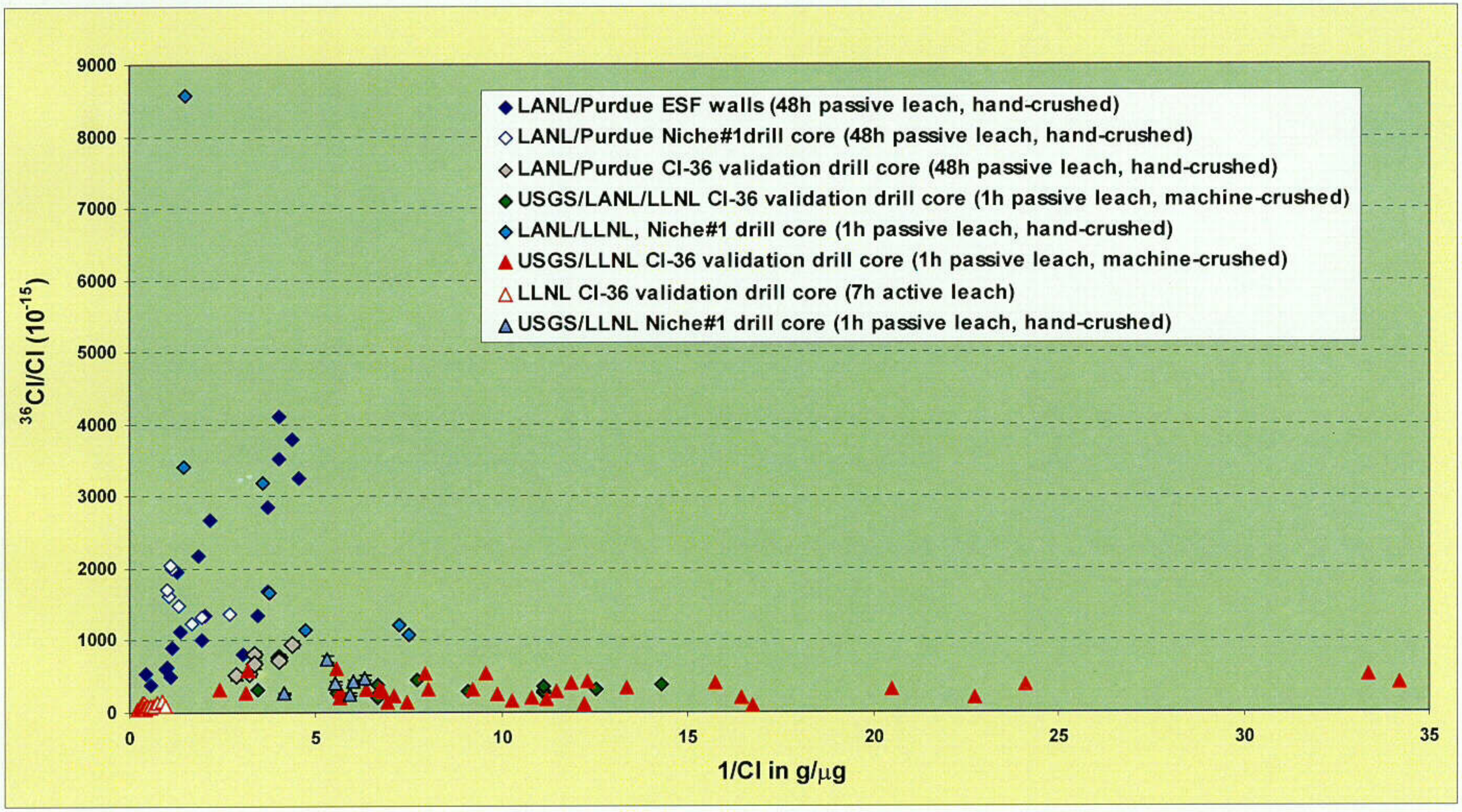
- Sampling from the drill core (several ft away from the tunnel walls)
- Crushing
  - With hydraulic press or jaw crusher (validation core)
  - With hammer (Niche#1 core)
- Leaching by DI water
  - In a rotating barrel for 7 hours (active, old data)
  - In a stainless steel stock pot for 1 hour (passive, recent data)
- Spiking with ^{37}Cl and precipitation as AgCl
- Accelerated mass spectroscopy analyses at Lawrence Livermore National Laboratory



36Cl/Cl data for the Sundance Fault area in the ESF
10000
1000
100
10
36Cl/Cl E-15
3200
3300
3400
3500
3600
3700
3800
ESF Distance in meters
LANL/Purdue Niche#1drill core (48h passive leach, hand-crushed)
LANL/Purdue Cl-36 validation drill core (48h passive leach, hand-crushed)
LANL/LLNL, Niche#1 drill core (1h passive leach, hand-crushed)
LANL/Purdue ESF walls (48h passive leach, hand-crushed)
USGS/LANL/LLNL Cl-36 validation drill core (1h passive leach, machine-crushed)
LLNL Cl-36 validation drill core (7h active leach)
USGS/LLNL Niche#1 drill core (1h passive leach, hand-crushed)
USGS/LLNL Cl-36 validation drill core (1h passive leach, machine-crushed)
"Bomb Pulse" limit
Sundance Fault

C13

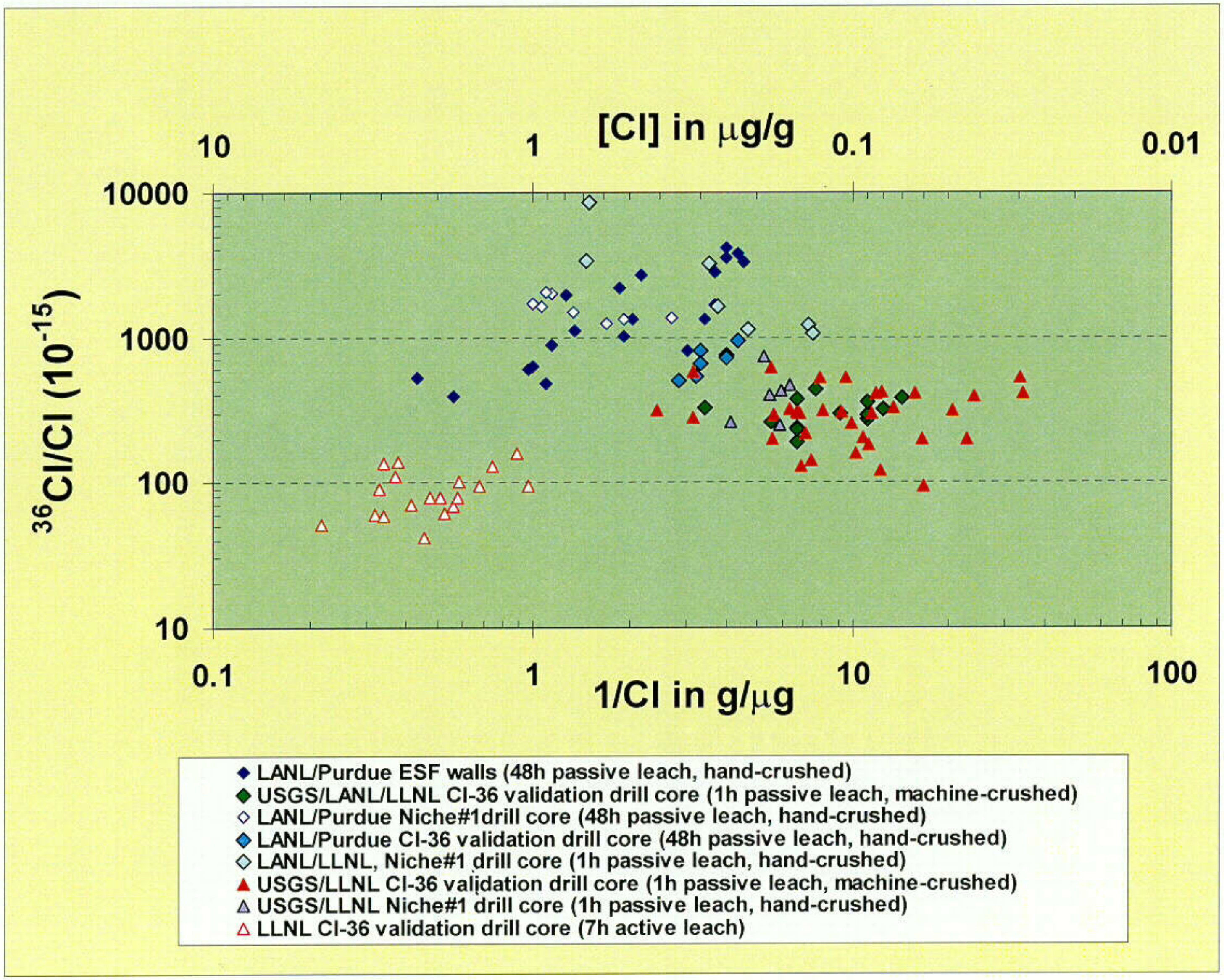
$^{36}Cl/Cl$ versus 1/Cl, Sundance Fault area, Exploratory Studies Facility (linear plot)



YUCCA MOUNTAIN PROJECT

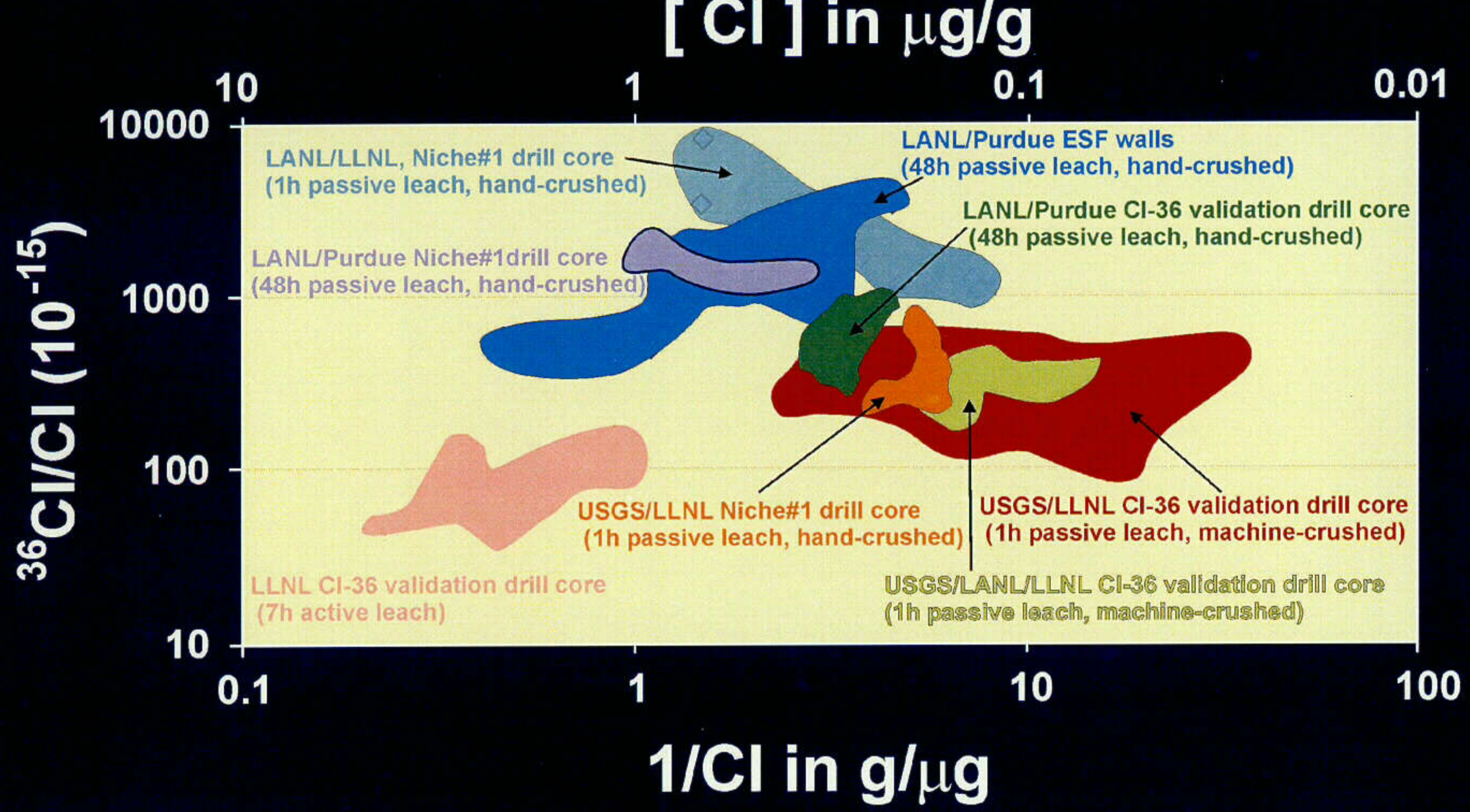
C14

$^{36}Cl/Cl$ versus 1/Cl, Sundance Fault area, Exploratory Studies Facility (log-log plot)



C15

$^{36}Cl/Cl$ versus 1/Cl in the Sundance Fault area in the ESF



C16

HISTORY OF WATER USE and WELL DRILLING IN THE YUCCA MOUNTAIN AREA

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Presented to the
Advisory Committee on Nuclear Waste
September 25, 2002
Las Vegas, Nevada

BACKGROUND

- NRC Roles in HLW Program…to Develop…
  - Regulatory Framework
  - Independent Review Capability

- Need for Staff to be Knowledgeable on Water-Use Issues
  - No Single (Comprehensive) Source of Information
  - Multiple Sources of Information

- Literature Review Useful Research Tool to Staff
  - Printed Media (Scientific Literature)
  - Electronic Media (Data Bases)

C17

WATER-USE STUDY

- Purpose
  - Summarize Information Reported in the Literature
    - No Proprietary or Unpublished Data Sources
    - Only Data Currently in the Public Domain

- Provide Information on History of Water Development
  - Late 1800s to 1999

- Describe Frequency, Amount, and Density of Drilling
  - Amargosa Valley Hydrographic Area
  - Crater Flat Hydrographic Area
  - Jackass Flats Hydrographic Area (NTS Area 25)
  - NTS Water Supply System

C18

WATER-USE STUDY
(Continued)

- Information Sources
  - Printed Media…
    - Geologic and engineering reports
    - Historical treatises
    - Archeological investigations
    - Enthnological studies
  - Electronic Media (data bases)…
    - State of Nevada
    - U.S. Geological Survey
- Limitations of Study…
  - Literature Not Reviewed
  - Drilling Records Not Reported
  - Incomplete and/or Inconsistent Drilling Records

C19

STUDY SUMMARY

- Factors Affecting Water Use
  - Adoption of Drilling Technology from Petroleum Industry
  - Evolution of Pump Technology
  - Introduction of Electric Infrastructure
  - Growth in Geologic Knowledge
  - Government Land-Use Polices
  - Soil Conditions (Submarginal)

- Specific Milestones
  - Native American Farming (early-mid 1800s)
  - Mining (late 1800s)
  - Introduction of Railroads (ca. 1907)
    - Drilling technology
    - T&T Experimental Ranch (1917)
  - Homesteading/Desert Reclamation (late 1800s, 1950s)

C20

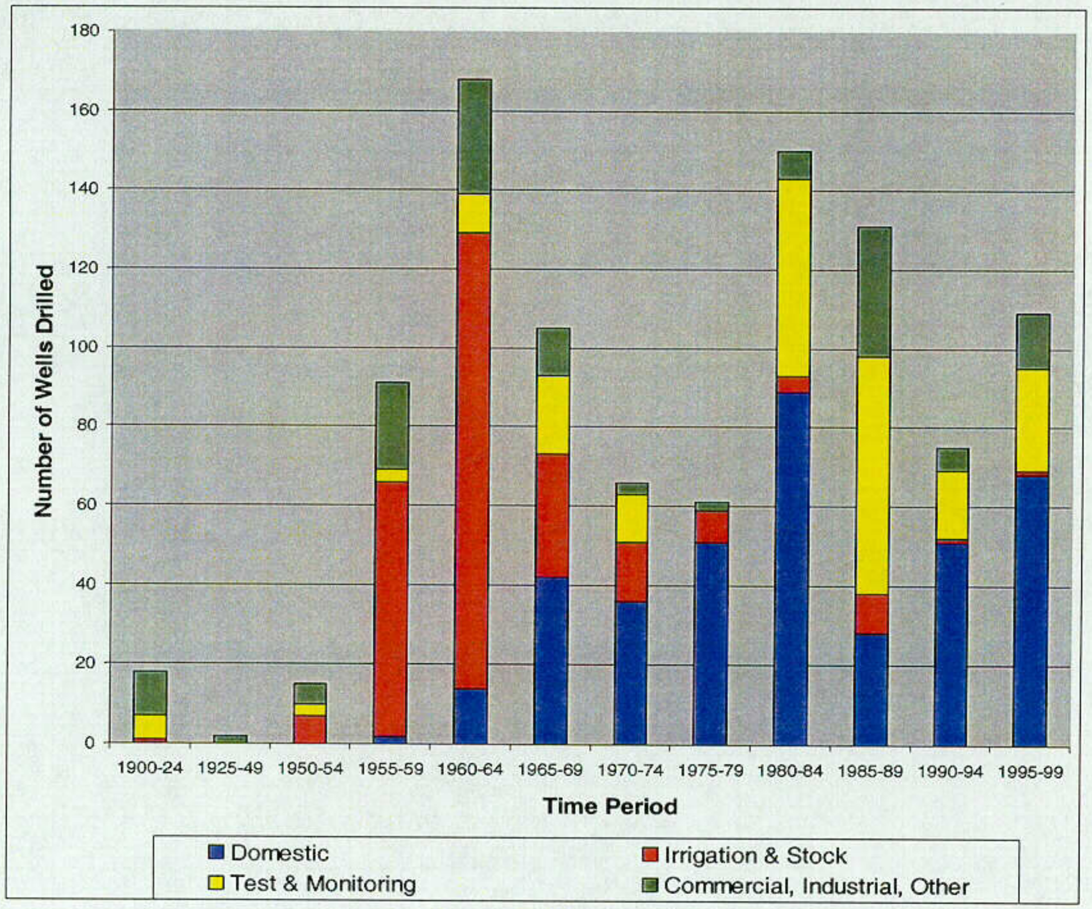
STUDY SUMMARY
(Continued)

- 985 Wells Dug and Drilled
  - Dug Wells
    - Mid-Late 1800s
  - Drilled Wells
    - First in 1906
  - Sustained Drilling Activity
    - Late 1950s

- Nature of Drilling Can be Described in Terms of....
  - Frequency: *How many boreholes?*
  - Amount: *How much drilling?*
  - Density: *Where has the drilling taken place?*

C21

HOW MANY BOREHOLES ?
DRILLING FREQUENCY BY END-USE



C22

HOW MANY BOREHOLES ?
DRILLING FREQUENCY SUMMARY

- Amargosa Valley Hydrographic Area
  - 960 boreholes
  - >1900-99 time frame
- Crater Flat Hydrographic Area
  - 24 boreholes
  - 1981-99 time frame
- Jackass Flats Hydrographic Area
  - 185* boreholes
  - 1953-86 time frame
- NTS Water Supply System
  - 17 wells
  - 1950-64 time frame

** 450 boreholes through 2001*

C23

HOW MANY BOREHOLES ?

DRILLING FREQUENCY SUMMARY (Continued)

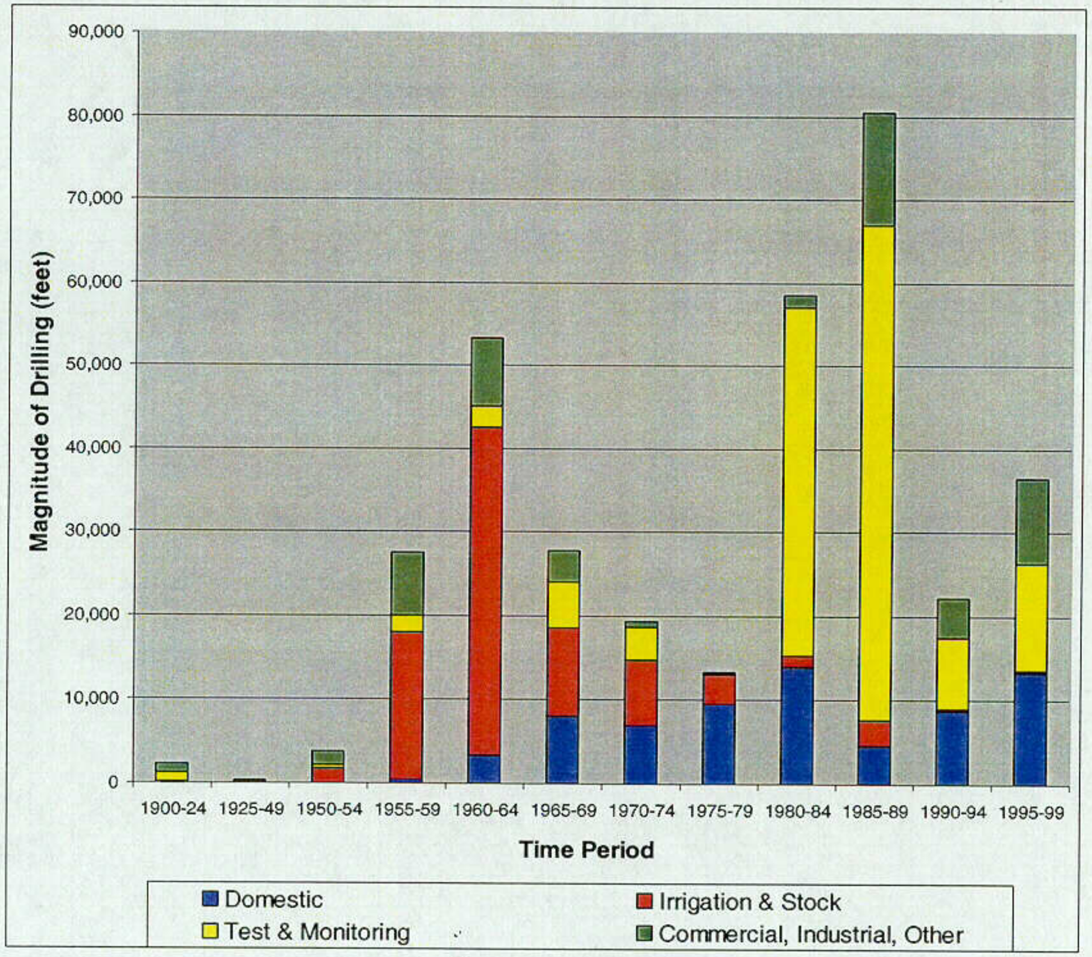
- 43% Fresh Water Supply
- 27% Agriculture Uses
- 19% Scientific Applications
- 9% Unused or Unspecified

- Conclusion:
  - 45% of Drilling Performed in Last 20 Years
  - Greatest Period 1960-64: 17% of Drilling
    - 44% of drilling for agriculture use

C24

HOW MUCH DRILLING ?

DRILLING AMOUNT BY END-USE



C25

WHERE HAS DRILLING OCCURRED ?

DRILLING AMOUNT SUMMARY

- 43% Scientific Applications
  - Test wells: median depth 405‘
  - Monitoring wells: median depth 215'
- 25% Agriculture Uses
  - Irrigation wells: median depth 300‘
  - Stock wells: median depth 513'
- 20% Fresh Water Supply
  - Domestic wells: median depth 181'
- Conclusions:
  - 45% of Drilling Effort Undertaken in Last 20 Years

C26

WHERE HAS DRILLING OCCURRED ?
DRILLING DENSITY

- Reviewed Primarily State of Nevada and USGS Data Bases

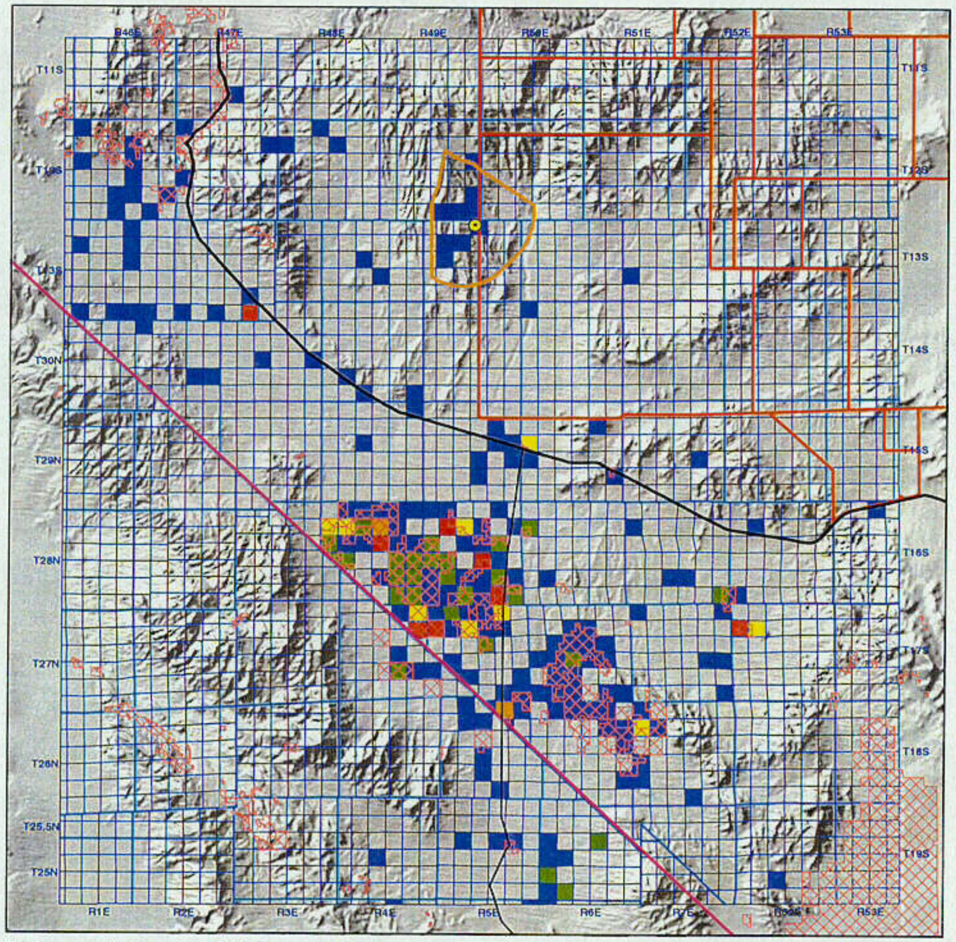
- Description of Physical Location of Drilling Limited to…

- ***Unit-Regional-Value**** Analysis Technique
  - Concept borrowed from mineral economics field
  - Physical quantity per unit area
    - Normalized with geologic diversity index
  - Allows comparison of different geologic environments using common metric
    - Ounces gold produced per square mile
    - Tons of sand and gravel mined per square mile

* J.C. Griffiths "Mineral Resource Assessment using the Unit Regional Value Concept," in S.M. Cargill and A.L. Clark (eds.), "Standards for Computer Applications in Resource Studies," *Journal of International Association of Mathematical Geology*, 10[5]:441-472 (1978).

C27

WHERE HAS DRILLING OCCURRED ?



Number of Boreholes Drilled Per Section

0	6 - 10	16 - 20
1 - 5	11 - 15	> 20

C28

WHERE HAS DRILLING OCCURRED ?

DRILLING DENSITY SUMMARY

- Drilling Generally Concentrated in the Amargosa Farms Area
  - 35-45 km South of the Proposed Repository
  - Shallow Water Table (< 100')
  - Drilling Classified Principally as *Domestic, Irrigation*, or *Stock*
  - Highest Single Concentration of Drilling…
    - Beatty LLW Disposal Facility

C29

WHERE HAS DRILLING OCCURRED ?

DRILLING DENSITY SUMMARY
(Continued)

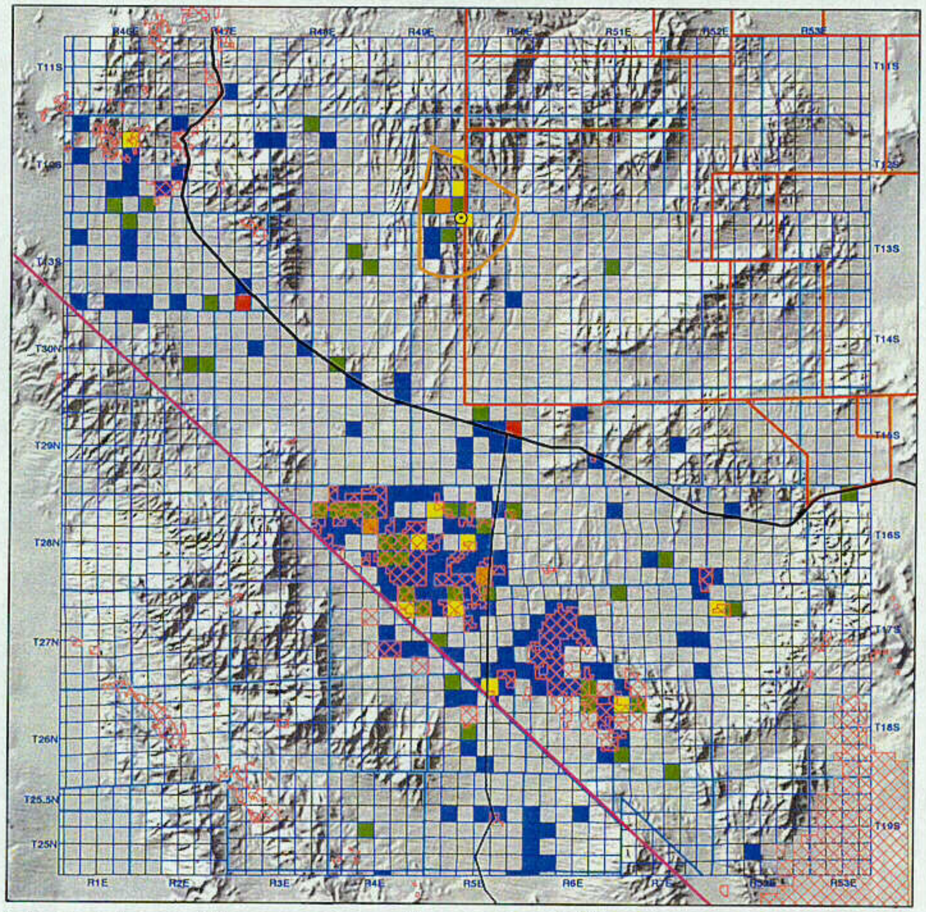
- Test and Monitoring Wells
  - Occupy 91 sections
  - Average 1 well/section
  - Maximum: 8 to 20 wells/section

- Irrigation Wells
  - Occupy 85 sections
  - Average 3 wells/section
  - Maximum: 9 wells/section

- Domestic Wells
  - Occupy 69 sections
  - 6 wells/section
  - Maximum: 40 wells/section

C30

WHERE HAS DRILLING OCCURRED ?



Total Depth of Borehole Drilling in Feet Per Section

(white)	0	(green)	2,001 - 4,000	(orange)	6,001 - 8,000
(blue)	1 - 2,000	(yellow)	4,001 - 6,000	(red)	> 8,000

C31

WHAT'S NEXT ?

- Initial Presentation at Spring 2002 American Geophysical Union Meeting (Washington, D.C.)
  - Abstract published in conference proceedings
  - Poster session

- Publish Staff Analysis as NUREG-1710
  - Part A: Literature Review (History)
  - Part B: Analysis of Drilling Statistics

C32