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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON NUCLEAR WASTE

April 19, 2006

The contents of this transcript of the proceeding of the United States Nuclear Regulatory Commission Advisory Committee on Nuclear Waste, taken on April 19, 2006, as reported herein, is a record of the discussions recorded at the meeting held on the above date.

This transcript has not been reviewed, corrected and edited and it may contain inaccuracies.

1 UNITED STATES OF AMERICA

2 NUCLEAR REGULATORY COMMISSION

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4 ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW)

5 169th MEETING

6 + + + + +

7 WEDNESDAY

8 APRIL 19, 2006

9 + + + + +

10 ROCKVILLE, MARYLAND

11 + + + + +

12 The Advisory Committee met in Room 1 G16 of the
13 U.S. Nuclear Regulatory Commission, One White Flint
14 North, 11555 Rockville Pike, Rockville, Maryland, at
15 8:30 a.m., Michael T. Ryan, Chairman, presiding.
16 PRESENT:

17	MICHAEL T. RYAN	ACNW Chairman
18	ALLEN G. CROFF	ACNW Vice Chairman
19	JAMES H. CLARKE	ACNW Member
20	WILLIAM J. HINZE	ACNW Member
21	RUTH F. WEINER	ACNW Member

22

23

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25

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1 P R O C E E D I N G S

2 (8:32 a.m.)

3 CHAIRMAN RYAN: Good morning. I think we

4 will come to order please. This is the second day of

5 the 169th Meeting of the Advisory Committee on Nuclear

6 Waste. My name is Michael Ryan, Chairman of the ACNW.

7 The other members of the Committee present

8 are Allen Croff, Vice Chair, Ruth Weiner, James

9 Clarke, and William Hinze.

10 We have a panel of invited experts today

11 that will be giving us presentations on matters that

12 Professor Hinze will discuss in a minute. And that

13 will be today's working group session.

14 I'm not sure who the Designated Federal

15 Official is. Oh, John Flack is the Designated Federal

16 Official for today's meeting.

17 We have received no written comments or

18 requests for time to make oral statements from members

19 of the public regarding today's session. Should

20 anyone wish to address the Committee, please make your

21 wishes known to one of the Committee staff. It is

22 requested that speakers use one of the microphones,

23 identify themselves, and speak with sufficient clarity

24 and volume so they can be readily heard.

25 And it is also requested if you have cell

1 phones or pagers that you kindly turn them off.

2 Let me turn the meeting now over to

3 Professor who is going to lead our technical sessions

4 this morning and early afternoon on matters related to

5 Yucca Mountain and igneous activity. Professor Hinze?

6 Thank you very much.

7 MEMBER HINZE: Thank you, Chairman Ryan.

8 As Mike Ryan has said, we will be hearing this morning

9 three briefings on updating of activities at the Yucca

10 Mountain site, two of them by representatives of the

11 Department of Energy and one from the Nye County.

12 We will start off with an update on the

13 Yucca Mountain activities by Scott Wade who is

14 Director of the Office of Facility Operations and

15 Scott you will be discussing with us, as I understand

16 it, the Infrastructure Improvement Plan. Is that

17 correct?

18 DR. WADE: That's correct.

19 CHAIRMAN RYAN: Scott, just for the

20 record, we do have some participants on the conference

21 phone. So if I may, for the record, just ask the

22 folks around the conference phone to identify

23 themselves for the recorder and then we will turn

24 right back to you. Thank you for the interruption.

25 MR. FITZPATRICK: This is Charlie

1 Fitzpatrick, State of Nevada. Can you hear me?

2 CHAIRMAN RYAN: Just fine. Can you hear

3 us all right?

4 MR. FITZPATRICK: Yes, thank you.

5 CHAIRMAN RYAN: All right. Thank you.

6 DR. WADE: Do we need to have the

7 microphone on here?

8 CHAIRMAN RYAN: Yes. The red part needs

9 to be showing.

10 DR. WADE: Okay, great.

11 Good morning. My name is Scott Wade. I

12 am the Director for the Office of Facilities

13 Operations, the Department of Energy's Office of

14 Civilian Radioactive Waste Management. And I'm here

15 today to discuss site safety upgrades and improvements

16 going on at the Yucca Mountain site.

17 Well, why am I here? To try to

18 communicate to you what the department is doing at the

19 Yucca Mountain site, how we are focusing on improving

20 the status of the systems at the Yucca Mountain site.

21 Quick introductory about my organization,

22 the Office of Facility Operations is responsible for

23 not only the Yucca Mountain site, including the

24 exploratory studies facility tunnel, but all of the

25 facilities within Yucca Mountain including our leased

1 facilities in Las Vegas, our new one we are about to
2 open in Pahrump, facilities in Washington, D.C. as
3 well. Our major charge is to ensure that they are
4 maintained in a safe and reliable means.
5 Turning to the second slide, we focus on
6 the Yucca Mountain site facilities. I know that you
7 are very well acquainted with these facilities but
8 this consists of the exploratory studies facility, the
9 ESF tunnel, eight miles of tunnel that we developed in
10 the '90s, the facilities in both the north and south
11 portal, the utility systems that support our
12 activities within the tunnel: water, power, sewer
13 ventilation, et cetera.
14 I'm going to focus a great deal of time
15 this morning talking about what we are doing with
16 these systems. The paved and unpaved roads that
17 support activities at the site, parking and
18 presentation areas, our bore holes, trenches, and test
19 facilities, we are accountable for maintaining and
20 operating those as well, as well as lay-down areas for
21 equipment.
22 Next slide please. We focus now on the
23 north portal facilities. It consists of two permanent
24 structures. I was expecting a slightly different
25 slide so I've got a laser pointer but I'm going to try

1 and use one of these where you can see it here. So I
2 apologize --
3 CHAIRMAN RYAN: I'm sure that everybody
4 can see it because we can see it behind you. So I
5 think everybody has a view. If you just describe it,
6 I think we'll be okay.
7 DR. WADE: Okay, I'll do that. In the
8 upper picture there is an aerial shot of the north
9 portal of the exploratory studies facility. It
10 consists of 121 structures and two permanent
11 structures. The two permanents, of course, are -- I'm
12 just going to use the laser pointer, the change house
13 and the switchgear building right there.
14 And then temporary structures consisting
15 of trailers, cargo containers, sea/land containers or
16 Conex shops, whichever terminology you are familiar
17 with. And then two sprung structures. These are
18 laminar covered, plastic covered tent structures we
19 use for material storage. I have approximately 225
20 full-time employees stationed out the Yucca Mountain
21 site.
22 Next slide please. We focus a great deal
23 of funding -- and, again, to answer the question why
24 am I here, the Departments focus a great deal of
25 funding starting in 2005 and planning through 2008 to

1 invest in the condition of the ESF systems. We focus
2 quite a bit on the underground. The next three slides
3 are going to focus on the underground systems.
4 Next please. Underground electrical
5 maintenance, as with all of the systems, we've done
6 detailed assessments to make sure we understood the
7 conditions of these systems, understood what needs to
8 be prioritized for maintenance and operations.
9 Electrical is a great example. We did an assessment
10 back in 2004 that led us to wanting to invest a great
11 deal of time and energy in maintaining the system.
12 Now the underground electrical system
13 consists of 13 of these items. These are mine power
14 centers, the large orange units you see there in the
15 picture. These are stationed at various locations
16 within the ESF tunnel. What you have is 12,000 volt
17 power lines that come into them. You have a dry air-
18 cooled transformer within the unit. And you have
19 breaker boxes. We needed to make sure that we are
20 doing effective maintenance of these units. This
21 actually required us to shut down underground
22 activities, you know, to limit tours for about a six-
23 month period as we went through and systematically
24 maintained each and every one of these.
25 Now a little bit later I am going to talk

1 about some more planned activities in 2008. And one
2 of those planned activities has to do with further
3 work on the underground electrical maintenance
4 components. And that includes the platform that you
5 see on the left.
6 The original design for the underground
7 electrical system had us actually cutting out small
8 niches for these transformer units. Instead, they
9 were mounted up above grade so that that platform
10 projects out, you know, kind of from the position
11 where the camera is looking right now is where the
12 tunnel train would be. And it creates very limited
13 access.
14 So I will talk a little bit more about how
15 we are going to fix that but I wanted to focus on that
16 for a moment. We did get all of our electrical
17 maintenance completed at the very end of calendar year
18 2004 and the very beginning of fiscal year 2005. We
19 are now in a three-year maintenance cycle for it.
20 Next slide please. We don't want to just
21 assume that everything has been adequately planned in
22 the '90s for things that needed to be installed. One
23 of those great examples is our fire detection alarm
24 system. We did an update to our subsurface fire
25 hazard analysis in 2004. And identified that we

1 needed to reduce risk by putting some systematic means
2 of detecting fires within the underground.
3 There is not much that can burn within the
4 ESF tunnel, you know but that doesn't mean that there
5 isn't combustible materials within it, the cabling
6 certainly is, the conveyer belt, which I'll talk about
7 in a few moments, while flame retardant, is
8 combustible.
9 Some of the material in what we call our
10 301X areas where we had poor ground, particularly
11 newer the surface where we have cribbing material,
12 wood cribbing, excelsior, hay, and such. All of these
13 things are combustible.
14 Our subsurface fire hazard analysis
15 determined that we would be best suited to find some
16 systematic means of detecting fires in the underground
17 and alarming surface firefighting personnel.
18 So we started deploying this. It starts
19 at the north portal. We are currently about halfway
20 through the tunnel. We have done zones 1, 2, 3, and 4
21 and are focusing on zones 10 and 11 within the cross-
22 strip. Every 25 feet within the tunnel, we've mounted
23 a temperature sensor that alarms back to our
24 changehouse which then alarms all the way back to
25 mercury to the firefighters. So that if we have

1 changes in the ambient temperature, we would be able
2 to detect those, there was some indication that there
3 was a fire event.
4 The importance then is then you can
5 trigger the communication system and tell underground
6 workers which way to egress. So we intend to continue
7 the installation of this the remainder of this fiscal
8 year and complete it in early next fiscal year.
9 Next slide please. Underground lighting -
10 - this again listens to some of our craft personnel.
11 They identified the very early part of this decade
12 that we needed to do some improvements to the lighting
13 system. The lighting system when originally installed
14 led towards low maintainability, led towards early
15 failure rates.
16 To make sure that -- and again in the
17 event of an underground fire or some reason for egress
18 for the site, you want to make sure the people can see
19 clearly to get out of the tunnel. So we have been
20 going through and upgrading the underground lighting
21 system to make sure it is reliable.
22 We are doing this actually as we are
23 installing the fire detection alarm system. And we
24 will complete that again early next year.
25 Next slide. Ventilation system -- we have

1 a series of ventilation fans that provide the air flow
2 for the workers. Many of those fans were installed in
3 the '90s, have been operating since installation.
4 What we wanted to do was again, achieve two
5 objectives. One, make sure that they are reliable and
6 have some predictive means of identifying when there
7 is a fan failure.
8 So the first thing we've done is installed
9 temperature and amperage alarms with each of the fans
10 systems to give us a means of identifying if there is
11 an imminent failure coming. And then we have also
12 ordered some new fans that will have lower noise so we
13 can reduce the noise zones around the fans.
14 Some of the fans that were originally
15 deployed -- and I believe this is fan three in the
16 north ramp -- also weren't configured in a way that
17 would allow for easy maintainability. So the new fans
18 will also be much more maintainable.
19 Between these two efforts, it is going to
20 allow for the system to be a lot more operable in the
21 coming years.
22 Next slide. Ground support -- the ground
23 support shown here basically the two main types you
24 are going to see within the tunnel, the upper left-
25 hand is where -- deeper in the tunnel where the ground

1 is very competent, you have minor ring steel near the
2 crown and then match mostly for safety purposes.
3 The lower slide shows particularly nearer
4 the surface where you have more consolidated ground,
5 where you have a great deal more of the ring steel.
6 You have the steel lagging between. And behind it you
7 can even see -- in the picture it is kind of right
8 there -- that is some of that excelsior.
9 This is probably one of the 301X areas.
10 And I'm not sure exactly which of the areas are
11 photographed here but behind that, you will find wood
12 cribbing. You will find some of the excelsior that
13 goes to some of the fire load issues we wanted to
14 address in multi-year.
15 We've had ground support monitoring going
16 on since installation and we have continued that.
17 What we have done in the past year is augmented it.
18 We have completed some additional ground support at
19 278 locations in the underground.
20 We have continued our convergence as well
21 as ground support inspections. And we are planning --
22 and again in multi-year to address the fire load
23 behind some of these 301X areas.
24 Next slide. Conveyer belt system -- the
25 conveyer belt was deployed in the '90s to support TEM

1 excavation. And we haven't operated it since 2001.
2 The conveyer belt itself while flame retardant still
3 is combustible. And again in our subsurface fire
4 hazard analysis, the engineers have determined that a
5 design basis event for some sort of tunnel fire could
6 consume a section of the conveyer belt, producing
7 thick dark smoke.
8 What we wanted to do was reduce risk from
9 that so starting this fiscal year, we have been
10 removing the conveyer belt system. We started by
11 removing the surface sections. So if you were to go
12 out to the ESF site today, that surface section that
13 you see in the picture there coming out of the north
14 portal of the tunnel is completely gone.
15 The subsurface sections within the cross-
16 strip we have completely removed. And now are working
17 our way through the rest of the tunnel to remove the
18 belt first and then the supporting structures later.
19 And all the material is now being maintained up at a
20 location called our subdoc. So we haven't gotten rid
21 of the belt. We're just removing it to provide for
22 enhanced safety.
23 Next slide please. Future subsurface
24 upgrades -- you know I mentioned a little bit earlier
25 about things we want to do. One of them is to address

1 those pinch points on our underground electrical
2 system. Maintaining the system was first and foremost
3 our objective. Now what I want to do is reduce risk
4 for operations of our tunnel rail locomotives for
5 personnel transport, for material transport.
6 So what we are looking at starting in
7 fiscal year 2008 is reworking the electrical system in
8 the underground, probably cutting in the niches that
9 were originally planned so that we can drop those mine
10 power centers to provide for greater safety for
11 underground personnel access.
12 To do that, we also want to go underground
13 and improve the rail. If you have been on the rail,
14 it was not installed to its original design. We have
15 what is called a floating head for our rail system.
16 It is not fully secured so the gauge wanders somewhat.
17 This leads to derails.
18 Now we have been addressing everything
19 that we have through mitigations. One of them has
20 been a speed mitigation for our locomotives. They
21 can't operate at any speeds greater than ten miles per
22 hour in the underground. What we want to do in 2007
23 is go in and grout the rail, permanently secure it to
24 the invert such that the risk of derails is
25 dramatically lowered.

1 Once we complete our entries into the
2 cross-strip -- I'm sorry -- into the Alcove 5 Heater
3 Test, we are going to demobilize that in 2007.
4 We are also looking to remove the small
5 TBM we have at the very end of the cross-strip. They
6 completed excavation back in 1998. It has been there
7 since. We actually brought in the Colorado School of
8 Mines recently to go and access its condition. And we
9 are looking in 2008 to remove the TBM and probably
10 access it through our property access requirements.
11 Next slide. Let me turn to surface
12 facilities for a few moments and talk about what we
13 are planning on the surface. On this particular slide
14 here -- and I apologize to those that may not be able
15 to see the pointer here but I will actually hit a
16 couple screen so that people can see the same things.
17 Again, we have a shot of the north portal
18 of the ESF. And right about there in the center of
19 the picture is our heavy equipment maintenance area.
20 And right -- boy, my hands are shaky this morning --
21 right about there is a trailer. At the very beginning
22 of February this year, we had a fire at the north
23 portal. Our work crew arriving on a Monday morning at
24 six in the morning -- and, again, in February it is
25 still very dark at six in the morning -- saw low-lying

1 smoke.

2 What had happened over the weekend shift,

3 since the site is not maintained with personnel 24/7,

4 during the weekend the heater unit within that trailer

5 had caught fire. It fully consumed that trailer. It

6 also destroyed an associated Conex shop and damaged

7 two others. It also damaged the electrical

8 distribution panel that was right next to the trailer.

9 Well, this is a great example of one of

10 the risks that we are trying to reduce. And I'm going

11 to talk in a few minutes about a planned fire station

12 we are going to deploy starting this fiscal year and

13 completing it early next fiscal year.

14 But the fire risks on the north portal are

15 addressed through fire response that comes from

16 Mercury, which is 45 minutes away. None of the

17 trailers, Conex shops, the sprung structures, none of

18 them have fire detection units. Only two of the north

19 portal structures, both the changehouse and the large

20 CMO trailer, large construction trailer right there,

21 have sprinkler systems. So we have a fire risk we are

22 trying to address.

23 Let me turn to the next slide. One of the

24 things that happens if you come out --

25 MEMBER HINZE: Where do you get your water

1 from? Do you have wells there on the site? Or is
2 that shipped in?
3 DR. WADE: Yes, we do. We get our water
4 from wells J12 and J13. There is a piping system that
5 brings it all the way up to the north portal pad to
6 two storage tanks up on Exile Hill. They are then
7 piped down on to the ESF area for operations and there
8 are also hydrants for fire response.
9 MEMBER HINZE: Thank you, Scott.
10 DR. WADE: When people come out to visit
11 the Yucca Mountain site, they arrive at this location.
12 This is Gate 510. So this is the very entry on to the
13 Nevada Test Site in the far southern and western edge
14 of the Nevada Test Site.
15 If you arrive there and you have
16 appropriate badging in hand, you the proceed up to the
17 north portal to the ESF to check in. This is about 30
18 miles from this location. One of the things we
19 identified is that that is a long drive from there.
20 We have had people that have gotten lost. We have had
21 people that have gotten into areas that they shouldn't
22 get into because there are other NTS activities
23 underway.
24 What we wanted to do was to reduce risk
25 and to optimize our security components. So one of

1 the things we recognized early on is the very limited
2 capabilities of Gate 510. It is only a ten by ten
3 foot guard station manned by Wackenhut Security.
4 It has no utilities there. It has no
5 ability to issue badges so if you don't have a badge
6 with you, they send you back to Gate 100, which is
7 about -- you would have to go down US 95, which is
8 probably about another 30-minute drive to check in.
9 And then another 30-minute drive to return back to
10 Gate 510.
11 It has no means of tracking personnel even
12 if after they have been badged from the point of
13 access to their point of activities. It has no ranch
14 control capabilities. That is our access control
15 function we perform at Yucca Mountain where we track
16 where everybody is performing their field scientific
17 activities. Depending on how remote they are, we have
18 requirements that they check in by radio. We make
19 sure that they are issued the appropriate radios and
20 communications devices.
21 Well, to address this -- next slide -- we
22 are planning to construct a new 9,300 square foot
23 facility adjacent to Gate 510. Its major function is
24 security and in access control. What you would find
25 at this location when completed is you would arrive

1 there, you could issue your badges. They would be
2 able to verify your training before you go out in to
3 the field.
4 We have a large training room there so
5 that if you didn't have your training, we could give
6 you the training at the location. We would track then
7 where you went within the Nevada Test Site.
8 We would also be tracking all hazardous
9 materials loads and activities coming on to the Nevada
10 Test Site. We actually have started some initial dirt
11 work to relocate the guard station to create a safe
12 work zone. Sometime within the next few weeks, we
13 will be releasing a procurement for design build for
14 the structure.
15 It is funded this year and we hope to have
16 completion by the end of this calendar year, early
17 part of next calendar year. What you see is a
18 conceptual design that we have completed so far. It
19 gives you kind of a sense of the site layout and site
20 elevation.
21 Next slide. Site access road -- most of
22 the utilities and things on the Nevada Test Site that
23 Yucca Mountain has been working with during site
24 characterization were originally developed by the
25 Nevada test site and its support contractors often

1 decades before. The roads is a great example.

2 This is a picture of actually Jackass

3 Flats Road coming towards Area 25. And as you can see

4 from this particular shot, there are a lot of pot

5 holes in it. There is a lot of uneven road surfaces.

6 Well, you know, of my laundry list of

7 worries I have on a daily basis, one of my worries is

8 those 225 folks that come out to work at the Yucca

9 Mountain site, making sure that they get out there

10 safely.

11 We bus them out there but we worry about

12 the road condition. We went and did a detailed

13 assessment of the roads, determined that most of the

14 roads are probably constructed in what is called hill

15 and dale road construction. In other words, they

16 graded the area then they asphalted over it. There is

17 very minimal sub bed.

18 You can drive on the roads and look over

19 and notice that the desert surface, in some cases, is

20 actually elevated above the road structure. So you

21 have washouts frequently in many of the areas. So

22 what we are looking at is a means of providing for

23 better and more safe road access for our work crews.

24 Next slide. What we are studying and what

25 we have created is a draft environmental assessment

1 that is looking at two alignments for road. Again,
2 what you see here -- and it is easier in the handout
3 and I apologize to those in the audience -- is a map
4 of the Nevada Test Site's western edge. And let me
5 kind of use this laser pointer to describe the
6 locations.
7 The western edge of the Nevada Test Site
8 is slightly off screen here. This is that Gate 510
9 location I mentioned earlier. Let me do it on a
10 couple of locations here so people in the audience can
11 refer to what I am referring to.
12 We are studying two different alignments
13 for roads. So right now when our work crew domes in,
14 they come into -- since they are all badged, they come
15 in on US 95, they come up to Gate 510, security guards
16 check their badges, then they proceed up to our
17 exploratory studies facility, all the way around to
18 this final point here.
19 That is about 30 miles. What we want to
20 do is make for a much more direct route. Now keep in
21 mind, for particular the winter parks of the year,
22 those buses arrived during the dark. And, you know,
23 it is pitch black out there in the winter months.
24 So we're looking at two alignments. One
25 is completely different redo existing road all the way

1 around with an engineered road, two lane or we are
2 also looking at a direct alignment which would cut out
3 about ten miles of road.
4 Our environment assessment wis looking at
5 the impacts of either of those two activities. But
6 either one will enhance safety because we will have an
7 engineered road. It won't just be the hill and dale
8 road construction.
9 What we have done is we have funded the
10 U.S. Army Corps of Engineers to do a road
11 specification and preliminary design. Once we've come
12 to our NEPA decision points, we will then look at
13 which of the activities to implement or whether we
14 just go with the no action alternative and we don't
15 implement anything with it.
16 But should we make the decision to
17 proceed, we have funding this fiscal year to start
18 construction on the road.
19 Next slide. At the Yucca Mountain site,
20 we also have probably another 30 miles of dirt roads.
21 And one of them that is routinely used as the crest
22 road. And shown here actually in this topal map is
23 alignments coming up to the crest road, particularly
24 this section right there. I want to call your
25 attention to it.

1 If you have been on the crest road it is
2 a graded dirt road. As you get nearer the crest, the
3 grade goes up to 25 percent. And actually I was
4 struck with that figure and I've been on it hundreds
5 of times. I've been on the crest many times with
6 visitors. And we mitigate that by driving very slowly
7 and carefully. But I had no idea that it was a 25
8 percent grade.
9 Well I asked the question well is there
10 any way we can improve it on its existing alignment
11 and the road engineers advise back no, not with that
12 alignment. The topography wouldn't even support
13 getting it down to the preferential grade of seven to
14 eight percent maximum.
15 On the next slide, you've got kind of an
16 aerial shot. Again, for everyone's information this
17 is the crest road coming through there. And this is
18 that same section we've been focusing on where the
19 grade is particularly bad.
20 What we're looking at now is -- next slide
21 -- is an alternative to pioneer a new direct
22 connection to the ridge crest. This is H Road. ESF
23 is right there. H Road paving stops at about that
24 location. To go ahead and complete paving up on this
25 existing graded dirt road and develop a new road

1 connection of about 1.3 miles onto the crest.

2 In looking at topography with our road

3 models believe that we can get it down below the eight

4 percent grade. So that same environmental assessment

5 that I mentioned earlier is also looking at options

6 for pioneering a new crest road.

7 The reason for doing a crest road is not

8 just for taking visitors to the top. We have a series

9 of bore holes on the ridge crest that we have to go

10 out and continue to inspect. We have weather stations

11 on the crest. So we have operational reasons for

12 being on the crest in addition to institutional

13 reasons for going up there.

14 The other advantage of doing a crest road

15 here is this also would give us a good connection down

16 to Solitario Canyon. And I really like that idea

17 because that then gives me a second egress capability

18 from the Yucca Mountain site.

19 On rare occasions, we actually do have

20 storm water flow within 40 mile wash. We've had to

21 actually stop our field work activities a couple of

22 times last fiscal year to allow work crews to go home

23 early because of fears that there would be enough

24 storm water flow in 40 mile wash it would impact our

25 ability to egress the site.

1 Since we lack some of the basic emergency
2 response capabilities, fire and such, we sent the work
3 crew homes. With a second egress, we will have other
4 options for getting the work crews home.
5 Next slide. Let me talk a little bit about
6 what we are planning to do with the conditions of some
7 of the other facilities on the north portal. What you
8 see here is a number of photographs from our
9 Exploratory Studies Facility North Portal Pad. Upper
10 left corner is one of those Conex shops, a sea-land
11 container with an awning. I believe that is our
12 electrician's Conex shop right there.
13 Adjacent to it in the next picture is one
14 of our heavy equipment maintenance areas where we pull
15 the locomotives in. There are tracks that run into
16 the center of that shop.
17 Final lower picture is also a series of
18 Conex shops. Now if you have been out there, the
19 approximately 100 to 125 craft workers out there have
20 been working in those kinds of conditions since the
21 early '90s. Temperatures, you know, vary anywhere
22 from near freezing in the winter to over 100 degrees
23 in the summer. The shops aren't climate controlled.
24 I've been out there actually in January
25 during rain events and watched electrical workers

1 standing in several inches of rain in that very shop
2 trying to do their work. We feel strongly that we
3 need to give our work crew the kind of conditions that
4 they deserve to do their maintenance activities
5 safely.
6 Now in the earlier photographs of the
7 North Portal Pad, I talked about the other kinds of
8 structures out there. We also have a series of
9 trailers. Many of those trailers date back to a
10 vintage in the late '80s. Some of them go back to the
11 very, very early '80s.
12 Actually before I worked for the
13 Department of Energy, I worked as a contractor on the
14 Nevada test site and I actually worked in one of those
15 trailers in a different area. We actually borrowed --
16 or as they excessed trailers, we took them and brought
17 them to the North Portal Pad. So some of those
18 trailers are getting fairly old.
19 And as they get older, they create
20 maintainability issues and they create safety issues.
21 We've actually had some workers put their foot through
22 the floor of some of the trailers.
23 The sprung structures I mentioned earlier,
24 those were deployed in the mid '90s. They were
25 deployed new but the tent covers are beginning to

1 fail. That is not unforeseeable after ten years in
2 the hot desert sun. As I looked at options to address
3 the imminent failure of a tent structure, I had a
4 couple of other different challenges. If I wanted to
5 go replace that tent structure, I'd have to go and do
6 a couple of things.
7 First off, I'd want to size it to meet all
8 of our property needs. It is not sized to meet all of
9 our property needs. I can't even store all of our
10 materials within that tent structure right now. So we
11 have to store our other materials out in the open air.
12 It is not climate controlled. So the
13 workers in there can't even store materials in
14 accordance with manufacturer's specifications. I'd
15 have to address the drainage issues in the North
16 Portal Pad. I mentioned looking at some of the raft
17 workers standing in water. That is because we never
18 finished the final drainage on the North Portal Pad.
19 We never brought the final surface contours up to
20 control drainage.
21 I would also want to address buried
22 utilities. We don't have very good as-built drawings
23 for the buried utilities in the North Portal Pad. So
24 just putting them in place is taking something out
25 that I have today and putting a new one in that same

1 place wasn't a good investment.

2 So what you are going to see in the

3 following slide -- next slide please -- is what the

4 department is examining alternatives on. We are

5 looking at an alternative that will be addressed in

6 the environmental assessment.

7 In this picture here, again what you have

8 is an aerial shot of the North Portal Pad right there

9 -- I can do it for the rest of the audience -- an

10 aerial shot of the North Portal Pad. And that is the

11 ESF right there. Adjacent to it is what we called the

12 Lower Muck Yard. This was an area that was graded in

13 the '90s when we originally intended to extend our

14 conveyer belt system and stack all of the 600,000

15 cubic yards of muck down at that location.

16 For budgetary reasons, we didn't end up

17 constructing the conveyer belt all the way down there

18 so it was cleared and then unused. The shot that you

19 see there has superimposed on it a proposal that we

20 are examining alternatives to construct a series of

21 new facilities on that location.

22 These new facilities are not repository

23 structures I want to emphasize. These are simply to

24 replace those 121 existing structures to maintain the

25 existing operations of the Yucca Mountain site. So

1 they are not repository assets.

2 What we are looking at is a series of four

3 to five structures, all about approximately 30,000

4 square feet with the exception of a fire station. And

5 I want to talk about the fire station in more detail

6 in a subsequent slide.

7 These structures would be completed over

8 the next several fiscal years. These would completely

9 replace all of the structures in the North Portal Pad

10 other than the changehouse which was a completed

11 permanent structure and the switchgear building which

12 is a partially completed structure. It has the site

13 information center in it. And it also has a 5,000

14 volt on one end -- a 5,000 volt electrical switch.

15 So we will maintain those two structures

16 up there. We will keep our locomotive maintenance up

17 there. But we will migrate our craft workers, our

18 field engineers, our maintenance personnel, everyone

19 down into these new structures at the proposed

20 location in the Lower Muck Yard.

21 Next slide. Let me talk a little bit

22 about the fire station. I mentioned the fire we had

23 at the ESF in February. If we had a fire today, we

24 would summon fire response from Mercury, which is over

25 45 minutes away. They have fire crews stationed 24/7

1 in Mercury. There is no fire response within Area 25
2 of the Nevada Test Site. And as you look at changing
3 requirements within DOE including the recent
4 promulgation of 10 CFR 851, the Worker Safety Rule, it
5 brings into play new requirements for compliance with
6 NFPA 1710 for fire response timing.
7 In fact, actually even within the State of
8 Nevada, fire response within rural areas is very, very
9 limited. We want to have on-site capability for not
10 only fire response but technical rescue.
11 An example of how important this is
12 actually happened last Thursday. One of our site
13 electrical craft workers driving her own private
14 vehicle on US 95, actually near Mercury, rolled the
15 vehicle several times.
16 Response came from Mercury from mutual aid
17 down to U.S. 95. They had to cut the top of her truck
18 apart to extricate her. That's technical rescue
19 expertise, they were able to remove her. She was
20 Flight-for-Life air lifted back to Las Vegas. And
21 thank Goodness she actually left the hospital that
22 same day with only minor injuries.
23 But every day as we bring our workforce on
24 to the site, we have that same risk. We also want to
25 be able to, as a good neighbor, address any mutual aid

1 requests down at US 95. So what we are proposing is
2 a new 8,300 square foot fire station located out at
3 the Lower Muck Yard area.
4 This fire station, when constructed, will
5 house a five-person fire crew with full technical
6 rescue capabilities. So any incident on Area 25 or in
7 mutual aid on the Nevada test site they would be able
8 to assist on.
9 They would have the ability to fight
10 structural fires as well as range fires. You may have
11 been informed last summer there was a series of range
12 fires adjacent to the Nevada test site. One of them
13 actually came on to the Nevada test site. That same
14 range fire that came on the Nevada test site started
15 in Solitario Canyon. So it started several miles to
16 the west of our ESF facilities.
17 So by deploying this capability, we are
18 going to be able to really reduce a risk for Yucca
19 Mountain operations.
20 Also located within this structure is
21 going to be onsite medical facilities. We currently
22 keep two paramedics out at the north portal pad. In
23 this location, we will be able to do all of our worker
24 physicals, ideometric measurements as part of our
25 worker safety program, and in multi-year I'm looking

1 at deploying augmented medical capability probably
2 with a nurse practitioner such that the work crew, if
3 they are sick, if they are not feeling well, whereas
4 today we would either send them to Mercury Medical,
5 you know, 45 minutes away, or back into town. They
6 would have the ability to come into our medical
7 facility and to give medical aide.
8 This fire station is funded this year.
9 And as we complete our environment assessment and come
10 to our decision point so if we decide to go forward,
11 it is funded for construction starting this fiscal
12 year and completed by December of next year.
13 Next slide. Offsite power to our
14 facilities. Right now we use power coming from the
15 Nevada test site's power grid. I know I am burying
16 you with a lot of detail and I apologize but, you
17 know, you've probably have never hear a lot of these
18 components. And I just wanted to give you a sense of
19 the operational challenges that we have on a daily
20 basis for our field activities in supporting our
21 scientific testing.
22 And one of them is just the reliable
23 provision of power as well as cost effective power.
24 The Nevada test site power grid, a lot of it was
25 developed decades ago.

1 There is only one section of 69,000 volt
2 lines remaining on the Nevada test site and that is
3 the section that serves Yucca Mountain. Now we don't
4 maintain those sections. That is maintained by the
5 Nevada site. And as they have developed their multi-
6 year infrastructure of maintenance and improvements,
7 they not planning to fund any improvements to our
8 areas.
9 They are not planning to fund any
10 improvements to our areas. They have made it very
11 clear that that is Yucca Mountain's responsibility to
12 fund. They have limited our power access to only ten
13 megawatts. And for all of this service, they charge
14 us between 21 and 25 cents per kilowatt hour power
15 charge. So our power consumption cost per year is
16 greater than two million dollars.
17 What we are looking at now is options that
18 would replace this. And options that would also
19 replace this one transformer shown in the picture
20 here. This is a 6,900 1247 transformer. It is
21 decades old. If that transformer goes out, it would
22 be 42 weeks to replace it. It is not an off-the-shelf
23 item. So it would actually shut down underground
24 operations for the better part of a year.
25 So what we are doing is working with

1 consultants in environmental assessment looking at
2 options to replace this system.
3 Next slide. To do this, we are studying
4 alternatives to bring a new 138,000 volt line from the
5 Lathrop Wells switch. This is a very similar slide to
6 what you saw in the road. What you see again -- I'll
7 hit a couple of different screens so people can see it
8 -- what you see in this slide -- again for
9 perspective, is roads coming on to Yucca Mountain.
10 What you also have is the existing NTS
11 power grid. There is 138 kV power line that comes in
12 to what they call Canyon substation -- I'm sorry,
13 Jackass Flats substation right here. And then goes on
14 to the rest of the Nevada test site. They then carry
15 a 69 kV feeder line down to canyon substation then
16 feeds ESF.
17 What we are studying is alternatives that
18 would deploy new 138 kV line in one of a couple
19 different alignments. Either completely redoing this
20 line or teeing off of it from right here, coming
21 directly over to that lower muck yard facility layout
22 that I showed you a few moments ago, or paralleling a
23 new site access road.
24 And what we would have is 90-foot
25 monopoles spaced about 400 feet apart. The 138 kV

1 line would provide us the kind of reliable power that
2 we are looking for. Right now, we have about four
3 power losses per quarter. Sometimes we have several
4 per week, you know, and these range in times from
5 milliseconds to hours.
6 I believe it was in the month of March we
7 had a power loss in Area 25 that shut down all of our
8 power to the ESF. It went on for about 12 hours. A
9 lightning strike on to the power lines. We want to
10 improve the reliability and in studying these
11 alternatives we believe that this new 138 kV line will
12 address that.
13 To do this, though, is a very tricky
14 negotiation. We have to work with the offsite power
15 vendors and negotiate a power procurement agreement.
16 They will want from us what we will commit to a power
17 consumption in multi-year. The advantage is we would
18 be able to potentially have them extend their power
19 transmission lines so basically they will carry the
20 burden of the cost and installation.
21 If we determine that through the
22 environmental assessment this is the plan we want to
23 proceed with, we will enter into negotiations with the
24 offsite power providers. And hopefully start
25 construction of that in fiscal year 2007.

1 Should we proceed again, the longpole in
2 the tent is the 42-week transformer procurement. The
3 actual construction of the power lines would be done
4 within about a two-month period. So it goes pretty
5 quickly.
6 Next slide. We talked a little bit
7 earlier about some of the things that we want to
8 address in the underground. And one of those is the
9 rail alignment. What we don't have any more is a
10 batch plant concrete production capability. We had an
11 older batch plant that was used during the site
12 characterization that was excessed several years ago.
13 It was not a preferable unit by any means.
14 What we are looking at now and what we are also again
15 addressing in this environmental assessment is
16 decisions for procuring a new batch plant that would
17 support a couple of different activities. It would
18 allow us to have Q-grade concrete to grout the
19 subsurface rail system.
20 It would allow us concrete for development
21 of any of those structures that we are currently
22 evaluating, whether it be the fire station or the
23 security station, or the subsequent, you know, craft
24 building or warehouse building, or an administrative
25 facility that we are looking at.

1 It would provide us concrete for those
2 301X areas I mentioned within the tunnel ground
3 support where we have the timber cribbing. We would
4 want to do pressure grouting to encapsulate that
5 cribbing to reduce the fire load.
6 So we are examining buying a new batch
7 plant, putting it in the exact location as pictured
8 here. This is the old batch plant location. That is
9 actually a picture of the old batch plant. So a new
10 readi-mix batch plant located it the same location,
11 supporting current site concrete needs.
12 New slide. Communications. These are
13 interesting photographs. What you see in the upper
14 photograph is a picture of the analog microwave system
15 that all of our communications go through. So phone,
16 commuter communications all go via an onsite fiber
17 system into this microwave repeater that is then
18 bounced off Skull Mountain all the way across Area 25.
19 In the lower picture, though, what you see
20 is the cut out in the muck pile. This is actually the
21 muck pile right here. And that is that same two-item
22 power transmission. We actually have to put a notch
23 in the muck pile so that we are not defeating line of
24 sight for the communications system.
25 If you go out and you want to work on your

1 computer at the ESF, it takes you about 30 minutes to
2 log on. It is that slow. About 1 Mb communication
3 rate. It is very annoying. Very, very annoying And
4 what always happens is never fails, I'll get a phone
5 call, Scott, you need to work on something.
6 Headquarters wants it right away. And I'll be out at
7 the ESF. And okay, I'm logging on. Bear with me. It
8 takes forever. We can't even add new phone systems
9 out there. We have reached the maximum of our ability
10 to even add new phone systems out there for our site
11 workers.
12 If that system goes down -- and it has
13 gone down -- we have nothing other than we have two
14 satellite cellular phones that we keep out there for
15 emergencies. That is our only backup for
16 communication. So if everything goes out, that is the
17 only means that we can use to summon help.
18 So we want to eliminate our single point
19 failure we have here. What we are looking at and what
20 we are addressing again in that environmental
21 assessment is deploying a new digital microwave
22 repeater system.
23 Next slide please. There you go. Thank
24 you. It would bounce off a new antennae adjacent to
25 the North Portal Pad onto the Yucca Mountain crest and

1 then down to that Gate 510 structure where it will
2 interface with a fiberoptic system. It actually comes
3 all the way up US 95 and comes up the edge of the
4 Nevada test site.
5 This would increase our transfer rate to
6 40 megabauds. It will eliminate the single point
7 failure. And if we get to our NEPA decision point and
8 implement this, we've got funding this year to start
9 construction of it. And hopefully finally have better
10 computer speeds. I can't tell you how happy that will
11 make our site workforce.
12 The last thing I wanted to talk to you
13 about is some strategic planning that we are looking
14 at. What you see on this slide here is, of course,
15 Las Vegas facilities versus the Nevada test site and
16 Yucca Mountain field facilities. We have those 121
17 facilities at the North Portal for our field workforce
18 but we also have 1,500 folks that we keep at Las Vegas
19 who work at our leased facilities.
20 What we are planning in multi-year is the
21 strategic migration of those folks out to where the
22 work is. Now keep a clear reminder that our work
23 objective is not to work in Las Vegas. Our work
24 objective is in the field.
25 So it all starts actually with our first

1 new facility that we will bringing online sometime in
2 the month of June. We have negotiated for signing for
3 -- signed a lease for a new facility in Pahrump. This
4 will be a new combination facility that will have an
5 augmented site information center for answering
6 questions of the public. It will also be a new
7 workplace for interacting with local government. So
8 that facility comes on line in June.
9 And we are also looking at leasing a new
10 facility somewhere within hopefully ten miles of the
11 Lathrop Wells area that would replace our sample
12 management facility. The sample management facility
13 is on the Nevada test site approximately about 10 to
14 15 miles from the ESF. Again, it is another structure
15 that was developed in the '60s.
16 The roof is failing on it. This is where
17 we keep all of our geologic core in our chain of
18 custody. If you want to go and maintain the air
19 conditioners on the roof, you can't now unless you are
20 in a crane in a basket because the roof has become
21 unstable enough you can't walk on it safely. So we
22 are looking at leasing a new structure that would
23 allow fur us to move in entirety all of our core into
24 that structure. Hopefully that will be somewhere near
25 the Lathrop Wells area.

1 The same thing with the Las Vegas
2 facilities. We are coming up with a strategic plan
3 that would allow for us when we have the new
4 facilities available, whether they be onsite or near
5 site, to start migrating our engineers, migrating our
6 ES&H staff, migrating the federal staff as well nearer
7 to the Yucca Mountain site.
8 Caliente -- as we are doing our
9 environmental statement for the Caliente rail
10 corridor, we are currently looking at opening an
11 office up in Caliente that would provide for better
12 communication with local government as well as
13 interested members of the public on what both the
14 environmental impact statement is looking at as well
15 as what is going on with the Yucca Mountain project.
16 Now most of our Las Vegas leases run
17 through 2010 so a lot of those lease -- these
18 transitions will start towards the tail end of this
19 decade. We want to do it in a strategic manner.
20 That pretty much completes the key things
21 I wanted to discuss with you today. And I would be
22 glad to answer any of your questions.
23 MEMBER HINZE: Thank you very much, Scott.
24 We'll ask the Committee if they have questions. Ruth?
25 Dr. Weiner?

1 MEMBER WEINER: Thank you very much for a
2 very thorough presentation. I'm going to start with
3 your last point first.
4 And looking at the Waste Isolation Pilot
5 Plant in which -- in Carlsbad, and I wanted to tell
6 you that Carlsbad is a metropolis compared to some of
7 your more local facilities in Nevada, and it is
8 difficult to get people to stay. Sandia and DOE and
9 the contractor have all maintained offices in Carlsbad
10 that do not deal with the operational part of the
11 Waste Isolation Pilot Plant. It is very difficult to
12 maintain something like an engineering force in a
13 place like that. I mean the schools are not that
14 good. There is no good medical facilities. All of
15 the facilities that exist in a larger community are
16 absent.
17 There is no higher education facility.
18 There are no good libraries. The whole thing -- and
19 you can't do everything electronically. I somewhat
20 question how are you going to address that in trying
21 to move people to places like Caliente and Pahrump --
22 out of Las Vegas?
23 DR. WADE: A couple different responses
24 for you. First would be complete agreement
25 recognition of the challenges in rural locations.

1 There are also challenges in Las Vegas. I actually
2 was born and raised in Las Vegas and what has just
3 become striking is the cost of living in Las Vegas,
4 particularly buying a home. It is very difficult now
5 to actually attract workers because it has become so
6 pricey.
7 Pahrump is a little bit better but not
8 much. Pahrump has been developing a great deal of the
9 infrastructure that rural communities strive for. I
10 believe their first hospital is going to open within
11 the next few months.
12 Nye County has been studying and they have
13 discussed it with Department of Energy several
14 different options for developing assets with Amargosa
15 Valley. And I would encourage you to discuss it with
16 Nye County. I don't want to go on record for all of
17 their proposals. But they are thinking strategically
18 as well.
19 They are looking at not only the
20 communities of Beatty but the Amargosa Valley area as
21 well as Pahrump. And they are trying to come up with
22 a strategic plan that addresses what kind of
23 communities would be developed to best support not
24 just Yucca Mountain development needs but NTS actions
25 as well as economic diversification.

1 MEMBER WEINER: You also have the problem,
2 especially with professional families, of two-career
3 families. And this has been one of the points in
4 Carlsbad that has really kept people from moving to
5 Carlsbad. It is okay one member of a married couple
6 has a career there. What does the other person who is
7 also an engineer or a professional or a university
8 professor, what do they do?
9 DR. WADE: Yes.
10 MEMBER WEINER: And I point out that
11 beyond just the physical infrastructure problems, that
12 is a major problem. And, you know, I hope you find
13 ways to address that. But I think that that really
14 needs to be taken into account in your planning.
15 DR. WADE: I would whole-heartedly agree.
16 In fact, I think we have the luxury of a little bit of
17 time but not a whole bunch.
18 The idea would be as we understand and
19 layout our repository schedule, subject of course to
20 decision-making of NRC or construction authorization
21 to work with local government, have them understand
22 what our workforce is going to be, where our workforce
23 might be located so that they can work with the local
24 communities to anticipate those, to address just what
25 you are referring to, to address the types of jobs

1 that might be coming as well as the associated family
2 conditions that they would want to address.
3 MEMBER WEINER: Another question, why were
4 not things like proper drainage in the muck yard, why
5 weren't they completed? I mean it seems like such a
6 logical thing to complete.
7 DR. WADE: That is an excellent question.
8 I probably can't do it full justice but in the '90s,
9 decisions were made for a couple of reasons including
10 money reductions in the mid-'90s. There were some
11 striking funding reductions. So because of those
12 funding reductions, decisions were made not to
13 complete some of the original design for those onsite
14 structures, those onsite utilities.
15 And we had designs for everything
16 including the underground rail system, underground
17 power system, even the surface attributes. We had
18 designs for all of that. Our onsite constructor at
19 the time was allowed to not complete those, to do what
20 we call temporary construction, which is great if you
21 do that for a short period but where it falls apart is
22 in multi-year because that kind of construction means
23 it has a very, very poor longevity.
24 So it was probably poor decisions that
25 were made in essence.

1 MEMBER WEINER: Finally, I've heard just
2 at other meetings in Las Vegas now and again somebody
3 will get up and complain about some kind of health
4 problem for workers in the underground, talks about
5 injuries. How is your occupational safety and health
6 record? And is that generally known to the public
7 what it is like? Do you make that public?
8 DR. WADE: A very good question. I'm also
9 in charge of Environmental Safety and Health for the
10 project. And we have a very good safety and health
11 record. Our recordable incident injury rate and our
12 lost work rates are some of the lowest in the
13 Department of Energy and we are very proud of that.
14 We are always striving to assure that we
15 have got the right safety programs, the right design
16 safety solutions in place to protect our workers
17 overlaying those with both personal protective and
18 administrative controls. Everything from our
19 selective control program to protect workers in the
20 underground to all the other OSHA requirements. For
21 example, if you were to enter a confined space to work
22 on our electrical system in some of the vaults on the
23 surface, those kinds of things.
24 We haven't shared with the public a lot of
25 that directly. We haven't talked with them about

1 those work case rates of late. I would acknowledge
2 but they are quite good. They are readily available.
3 I don't know, did I answer your question?
4 MEMBER WEINER: In part. Have you
5 actually had cases of silicosis or anything like that?
6 Then I'll quit.
7 DR. WADE: There is the issue of
8 silicosis, including some ongoing litigation between
9 members of -- former workers for the Yucca Mountain
10 project in a class action lawsuit against the various
11 contractors that have worked for the project. That is
12 underway.
13 The Department is not a party to that
14 litigation but I would probably be the wrong person to
15 try to describe where that litigation is.
16 MEMBER WEINER: Well, I don't want to put
17 you on the spot. I was just curious.
18 MEMBER HINZE: Thanks very much, Ruth.
19 Other questions? Jim?
20 MEMBER CLARKE: If you do all the onsite
21 upgrades that you've presented to us, do you have a
22 total project cost estimate for that?
23 DR. WADE: Yes, the onsite upgrades will
24 probably be in the neighborhood of 100 million
25 dollars. We are still coming up with detailed

1 estimates but in my budget this fiscal year alone,
2 I've got 91 million dollars for the operation and
3 initial seed funding for a lot of these things.
4 I've got -- until we arrive at the NEPA
5 decision points, I've got funding identified for
6 development of the first ten miles of road. I've got
7 funding for that offsite power. I've got funding for
8 the fire station including the initial utilities to
9 support that. I have funding for the Pahrump facility
10 as well as replacement for the sample management
11 facility.
12 So last year actually I developed a
13 strategic plan in multi-year to try to look at all of
14 these things. We have range estimates. I'm actually
15 trying to look at any initiatives I can to reduce the
16 cost where I can. In fact, I just got from the Corps
17 of Engineers yesterday the cost estimate for the first
18 three miles of road, which is about 3.1 million
19 dollars, about a million a mile.
20 MEMBER CLARKE: That answers my question,
21 thank you.
22 MEMBER HINZE: A quick one, Scott, the
23 1992 Little Skull Earthquake created quite a bit of
24 damage on the NTS and on the field operation center.
25 What is being done in terms of preparing for seismic

1 hazards in these new constructions?

2 DR. WADE: These will all be built to

3 Uniform Building Code and International Building Code

4 requirements for a seismic hazard. They don't have to

5 be as robust as a nuclear-grade facilities would be

6 for the repository phase. But they would be built to

7 the same building standards that you would have of any

8 industrial facility you'd find in Las Vegas, for

9 example.

10 MEMBER HINZE: So any electrical

11 structures that are being constructed as part of this

12 enhancement of the infrastructure would not

13 necessarily be used in any way in terms of the

14 repository or the pre-closure operational facilities?

15 DR. WADE: Correct. Actually that is an

16 excellent point. All the assets that I have

17 described, whether it be the new facilities we are

18 proposing to construct, the new offsite electrical

19 connections, et cetera, these are not repository

20 assets. These are simply for the continued operation

21 and maintenance of the Yucca Mountain site.

22 MEMBER HINZE: Thank you very much.

23 If there are no other questions, what I

24 would suggest is it is not in the agenda but that we

25 take a ten-minute break. We'll start at a quarter to

1 and tat will give us all a chance to get a breath and
2 to then hear about the Nye County Early Warning work.
3 We will return at 9:45.
4 (Whereupon, the foregoing matter went off
5 the record at 9:35 a.m. and went back on the record at
6 9:45 a.m.)
7 MEMBER HINZE: Thank you again to you,
8 Scott. And now we move to the final two presentations
9 of the morning on the update on the Nye County
10 Independent Early Warning Drilling program, and we'll
11 start off with Drew Coleman, who will be discussing
12 the Department of Energy's interaction with this
13 program, if I understand correctly. Drew, it's
14 your's.
15 DR. COLEMAN: Yes. Thanks again for
16 letting me address the committee again. I hope I can
17 be worthy of this two-hour block of time you got for
18 me here. I was asked to talk, give an update on the
19 cooperative agreement with Nye County, and so my
20 suggestion was we have a Nye County technical person
21 also come and talk, and that'll be John Campanella
22 later. I was going to give my overview of how the
23 cooperative agreement works, and then he was going to
24 talk about some of their technical work. And it's
25 possible that --

1 MEMBER HINZE: Drew, you do it the way you
2 wish.
3 DR. COLEMAN: -- there was some
4 misunderstanding here. I don't know that you sent
5 your slides, so I guess maybe there's not hard copies
6 around. Anyway, I think he came with a presentation
7 that will be viewable on the screen. But for this
8 talk, I guess I'd be a technical monitor for the Nye
9 County Cooperative Agreement. And as I administer the
10 cooperative agreement with Nye County, I kind of look
11 at the regulations that guide the Department. 10 CFR
12 600 has some descriptions of how cooperative agreement
13 works and there are grants that allow participation by
14 DOE, and I kind of operate a cooperative agreement
15 that way.
16 A cooperative agreement is a five-year
17 over-arching agreement with scope in it for a number
18 of activities. I also look at the Nuclear Waste
19 Policy Act that talks about how affected units of
20 local government can engage in monitoring, and
21 testing, or evaluation activities, and so those are
22 kind of some of the guiding regulations or laws that
23 I use as I work with Nye County to run a cooperative
24 agreement.
25 Now annually, they submit a program for

1 the upcoming year to me, and I do a technical review
2 of that and get it approved. And their fiscal year
3 runs April to April, so that just happened. I just
4 finished reviewing their upcoming program, and I think
5 the Contract Group issued an approval of their planned
6 work for the upcoming year.
7 I also get the budget put in the set-aside
8 for the county activities and work with them to make
9 sure that everything is set from a contracts point of
10 view. And I also get some project scientists funded
11 to collect project data cooperatively with the
12 program. If we need Q Data from any particular
13 activity, then I would get project scientists funded
14 for that.
15 Another thing that we do under cooperative
16 agreements is we provide in-kind services, where they
17 make sense. Like we have a sample management
18 facility. It's a large facility with curators, and so
19 Nye County uses that facility to have their samples
20 curated and stored in, and then they don't have to buy
21 their own facility or whatever. It works pretty well,
22 I think. So with that, I was going to go right into
23 the work elements that they have in their cooperative
24 activity for the upcoming year.
25 They've got a ventilation-related studies

activity. That's kind of their small activity that they have going in the underground facility. They've got a work element for ATC, but they aren't doing anything in that this year. They have the over-arching agreement that can have scope. They've got their well drilling activity, and they're going to finish Well 32P. That's a well, I think, in one of the volcanism centers. And then the big activity there is the horizontal bore holes that we're discussing locations for and different things.

They got some geological sampling activities where they collect their samples, and curate them, and so some analyses of them. They've got some water chemistry activities where they sample a lot of the holes that they've drilled, and we often take splits of this samples, reflect our own samples for geochemistry. They do some water level monitoring, some geophysics.

MEMBER HINZE: Drew, are all these part of this fiscal year's --

DR. COLEMAN: This fiscal year's activities, yes. These are what they propose, and what I reviewed and approved. They've got tracer testing activities, and just general regional geological characterization activities.

1 Now I didn't really have a conclusion
2 slide here. I was kind of thinking what that might
3 look like. I listened with interest yesterday when we
4 talked about working together with stakeholders to
5 build confidence, and I think this is a nice example
6 of one of the ways that we are doing that. We work
7 with Nye County. They have an independent program.
8 I haven't reviewed his slides. Their work is their
9 work, and if we need to collect data, we have our
10 scientists work cooperatively with these guys to
11 collect our data sets. And it's been a mutually
12 beneficial way to work most of the day that's kind of
13 useful in the saturated zone. And I think with that,
14 I'll turn it over to John Campanella, who's one of
15 their technical contractors, to discuss some facets of
16 the technical work they've done over the past few
17 years. Go ahead, John. Thank you very much, John.
18 MR. CAMPANELLA: You're welcome. I'm
19 sorry that I didn't get the word that I was supposed
20 to come with hard copies. It kind of worked out for
21 me since I was doing this, finishing it up on the
22 plane on the way out here. Go to the next slide.
23 I'll tell you a little bit about me. I've
24 got a BS in Chemical Engineering, 25 plus years
25 experience in the oil and gas industry, so I'm coming

1 from a different perspective. I've done production
2 work, including well design, single and multi well
3 testing with pressure and chemical tracers, and then
4 reservoir engineering experience.
5 I've developed work with commercial
6 software in large simulation studies of oil and gas
7 fields, typically running about 200 plus wells. And
8 also did some detailed fracture mapping in a field
9 with 1500 plus wells, and we validated using actual
10 field performance. And then I continue to do
11 simulation studies in oil and gas fields around the
12 world. Next slide, please.
13 What do I do for Nye County? I assist Nye
14 County with independently gathering and verifying
15 ground truth data, such as well planning and design,
16 the pump testing, data gathering and analysis, and we
17 use the latest methods developed for the oil and gas
18 wells and apply it to the aquifer system we're looking
19 at. And then I've also done the chemical tracer test
20 design, data gathering, and I'll show you some of the
21 analysis that we're working on now. We analyze well
22 tests to improve the system models, and we evaluate
23 the technical data and methodologies used by the DOE,
24 YMP, USGS and the other researchers. Next slide.
25 My overview is going to be, we're going to

1 give an update on the EWDP drilling program. We're
2 going to look at a little bit of history, and then the
3 most recent wells, the Phase Five wells, location and
4 completion information that we've gotten off of those
5 new wells.
6 I looked at the last time Dale
7 Hammermeister was here, and he presented some stuff on
8 sonic coring to you guys, so we thought it would be
9 wise to kind of go back through and show you what work
10 has been done approximately since that time. We're
11 going to look at tracer testing at Site 22S. That's
12 taken up quite a bit of our time last year, and the
13 analysis phase this year. Look at the tracer testing
14 implementation and preliminary results from numerical
15 modeling.
16 We'll also show you some stuff from the
17 Office of Science and Technology and International
18 OSTI, the installation of the U-tube in 24PB well, and
19 then we'll follow that up with some information on the
20 proposed horizontal well. Go ahead, next slide.
21 The Early Warning Drilling Program was
22 begun in 1998, and it's a major part of Nye County's
23 Independent Scientific Investigation Program. It's
24 funded through cooperative grants from DOE. Data
25 collected under a formal Q&A program, and the data is

1 shared with all interested parties through the Nye
2 County technical reports and website. Next slide.
3 The goals, the characterization, the
4 potential flow paths between Yucca Mountain, Amargosa
5 Valley, the reduction of uncertainty in the DOE Yucca
6 Mountain project performance assessment models is
7 another goal, and support of ground water monitoring
8 network design. Next slide.
9 The activities that we have are drilling,
10 geological sampling and logging, and well
11 construction, bore hole and airborne geophysical
12 logging, aquifer pump testing, which I've been a part
13 of, ground water chemistry sampling and analysis,
14 ground water level monitoring, and lab testing
15 hydraulic parameters such as the geologic samples.
16 And here is the pre-EWDP wells, and as you can see,
17 they're kind of clustered around Highway 95, and down
18 in here where they've got some agricultural interest.
19 And then here's the test site boundary here. Here's
20 Yucca Mountain. And they're kind of poorly scattered
21 up in he, the well locations, so it was thought that
22 they needed to be kind of gaps filled in, and that's
23 how this program was designed. Next slide.
24 So we are looking at Phase One through
25 Four wells. And as you can see here. Here we go.

1 Basically it's kind of hard to see at this resolution
2 and stuff, and I'm sorry about not having the
3 handouts, but as you can see, we go Phase One, Phase
4 Two, Phase Three, and Phase Four wells, and so we
5 start out here with our Phase One. We end up here
6 with our Phase Four wells. And a lot of wells that
7 I've been working on here are the Phase Three area by
8 Forty-Mile Wash.
9 MEMBER HINZE: John, while that's up
10 there, can you tell us something about the depth of
11 the well, and thus the objective of the well?
12 MR. CAMPANELLA: Typically, they go down
13 into about 1,000 feet roughly. It depends on where
14 we're at. These wells here in the alluvium, and when
15 you get in over here you're into some of the
16 volcanics.
17 MEMBER HINZE: They're both in the -- they
18 go to the volcanics?
19 MR. CAMPANELLA: No. Typically, they just
20 end up in the alluvium. I've got a slide following
21 this on the new wells, and it shows what they're
22 completed in, and the depths. Next slide, please.
23 Here's the most recent wells, the Phase
24 Five wells. And these are the red dots in here.
25 That's 24PC, and that's completed in the alluvium.

1 This is 24 PD. It might be referred to a couple of
2 slides as PA. They tried drilling it as PA, couldn't
3 get it down, had problems with well, skidded over and
4 started and called it PB, and that goes into the top.
5 And we'll have some more information on the
6 installation of the U2 into that well. And the rest
7 of these all here, I believe, are all in alluvium.
8 Next slide.
9 Here's the slide that basically gives the
10 well type. They're P wells, and the drilling
11 completion date, the total depth as you can see. This
12 one goes down to about 15, 13, 657, and about 1,000
13 feet estimated for this well here, which I think is
14 32P. And as you can see, here's the lithology that
15 we're looking at, alluvium, alluvium, tertiary tough,
16 alluvium, alluvium, and this, I believe, is in
17 alluvium, too. Drew might know that one. Right? Is
18 that the last well they're finishing up in the
19 alluvium?
20 DR. COLEMAN: Yes. I think they're going
21 to drill it through one of these varied volcanic
22 centers is I think what that is.
23 MR. CAMPANELLA: Oh, that one.
24 DR. COLEMAN: Yes. It goes through some
25 alluvium, and then --

1 MR. CAMPANELLA: Into the varied volcanic.
2 Okay. So in that case, it actually does go through
3 alluvium to the varied volcanic. Next slide.
4 We'll go through the tracer testing. And
5 I've got a lot of slides, so we're moving pretty fast.
6 Reduce uncertainty in the saturated zone transport
7 parameters is one of the tracer testing goals, provide
8 estimates of the effect of flow porosity and
9 longitudinal dispersion, investigate possible
10 existence of a stagnate layer in there, and
11 investigate possible hydro stratigraphic layer
12 communication. Next slide.
13 The methodology we used was to build upon
14 the previous testing that we had done at 22S site, and
15 that was pump testing. We did two single well push-
16 well tracer tests were performed on the main well,
17 22S. We'll show some maps and some images of that.
18 And then we did multi well cross-hole tracer tests
19 were conducted at Site 22 during January of 2005 with
20 multiple tracers. Next slide.
21 We used a total of 10 fluorinated
22 benzoates and salts, and they were all injected as
23 conservative tracers. We used Lithium as a cadine for
24 one of the halides, Lithium Bromide, an additional
25 Lithium mass was added as a reactive tracer. We used

2.5 kilograms of 25DFBA, was used as a qualitative tracer, very small mass because as I'll show you, we are concerned that we'd never produce that back. And as it turns out we never did, so we put a small mass in there so we could get by with the state. And we're looking for stratigraphic communication in that case. We also put in two plus grams of fluorescent microspheres were injected. Next slide.

Here's the Site 22 plan view. This is a very nice site. Prior to the injection of the cross-hole tracers, we actually placed this well, 22PC, on this location. Originally, it was just these three wells with differing screen depths as we'll see in a figure here pretty quickly. This well was drilled and completed again during the testing prior to the injection of the cross-hole tracers.

MEMBER HINZE: What's the distance there? I can't see.

MR. CAMPANELLA: That is 18 meters, 59 feet from there, to there, to there. So equal distance from here to the producing well, pumped well, 22S, and the injection wells here, 22PC and 22PA. And it's pretty interesting the results that we did get out of that, them being equal distance. Next slide.

Here's a view of it, and again, the

1 comments have been made about the remoteness of the
2 locations and so on. And as you can see, you are out
3 in the middle of nowhere, so you have to set
4 everything up and be pretty self-sufficient out here.
5 We did a lot of work with PVC, and poly tanks to keep
6 the cost down. Here's our pumping well, and then back
7 here is one of the injectors. That's 22PA, or PB,
8 excuse me. And here's one of the discharge lines.
9 Next slide.
10 Here's our pumping well, 22S. We've got
11 submersible pump in here capable of about 46-48
12 gallons per minute out of one of the zones. And we
13 basically go through a meter run, and then we head off
14 into a sampling loop in here in the trailer, and then
15 head out and discharge out here. These lines back
16 over this way are basically used to fill our tanks
17 prior to mixing the tracers with produced water. Next
18 slide.
19 Again, you're remote so you need to have
20 generators to run all your equipment in your trailer
21 to generators, one for backup and fuel on site. Next
22 slide.
23 For the push-pull test, we rented some big
24 21,000 gallon what they're called Baker tanks, and
25 they're basically a big semi comes up and wheels back

there, and they fill up, and that line is going back into the submersible pump, and we just fill those two guys up for the push-pull test prior to doing any kind of tracer testing. Next slide. And then out here is our discharge point, and that's me out as the sun is setting here in the fabulous Nevada desert. Next slide.

Again, here's the site plan. We're looking at 59 feet 18 meters between these wells. These two wells here were the injection wells, and then when we look at it we'll see why this wasn't used for injection. Now it's interesting -- go ahead.

MEMBER CLARKE: Single well tests were done on --

MR. CAMPANELLA: On this well, 22S. Part of the reason why is because these are two inch pieziometers, and you can't pump out of them at any high rate. This well can handle, I think it's over five inch, so we put a four inch submersible into it right dipped into the top of the water table.

The permeability around this area, and I'm in the petroleum industry so I deal with permeability, is about 14 Darcis, so it's quite high. There is actually no visible gradient amongst any of these wells. It's a flat water table. Next slide.

1 Here's detailed information on the zones
2 and screened out since Site 22 wells, and it gives all
3 the footages and stuff. Suffice it to say, what we
4 are looking at for the test was this Zone 2, which is
5 about 115 feet thick. And again, there's no real
6 discrimination between any of these zones. There's
7 nothing that you can really see in the lithology that
8 says I'm in a subset of the zone. It's all cobbles
9 and various sorting of different type of gravels, a
10 giant gravel field, essentially. Next slide, please.
11 Here's a view in 3D of what we're talking
12 about. Here's 22S, which is the well that we're
13 pumping. What it has is four different screens in the
14 single well. They're each isolated with a packer
15 system made by Westbay with little ports that open up
16 to allow us to monitor pressure, and then other ports
17 that allow a sliding sleeve arrangement, allow us to
18 pump out of individual screens. Basically, we had
19 pressure gauges in each one of these screens
20 monitoring the pressure during this test, even in
21 these screens over in here, so we were fully monitored
22 on the pressure on each one of those screens. And
23 what we had is basically in this well, this port was
24 open, so this is where we are pumping from and
25 injecting the tracer during the push-pull tests, and

1 then pumping the fluid back during the push-pull and
2 then the cross-hole test.
3 Injection occurred in these - next slide,
4 please. I think I've got a better picture of that,
5 yes. Zone One, that top set of screens, we injected
6 qualitative tracer into Zone One in this well right
7 here, 22PA. And this Zone Two is where the major
8 action was occurring basically, and we're only looking
9 at these three wells now. I've removed the 22PB deep
10 well because it really wasn't involved except as a
11 pressure monitoring well in those lower screens for
12 the tracer test. Again, Zone Two right in here is
13 what we are looking at from the standpoint of tracer
14 injection and production with the exception of dumping
15 that 1.5 kilograms of tracer in here. Next slide,
16 please.
17 Here's the preliminary results that we got
18 from the first push-pull test. And again, it's a
19 little hard to see, but what we have here is we used
20 flourinated benzoate, PFB in this case, and Iodine as
21 the two tracers. They have different diffusion
22 coefficients, so we're looking for that stagnant layer
23 with that. As you can see from this plot, the lines
24 here are plus or minus 10 percent which the lab people
25 tell me is there level of accuracy on the analysis, so

1 it gives you kind of a confidence band of what you're
2 looking at.
3 MEMBER HINZE: That's just the instrument
4 measurement arrow. That's not a sampling there at
5 all.
6 MR. CAMPANELLA: No, just the instrument,
7 so it's coupled on top of that. You could have even
8 more.
9 CHAIRMAN RYAN: The instrument arrow will
10 typically be the smallest --
11 MR. CAMPANELLA: The smallest --
12 CHAIRMAN RYAN: So I don't think we should
13 put much value on it. It's probably much bigger.
14 MR. CAMPANELLA: Exactly. I agree with
15 you, absolutely.
16 CHAIRMAN RYAN: Okay.
17 MR. CAMPANELLA: I have some people talk
18 to me about subtle changes in these curves that they
19 feel indicate something, and to me they don't indicate
20 anything.
21 CHAIRMAN RYAN: Thanks.
22 MEMBER WEINER: Excuse me. What is the Y
23 axis there?
24 MR. CAMPANELLA: This is cumulative
25 gallons pumped on the Y axis. Oh, the Y axis - it's

1 normalized parts per million milligrams per liter
2 divided by the total mass injected.
3 MEMBER WEINER: Okay.
4 MR. CAMPANELLA: So we're normalizing both
5 tracer curves for the total mass injected. Sorry
6 about that. It got cut off, it's over here with your
7 display. These are the details of the test
8 information, and basically I'm not going to go through
9 that. That's just up there for information purposes.
10 The most important feature of this is these two curves
11 basically are laying right on top of each other,
12 showing no real diffusion effects in this case. This
13 test was only shut in for 72 hours. This was a very
14 short test. Next slide, please.
15 This is just --
16 CHAIRMAN RYAN: Just out of curiosity,
17 what's the diffusion length in 72 hours for these -
18 MR. CAMPANELLA: What's that?
19 CHAIRMAN RYAN: I mean, what would the
20 diffusion length be? Is that test long enough to show
21 diffusion effects? I don't know. I'm asking, because
22 I just don't know.
23 MR. CAMPANELLA: I don't know. I can't
24 tell you that. I can't answer that one. What we
25 wanted to do is we wanted to do a series of tests

1 instead of just one to look at the drift time effect
2 on it. And I think that's really important, too.
3 What's kind of interesting on these curves, if you
4 were to look at it from an idealized case, this is
5 basically where the center of mass would be, would be
6 right out in here. And so what happens to us in this
7 case, it actually looks like the tracer moves forward
8 in pumped barrels, so it moves closer towards the well
9 bore, and that's probably because of the gradient.
10 And we see more of a move towards the well bore in the
11 second test than in the first test. This test was for
12 over 700 hours, or days, excuse me, days. No, no,
13 hours. I can't read that, it's hours. It was about
14 30 days, 700 hours.
15 MEMBER HINZE: Well, what are we learning
16 from this, that shift is telling us what?
17 MR. CAMPANELLA: Well, what it's telling
18 us is most likely that we have a gradient that's
19 affecting us, and it's pushing the tracer. What you
20 can envision is, in ideal space, a perfect ring, a
21 donut would go out of the tracer, that donut moves
22 through time, so the short period of time, that donut
23 doesn't have a very long time to move. In the longer
24 period of time it moves faster, so you've got
25 diffusion going on, and then you've got the gradient

1 on top of that. And from the difference between these
2 curves - and again, this is plus or minus on the lab
3 stuff - they're really within the same band even here,
4 even though there's some difference between the
5 curves.
6 DR. MARSH: Can I ask one question?
7 MR. CAMPANELLA: Go ahead.
8 DR. MARSH: Tell me a little bit about the
9 experiment now. It's pumped in and then pumped out?
10 MR. CAMPANELLA: Yes.
11 DR. MARSH: You wait, you pump it in, you
12 wait 30 days and pump it out.
13 MR. CAMPANELLA: Right.
14 DR. MARSH: So there's a hydrostatic head
15 set up to begin with away from the well because you're
16 pumping in, so you're going to get a bulge of water
17 there. And the material is going to --
18 MR. CAMPANELLA: Yes.
19 DR. MARSH: You're going to have a
20 gradient away by itself, and then you're pumping it
21 back, and then you have a draw-down effect.
22 MR. CAMPANELLA: Yes, you do.
23 DR. MARSH: Okay. And so then you have
24 diffusion on top of it.
25 MR. CAMPANELLA: Yes.

1 DR. MARSH: Do you know what the
2 diffusivities are of these things?
3 MR. CAMPANELLA: Not off the top of my
4 head, but yes. There's literature.
5 DR. MARSH: Okay. Are they very
6 different?
7 MR. CAMPANELLA: They're fairly different,
8 yes. I think an order of magnitude.
9 CHAIRMAN RYAN: Just for the record,
10 Bruce, I'm going to introduce you. Bruce Marsh was
11 the one asking those last couple of questions.
12 DR. MARSH: One more quick one. What were
13 your recoveries?
14 MR. CAMPANELLA: Nearly 90 plus percent,
15 in the high 90s on these tests.
16 MEMBER HINZE: Do we see anastropity in
17 the diffusivity?
18 MR. CAMPANELLA: No.
19 MEMBER HINZE: Any direct fill effects?
20 MR. CAMPANELLA: No. When you go to the
21 cross-hole test, I'll show you some information that
22 shows you the anastropity in the reservoir, but you
23 can't see it on these. And it may be that we haven't
24 pushed it out far enough, and I'll show you some
25 information that kind of supports that process here.

1 If you do some modeling and you get out into one of
2 the fast flow paths, then you would expect to see a
3 double hump or a little bit of a break in here, and
4 you don't see that at this stage, the length of time.
5 And going back to the experiment, what we
6 did was we mixed up the tracer. It was in
7 approximately 4,000 liters of tracer volume, and then
8 we displaced it, and I'm going to switch units on you,
9 to about 19,00 gallons of water. And those big tanks
10 that you saw, those big blue tanks, those were the
11 displacement volume, so that pushed that ring of
12 tracer out into the formation away from the well bore.
13 CHAIRMAN RYAN: Again, I'm asking this
14 just because I don't know. Does that put any pressure
15 on the system or is it -- I mean, by the very nature
16 of the tests, do you influence the rates of movement
17 and so forth?
18 MR. CAMPANELLA: You do have some
19 influence on it.
20 CHAIRMAN RYAN: Yes.
21 MR. CAMPANELLA: Absolutely. You've got
22 to. In order to push it away from the well bore,
23 you've got to put a gradient on it.
24 CHAIRMAN RYAN: Well, let me ask the dumb
25 guy question; how do you then interpret that in terms

1 of the natural condition?

2 MR. CAMPANELLA: You really can't in terms

3 of the natural condition from the standpoint, except

4 for the drift period, and that's when it goes back

5 into a natural condition.

6 MEMBER CLARKE: You can't do it with one

7 well.

8 MR. CAMPANELLA: This was a test that they

9 had done at the ATC, and these kind of tests I'm not

10 real fond of.

11 MEMBER CLARKE: No, but if you wanted to

12 reproduce natural conditions, you'd need an injection

13 well, an observation well.

14 MR. CAMPANELLA: And a producer. You,

15 supposedly, are able to get some information out of

16 these from the standpoint of the gradient. Again,

17 from that movement of that volume of tracer, as that

18 donut basically moves down, or whatever shape it is,

19 as you move that volume away either towards the well

20 or passed the well.

21 MEMBER CLARKE: Okay. Thanks.

22 MR. CAMPANELLA: But these tests, again,

23 I'm not real fond of. Some people might look at that

24 and say that this is a signal here where they

25 crossover. I look at it, and again, back to your

1 comments on the sensitivity of the information, I
2 don't see anything really different between those two
3 curves to speak of that gets me too excited. Next
4 slide, please.
5 Now this is the raw data coming in,
6 preliminary data from the cross-hole test. And I'll
7 go through and tell you what this is. This is
8 producing time in days on this axis now, producing
9 time in days. These are the cross-hole. This is from
10 the well 22PA, which is the well to the north towards
11 22S. These are two different tracers. One was a FBA,
12 and the other is Bromide. Now there's some question
13 on the Bromide mass. We had some issues on that,
14 whether or not we have -- we, apparently, lost mass in
15 this from what we thought we injected, and we're still
16 scratching our heads because it doesn't make a whole
17 lot of sense to us. And I think it might be more
18 along the lines of either we had some spillage when we
19 were mixing up the tracers or something like that, but
20 things just don't really make a whole lot of sense.
21 I don't think there's enough discrepancy between these
22 two invalidating the information.
23 What's really very interesting here is
24 during this period of time we're pumping back and
25 producing, and then we have a shut-in period here.

1 And this is 159-day long shut-in period when we're
2 getting set up to do another tracer test, so we got
3 approval from the state to go ahead and shut-in. And
4 so what happened here is now we're getting a signal
5 from the natural gradient, direction, azimuth, and
6 magnitude is showing up in these production right in
7 here, so that, I find, is really interesting. And
8 that wasn't planned, basically. That was just kind of
9 fortuitous that we got that information.
10 CHAIRMAN RYAN: What are the different
11 colors?
12 MR. CAMPANELLA: The different colors are
13 the different types of tracers. The red is the
14 halide, the bromide, and the blue is the FBA. And I
15 try to keep that in all the slides to be that same
16 color scheme. Okay. Next slide.
17 Again, this is the response curve coming
18 in from the other well, 22PC, which is at 90 degrees
19 to 22S due east. Again, you see a similar shape
20 curve, and I'll put all of them together. And again,
21 right here, we also get a signal coming back. And
22 this signal is a little bit different, and you'll see
23 it in some of the other slides here from the ones we
24 just saw, which gives us, again, the gradient,
25 magnitude, and azimuth, some information along those

1 lines. Next slide, please.

2 Here's the curves all together. Here's

3 now the 22PC well. As you can see, there's a big

4 difference in basically the first arrival and the peak

5 arrival times between these wells, so this is the

6 north-south well, and tracers are coming in much more

7 quickly than the east-west well right in here.

8 CHAIRMAN RYAN: Just a quick question. I

9 guess the areas under these curves should be about

10 equal. Is that right?

11 MR. CAMPANELLA: Yes.

12 CHAIRMAN RYAN: Okay.

13 MR. CAMPANELLA: The recovery curves,

14 we're still in, I think in these cases, I don't have

15 it plotted up in this presentation, but we're looking

16 at 80 plus percent. A couple of the curves are a

17 little better than some of the other ones on recovery,

18 but again, within reason from the standpoint --

19 CHAIRMAN RYAN: And I guess I asked that

20 question just to kind of -- that's how you verify

21 nothing is going in a place where you don't --

22 MR. CAMPANELLA: Exactly.

23 CHAIRMAN RYAN: Okay.

24 MR. CAMPANELLA: Yes, exactly. Part of

25 the thing is, when we're looking at, I think on the

1 bromide side of things, that's where some of the
2 confusion comes in because it looks like we're getting
3 pretty close to 100 percent recovery on that curve,
4 and it's like no, it doesn't make sense compared to
5 some of the other ones.
6 MEMBER WEINER: Because I'm a complete
7 novice in this area, what exactly does the difference
8 in those peaks tell you, the difference in the
9 gradient, the difference in the flow rate, what?
10 MR. CAMPANELLA: This stuff right here,
11 we'll go through a little bit of that in the following
12 slides here, but this - the arrival time has
13 information on porosity, effective porosity.
14 MEMBER WEINER: Thank you.
15 MR. CAMPANELLA: And in this case, these
16 differences in the way these look is where I'm getting
17 some information on the gradient, azimuth, and
18 magnitude. And that was fortuitous in that case. But
19 basically, what we're seeing here, and we talked about
20 a fast path in the alluvium, we see a fast path in the
21 alluvium, compared to what we would expect. We'll go
22 through some of those numbers and some of the values
23 in the next couple of slides.
24 MEMBER WEINER: Thank you.
25 MR. CAMPANELLA: What we did is the reason

1 we shut down for that 159 days is because we had a
2 suggestion to go ahead and run in with Pherenached,
3 and we used Iodine as a tracer to look at the redox
4 conditions for Technetium. But basically, that's what
5 we were looking for here, was to see whether or not we
6 had the case where we basically would start to deposit
7 some Rhenium out in the formation. And again, looking
8 at these curves, I don't see anything within that
9 information that tells me that we've got any kind of
10 a situation like that occurring where we've got a
11 precipitation, and so it looks like it supports the
12 DOE assertation that it won't precipitate out. And
13 that's why we shut-in for those 159 days, was in order
14 to get the permit modified to get this test done. And
15 the reason we decided we could go ahead with this test
16 is because we found this fast flow path, so the
17 decision was made, wow, we've got a fast flow path.
18 It took a short period of time to see that; so,
19 therefore, we could pull off this other test, and if
20 we saw a delay, we'd still have a fast enough flow
21 path to pick it up. And that's one of the issues that
22 you run into in these type of tests.
23 The tests are easy to perform. They're
24 not very expensive to perform from the standpoint of
25 the materials involved. What kills you is the fuel

1 cost and the manpower really to monitor and keep these
2 things going over a long period of time. We pump for
3 like 60 days each series of tests, approximately, so
4 there's a lot of manpower associated with gathering
5 the samples and getting it analyzed, and going out to
6 location and refueling the generators and such.
7 MEMBER WEINER: So the fact that you
8 didn't see any reduction indicates that you have
9 oxidizing --
10 MR. CAMPANELLA: Yes.
11 MEMBER WEINER: You have unchanged
12 oxidizing conditions.
13 MR. CAMPANELLA: Right. Exactly.
14 MEMBER WEINER: Thank you.
15 MR. CAMPANELLA: Next slide, please.
16 Okay. What I'm going to show you here is an aerial
17 view - thank you Google Earth for their copyright -
18 but basically, this is where we're located, with that
19 location. We're pretty close to Forty-Mile Wash, and
20 I want you to look at these channels in here. You see
21 the sinusoidal thing going on there. We use that as
22 a model to set up our fast flow path, because we're
23 looking for something that makes geological sense that
24 we could put into a model that's not just totally made
25 up.

1 As you all know, when you model, they're
2 non-unique. They're essentially whatever you put into
3 it, you can force something to work, so we tried to
4 use that as information to help us put in some
5 discreet features here to allow us to do the fast flow
6 path, and then the offset performance. Next slide,
7 please.
8 So what we ended up doing here is the
9 original model was set up with this, and we can't
10 really read any of that, unfortunately. This is too
11 small a display, but what you're looking at here is
12 approximately - we'll stick with porosity in this case
13 to talk about, because I don't have anything closeup
14 to look at either. This is 30 percent porosity out
15 here in the green. We started out with that. That's
16 a good reasonable number for the alluvium. A little
17 bit towards the high side, but it's something that you
18 would expect to see in that kind of a system.
19 This ended up being matched in at 24
20 percent right in here. Again, a very reasonable
21 number for alluvium gravel. This here, and this was
22 a single layer model so it's the total 115 feet. This
23 was matched with 8 percent right in here effective
24 porosity, quite different. There's information in the
25 signal that's coming from these two wells that there's

1 probably some layering effects going on here, but in
2 order to get a first pass at a simple model, because
3 that's what we're shooting for, something that we can
4 simply model and then we could go into more
5 complexity. Again, when you do any kind of modeling
6 or history matching of models, you're limited by
7 budget and time. You can spend a lifetime doing these
8 kind of things, and coming up with a non-unique
9 solution.
10 MEMBER HINZE: Is there any support in
11 lithology of these holes?
12 MR. CAMPANELLA: To see only 8 percent?
13 MEMBER HINZE: Well, yes . We see the 8,
14 the 20, and the 34.
15 MR. CAMPANELLA: There is some
16 information, but it's very hard to look at. I looked
17 at the sonic core information, and there's nothing
18 there that really stands out and tells you that
19 there's something that's really low, low porosity.
20 MEMBER HINZE: No variation in the silt
21 content?
22 MR. CAMPANELLA: Oh, there is that type of
23 information out there, but there's just nothing that's
24 really definitive, I guess, from that standpoint, from
25 what I've seen. I tried to do some correlations like

on gamma ray cross to see if I can see any kind of gradations with these wells. Unfortunately, the quality of the logs in this area aren't sufficient to get a good normalized gamma ray to go back and forth between the two. I just couldn't make it work from that aspect, so when I was looking at the information, I could not see anything that I could just look at say ah-hah, here in this log information that we got or in the hydrology information that we got from the sonic core, here's the reason, here's the layer that suggests that this should be 8 percent.

MEMBER CLARKE: John, can I ask you to hold that slide up there. Again, just how you put all this together. You've got travel times, velocities from the travel times, hydraulic conductivity and gradient stay constant. You've calculated porosity. Is that what --

MR. CAMPANELLA: What we did was we vary all three, basically, but for the most part, the controlling factor here is that effective porosity. The hydraulic conductivity in these --

MEMBER HINZE: Did you get that from the single well test?

MR. CAMPANELLA: We have a pump test on this well.

1 MEMBER HINZE: Okay.

2 MR. CAMPANELLA: Yes, so we had something

3 to anchor it with, basically. And in addition to

4 that, we also have information because we have these

5 fully gauged, about some non-homogeneous behavior

6 between this well, this well having higher

7 permeability from engaging --

8 MEMBER HINZE: And that was the slower

9 travel time.

10 MR. CAMPANELLA: And that was the slower

11 versus that zone there. And again, this is a very

12 over-simplified model, because it's only one layer,

13 and there's multiple layers. When I first set this

14 up, I got a little too ambitious and had multiple

15 layers.

16 MEMBER HINZE: Just one more quick

17 question.

18 MR. CAMPANELLA: Go ahead.

19 MEMBER HINZE: When you did those

20 measurements you were using the packers to keep the

21 depths the same in all the wells? In other words, you

22 were measuring the same depth --

23 MR. CAMPANELLA: Oh, the screens.

24 MEMBER HINZE: Yes.

25 MR. CAMPANELLA: Yes, the screens are --

1 you basically have two P wells in each one of these
2 well bores, and they're set up in a different screen,
3 two-inch.
4 MEMBER HINZE: I understand, but you were
5 using them.
6 MR. CAMPANELLA: And in this well, yes.
7 We basically went and we did, opened up individual
8 screens and pump tested individual screens.
9 MEMBER HINZE: Okay.
10 MR. CAMPANELLA: So that's what we're
11 looking at, the values. When you get your hard copy
12 you can see some of the values that we ended up using
13 for the match in this, basically. But really, the
14 overriding driving force here is the effective
15 porosity that's really driving that. Next slide,
16 please.
17 MEMBER HINZE: Which is just another way
18 of saying the hydraulic conductivity and the gradients
19 are the same, and the velocity is inversely
20 proportionate.
21 MR. CAMPANELLA: Right. Yes, exactly. In
22 this area right in here, again we're looking at very,
23 very high perms, and there's not a lot of contrast in
24 the perms that could detect between the wells,
25 although it looked like there is maybe 30 percent

1 higher permeability that way than this way.

2 This is just a picture of - I've got

3 another presentation that I need to give at Devil's

4 Hole, so I have a mixed audience there, so you get

5 pretty pictures to show. Basically, here's our screen

6 number two, and that's the tracer plumes in the model

7 moving towards being picked up at 22S. And you can

8 look at this, it's coming in faster than the tracer

9 plume coming this way. And if this was a little

10 bigger screen, you could actually see the gradient

11 here pulling that tracer this way.

12 MEMBER HINZE: The high perms are in the

13 direction of the channels?

14 MR. CAMPANELLA: Actually, no, they're

15 not.

16 MEMBER HINZE: What are they? What is

17 their relationship to the channel?

18 MR. CAMPANELLA: I don't know. I don't

19 have any good definitive -- usually, that's what you

20 think of, and that's what I thought of originally, was

21 that was going to be the case, but looking at the

22 pressure data, it was the opposite, so I'm a little

23 bit confused at this stage as to why that is. They

24 don't see a whole lot of cementation. That's normally

25 what I look at, and would think would cause me some

1 stratification, would be some cementation. We really
2 don't have a whole lot in here. There's not a lot to
3 look, to kind of focus your attention in the sample
4 information that we have. It pretty much looks pretty
5 homogeneous and a bunch of junk.
6 MEMBER CLARKE: You said they weren't that
7 much different.
8 MR. CAMPANELLA: Right, they are not that
9 much different. But, obviously, the tracer response
10 tells us they are quite different. Next slide,
11 please.
12 Here's the match where it sits right now.
13 This is coming from the 22PA well towards, this is the
14 fast pathway. And on this area right down in here,
15 this is - we're looking at gradient sensitivity right
16 here. And here's the match, and this is the gradient
17 that is basically used in the current model. And I
18 have to say looking at it, here's what it does, it
19 goes down. Now the model, these are the data points
20 we have here. Right? And here's the model, is this
21 red line coming off of here, so what we're looking at
22 is trying to match that rapid breakthrough, the peak,
23 and we're missing a little bit here on this tail. And
24 then it peaks up here, and we're trying to hit it
25 right up in there.

1 Now this is the area where I'm saying that
2 you can get some gradient information on magnitude,
3 magnitude basically from the standpoint of how high
4 this moves up or down, and then on direction, what the
5 shape of this curve is. The fact that this just goes
6 right up and falls right off tells us that the tracer
7 plume is moving from the north into that south well
8 22S. And the reason why you see the peak and then
9 fall down has to do with the fact that you basically
10 are, through natural gradient, moving that tracer
11 plume towards the producing well. When you turn the
12 producing well on, then all of a sudden that tracer
13 plume starts to get diluted from all the fresh water
14 sitting around that well bore as it comes in, so
15 that's why you see this big immediate drop here. But
16 the fact that you get that rise because the plume is
17 moving towards the well, and then that immediate drop
18 in here.
19 So from our standpoint, we're probably
20 pretty close to being finished with the modeling
21 effort at this stage in the game. I have to talk a
22 little bit with Dale and see how much more he wants us
23 to put into it because, again, I could spend a lot of
24 time and a lot of money trying to flesh out something
25 that's still a little better match, but is still non-

1 unique that I can't answer the kind of questions you
2 guys are asking me about what specifically is driving
3 all these things. Next slide, please.
4 Here is the case of the other well which
5 had the more expected behavior with the 24 porosity,
6 effective porosity. As you can see here, we come up,
7 match that pretty well. In this case, what we're
8 looking at is this blue curve is what we're saying is
9 our best guess here. And what's interesting, you see
10 it actually better here in this case, which is 6.25
11 times the original gradient, which is in the current
12 models. As you see this type of behavior, see how the
13 plume actually drops down and then peaks up again so
14 you get that rollover, just like you see in here in
15 this data, where it drops down and picks up again.
16 And again, what's going on there is that tracer plume
17 is moving, 22S is here, that tracer plume got pulled
18 over that way, and now it's shifting away from the
19 well because the gradient is pushing it away. And
20 then when you turn the well on, you force it back into
21 the well, so that's why you see the dip down and then
22 the peak back up in here. And so that's where I'm
23 saying that I feel that we've got some pretty good
24 information that confirms that we have a good north-
25 south gradient, and it's in the magnitude that we

1 expect and have mapped out based upon the results that
2 we see from these tests.
3 Basically from that standpoint, using this
4 type of information we should be able to maybe do some
5 tracer testing in some other areas where we're not so
6 sure about the gradient, especially when you get down
7 around Highway 95 where we have some up-welling, and
8 we'll talk a little bit about that. And there's some
9 confusion, does the flow still go passed Highway 95 in
10 those faults, or is it basically effectively blocked
11 off from the up-welling from the carbonate system is
12 what the belief is, and kind of back-flows into the
13 alluvium. So there's, I think, some utility in doing
14 this type of thing, and doing the shut-ins on the
15 cross-hole tracer tests, any ones that we perform in
16 the future. Next slide, please.
17 MEMBER CLARKE: John, one quick question.
18 MR. CAMPANELLA: Go ahead.
19 MEMBER CLARKE: I think Bill asked this
20 already, but your porosity are a factor of three?
21 MR. CAMPANELLA: Yes.
22 MEMBER CLARKE: Eight to twenty-four?
23 MR. CAMPANELLA: Yes.
24 MEMBER CLARKE: Now is that consistent
25 with your understanding of the geology and those

1 things?

2 MR. CAMPANELLA: Well, I know that when

3 the DOE and they look at it, they use the lower limit

4 of 5 percent for the alluvium for their --

5 MEMBER CLARKE: Yes, I mean, that's a

6 fracture rock porosity.

7 MR. CAMPANELLA: Well, yes, it's high

8 fractured rock porosity. Typically --

9 DR. COLEMAN: Yes, that's a distributicn

10 of porosities that we use, and some of the lower end

11 ones are low probability. I think the reasonable ones

12 are -- I mean, these guys - this is their analysis,

13 and they don't look at PRA-style analysis. They're

14 more interested in actual analysis.

15 MEMBER CLARKE: That's not where it's

16 going at all. It's just that you're varying a lot of

17 different things.

18 DR. COLEMAN: Right. And we've been

19 questioned a little bit on some of the values of

20 porosity in the alluvium, and we think we got a pretty

21 good basis for our porosity values.

22 MR. CAMPANELLA: Again, yes, if you look

23 at the data that is out there, 8 percent - yes, it

24 seems pretty low, especially when you look at it. Now

25 you can do some more detailed work with some of the

1 analytical solutions. And actually, if you go back
2 and actually do a derivative on the response curve,
3 you can see multiple peaks in there. You can see
4 where it comes up and then starts falling off. And
5 there's at least three separate peaks which would
6 indicate there's probably three separate little flow
7 paths coming into that well, so one of them may be a
8 lot lower like around the range of 5 percent, and the
9 others might be higher than that, but they composite
10 back into that roughly 8 percent if I'm going to match
11 that on a single layer system.
12 And again, I guess the real big issue is,
13 from our standpoint, we look at this for understanding
14 bits of information, not trying to match the thing
15 perfectly in a non-unique way, because it just doesn't
16 add that much value. Again, I could spend my entire
17 budget on that and have no money left.
18 In this case here, what we're looking at
19 is what if we took the values that we have in those
20 bigger areas and impose them on this as a homogenous
21 system. And what you're seeing here is if we take the
22 fast flow path, the 8 percent, that's the type of
23 response that you would see. Well, we don't see that
24 kind of response. That's a little too aggressive.
25 This is in the Bromide, which is the pathway coming

1 from 22PA north-south to 22S. And then if you go out
2 here in the 24 percent that's the kind of response you
3 see. Well, we didn't get that. That's our actual
4 response, so that's too slow, so that tells you that.
5 And here's the 30 percent way out here. So
6 originally, what we are looking at was expecting this
7 type of behavior, and we ended up with that behavior
8 from the north-south well, so it was a surprise.
9 And again, you can see these different
10 type of end effects from the gradient and shutting
11 things in. Those are at the actual gradient that's in
12 the model right now north to south. Next slide,
13 please.
14 MEMBER WEINER: So do you then adjust your
15 model to conform to your experimental results? Do you
16 do that on a continuing basis, or you're just
17 collecting data at this point, and then eventually put
18 it all together?
19 MR. CAMPANELLA: As far as the
20 modifications to the overall large model?
21 MEMBER WEINER: Yes.
22 MR. CAMPANELLA: That probably needs the -
23 - I think these guys look at the information --
24 DR. COLEMAN: This is Drew Coleman. She's
25 asking about your model, so answer it with regard to

1 your model.

2 MEMBER WEINER: Yes.

3 MR. CAMPANELLA: Oh, our --

4 DR. COLEMAN: Or if you're talking about

5 my model --

6 MEMBER WEINER: No.

7 DR. COLEMAN: -- then you need to ask me.

8 MEMBER WEINER: I'm asking with respect to

9 your model. Do you then adjust your model to

10 correspond to your experimental results, or are you

11 collecting a lot of results, and then --

12 MR. CAMPANELLA: We're collecting a lot of

13 results. Right now, Nye County doesn't do like a

14 large-scale model.

15 MEMBER HINZE: You don't iterate your --

16 MEMBER WEINER: Yes, that's a better way

17 to put it.

18 MR. CAMPANELLA: Oh, we iterate on this?

19 MEMBER WEINER: Yes.

20 MR. CAMPANELLA: Yes, we iterate on this.

21 MEMBER WEINER: Okay.

22 MR. CAMPANELLA: And that's where we got

23 to the history match you're seeing right now, is

24 through iterations.

25 MEMBER WEINER: Thank you.

1 MR. CAMPANELLA: But do we take that
2 information and move it out beyond the 22S location
3 right now? No.
4 MEMBER WEINER: No.
5 MR. CAMPANELLA: Because we don't have a
6 large-scale model. All we have is a model set up for
7 22S right now. But yes, we do iterate, and we have
8 iterated in order to come up with the matches that we
9 have. And we've got plenty of plots to look at that.
10 We don't want to go through that.
11 MEMBER WEINER: I can see that, yes.
12 MR. CAMPANELLA: Basically, again, here's
13 the well coming from east to the west from 22PC. And
14 if we put in that fast flow path, that's what we'd
15 expect to see. Of course, we didn't see that, we saw
16 that. And here's what it would look like if we were
17 at 30 porosity, and the rest of the properties that
18 went into that area. That's the shape of the curve,
19 but it's dominated really by that effective porosity.
20 And again, we're not getting very close out here. You
21 could say well, that model here peaks out there, and
22 that looks a little better than that one. The problem
23 is you don't see the kind of humping in that last
24 little bit of the curve. Next slide, please.
25 This is one of the first matches. We now

1 went back and looked at -- got a parameter set for the
2 cross-hole test and then just ran on a more refined
3 case the push-pull test. And if we do that, this is
4 the type of response curve we end up with. And it's
5 the scale effect of the dispersivity. If we reduce
6 that by over a factor of 10, we get a much better
7 match in the first push-pull test. And there's
8 probably some more work that needs to be done. That
9 was something that was just recently done, is trying
10 to go back and look at those push-pull tests to come
11 up with some information on that.
12 Again, part of the reason why I wasn't
13 told I needed hard copies, and it would have been hard
14 for me to accomplish that, too - I think I got this
15 Saturday. Next slide, please.
16 Just to go through a summary. Multiple
17 tracer tests have been conducted on the saturated
18 alluvium at Site 22 in the lower Forty-Mile Wash. The
19 non-absorbing solid tracers, different diffusion
20 coefficients were used on two consecutive single well
21 push-pull tests beginning in December of 2004. And
22 yes, things do freeze in December in the desert, as we
23 found out. We were very concerned about breaking our
24 pipes because they're PVC and it was freezing.
25 Single well tests were followed by two

1 multi-well cross-hole tracer tests using conservative
2 reactive and microsphere tracers beginning in January
3 of 2005. The preliminary analysis of the tracer tests
4 using both analytical and numerical simulation
5 indicates that the diffusion into the immobile water
6 was minimal or non-existent, and that a fast flow path
7 exists between one of the injection wells, 22PA, and
8 the pumping well, 22S, and the shallow alluvium
9 aquifer.
10 A long pumping interruption between the
11 two cross-hole tests allowed natural ground water
12 drift to move the tracer plumes and tracer response
13 curves contain that information about the site's
14 natural gradient and magnitude, and azimuth from that.
15 MEMBER HINZE: In terms of the overall
16 objective which is early warning, what's the major
17 result that we're seeing here? Is this just a matter
18 of collecting data and parameters for modeling?
19 MR. CAMPANELLA: Where is this going?
20 MEMBER HINZE: Yes, where is this going in
21 early warning?
22 MR. CAMPANELLA: Well, it's going towards
23 better site characterization, really. The bottom line
24 is if you look at those well spacings, they're quite
25 few wells for such a large area. When I was out on

1 locations, for instance, we were trying to figure out
2 what the gradient was, and so one of the suggestions,
3 well, we've got four wells, go measure the gradient.
4 Well, we can't measure the gradient there, it's flat
5 as a pancake. We don't have any instruments. You
6 would have to basically use very, very - I don't even
7 know if you have a sensitive enough pressure gauge to
8 know exactly where they're sitting in the Z and the Y
9 and Y, in order to try to get a gradient. So we said
10 oh, well, we can go up and pick off the gradient that
11 you see in the big maps. And people said well,
12 there's a lot of contention that those aren't the same
13 gradients, because what happens is you have a pretty
14 steep gradient up in the volcanics, then you hit the
15 alluvium and it goes flat. Well, in my opinion, it
16 goes flat because it's a high perm. There's no reason
17 for it to stack up anywhere. And that's why I think
18 we see off of that. So from that standpoint, it's
19 that site characterization where we can use some of
20 that information.
21 Now as far as the fast flow paths, it
22 helps us try to determine whether or not what we're
23 getting from the DOE makes sense from the standpoint -
24 one of our concerns, I guess, that has been voiced,
25 is a little bit that there's a lot of stochastic

1 modeling going on, but that they have a tendency to
2 take all the values. And when you get done with the
3 methodology, they basically end up with kind of a flat
4 profile. There's not a worse case scenario, and then
5 there's not the longer case scenario. They don't all
6 kind of go to a catastrophic type of behavior where
7 you'd say we have a fast flow path, and it's fast in
8 the volcanics, and it's fast in the rest of it. Go
9 ahead.
10 CHAIRMAN RYAN: I guess just to put a
11 risk-significance kind of view on it, when you have a
12 range of values in any parameter, whether it's
13 gradient, or velocities, or those kinds of things, you
14 can factor some range of values based on however you
15 come to consensus on what that range ought to look
16 like and run your performance assessment code, which
17 is the impact part. It's does it matter or does it
18 not matter, and what the influences are. Have you
19 gained - and this may be an unfair question for your
20 part of the project - but do you have any insights as
21 to what the risk-significance of this work is from my
22 definition of it, if you'll allow it?
23 MR. CAMPANELLA: I don't know that I can
24 answer that. I know that --
25 CHAIRMAN RYAN: Fair enough. I realize I

1 was putting you on the spot, but for us, that's really
2 where the value of the work comes in. What's the
3 risk-significance of a range of values in porosity in
4 terms of calculating a dose at some reference point,
5 or to a reference individual, that kind of thing, and
6 does it matter or not?
7 MR. CAMPANELLA: What I remember looking
8 at is we looked at basically, kind of the controlling
9 mechanisms for the barrier systems in place. And it
10 seemed like once the material gets into the aquifer,
11 that's the shortest thing that you have to deal with.
12 So all of the work needs to be done --
13 CHAIRMAN RYAN: Oh, sure. No, I agree
14 with that, but does it matter is the real question,
15 what's the inside of the risk-significance to that
16 happening or not happening? So we're not there yet,
17 I guess.
18 MR. CAMPANELLA: Right. I don't know that
19 we're there. I know that some people inside of Nye
20 County's working group has put together a recent
21 position kind of paper on some of these issues that
22 you're discussing right now, but I wasn't part of
23 that.
24 CHAIRMAN RYAN: Fair enough. I appreciate
25 it. It's maybe a little out of your zone.

1 MR. CAMPANELLA: That's right.

2 CHAIRMAN RYAN: Okay.

3 DR. COLEMAN: Well, and that's one of the

4 project's challenges, is the county looks at things

5 differently than say the regulators and the DOE in

6 this whole risk-based analysis. And so they would

7 prefer to gather all the data that you need, and

8 understand it fully, and so that's a little bit of a

9 tension between the county and the project and the way

10 things are done.

11 CHAIRMAN RYAN: Well, it's my experience,

12 the one common thing among all geologists and

13 hydrologists is they want to dig one more hole, at

14 least.

15 MEMBER HINZE: And usually with good

16 reason.

17 CHAIRMAN RYAN: Your fast paths are both

18 horizontal and vertical in space that you're looking

19 at?

20 MR. CAMPANELLA: In this case, the way it

21 was modeled, yes. In reality, I don't think so. I

22 think you have vertical, a fast path that's probably

23 less - I'm pretty sure you have a fast path less than

24 8 porosity units that's thinner, that's giving you the

25 first arrival. Again, like I said, if you take and do

1 a derivative on that response curve, you can see
2 multiple peaks coming in, and they basically are
3 laying on top of each other.
4 Part of the issue from our standpoint on
5 the modeling side of things are the limitation of the
6 software. One of the things that I saw in the
7 software that we are using is that it didn't do a good
8 job of telling me what mass I was producing from each
9 layer; therefore, I couldn't get back to my response
10 curve, so it's easier to set it up as a single layer
11 than try to work backwards and try to figure that out.
12 And again, it's money, time constraints, any time you
13 model, especially from our standpoint. Unless Drew
14 wants to open up the flood gates of cash and mostly
15 like to drill other wells than watch me model.
16 DR. COLEMAN: Go for it.
17 MR. CAMPANELLA: Okay. Next slide,
18 please. Okay. Office of Science and Technology
19 International OSTI U-tube installation in 24PB. Next
20 slide, please. This is Barry Freifeld. Is that the
21 proper name? Yes, Barry Freifeld's design for U-2.
22 And the purpose of this is to allow for the down hole
23 sampling, and keep the sample at reservoir pressure,
24 so you don't have any kind of clashing of that, or
25 contamination with oxygen of the sampling. Of course,

1 any time you're dealing with little small U tubes,
2 you're limited in the size of the sample you can get,
3 and the volumes you can produce out of it. But that
4 was the basic design. It's real simple. A check
5 valve permits the native fluid to enter to the U tube,
6 and then prevents it from backing back out, so then
7 they have the drive line here, and they've used high
8 pressure Nitrogen then to lift that fluid up to
9 surface, and then they gather it at pressure so they
10 don't have any kind of oxygen, any contamination or
11 gases flashed out. Next slide, please.
12 This is a schematic, and I think this says
13 PA, but it's now PB. But basically, what they've done
14 is they've gone in here and here's -- it's really
15 difficult for me to see at this scale, but here's the
16 U tube bundles, and they've done four of them in here.
17 They have redundancy, so they went ahead and they've
18 actually done this installation. This well has been
19 drilled, and finally got drilled and was installed.
20 Next slide, please.
21 And there you are out on location. Again,
22 any time you're dealing with all those little U tubes,
23 it's quite an operation to make sure that everything
24 gets into the hole correctly. Next slide, please. I
25 think this was in February when they got this off. As

1 you can see, there's some snow on the ground. Again,
2 lots of things to keep track of and pay attention to
3 for these guys as they're running this equipment into
4 the hole. Next slide, please.
5 Okay. Now we're going to go through a
6 series of slides. Do we have enough time?
7 CHAIRMAN RYAN: You have 35 minutes.
8 MR. CAMPANELLA: Okay. Sounds good. Talk
9 about the proposed horizontal well. And these were
10 are some takeouts on some slides we presented at
11 Devil's Hole to talk about the horizontal well, so
12 it's got some information in here that's a little bit
13 out-of-date that we could discuss a bit.
14 How have we investigated large-scale flow
15 features, drifts, vertical well bores, large-scale
16 geophysical measurements, geochemical analysis, tracer
17 testing, lab testing of rock and fluid interactions,
18 and data integration in the modeling side of things.
19 Next slide, please.
20 Key hydro geologic features are still not
21 well understood. Hydraulic properties, the major
22 block bound faults, we don't know what they are.
23 Impact of fracture frequency, fracture minimalization
24 and matrix fracture interaction is still somewhat of
25 an unknown. Connection between the tuffs, alluvial,

1 and carbonate system. It's a big issue. Again, one
2 of the things I kind of got out of that last little
3 tracer test in that gradient was that yes, they are
4 communicated and they're not looking at two different
5 gradient systems myself.
6 These features can impact the transport
7 time by thousands of years, so I guess that kind of
8 comes back into some of the comments that you had.
9 That's what we see, is that it pushes things up by
10 thousands of years.
11 CHAIRMAN RYAN: Well, again, just that may
12 have been one piece of the story. That's not the
13 whole story of risk.
14 MR. CAMPANELLA: No, no, it's one piece on
15 the --
16 CHAIRMAN RYAN: Differences of thousands
17 of years may be unimportant in some Pas.
18 MR. CAMPANELLA: Exactly, what I was
19 saying before, what we see is that by the time it gets
20 to the aquifer, your big chances to slow things down
21 are in containment and that kind of thing. Next
22 slide, please.
23 How do we cost effectively reduce the
24 uncertainty? We need to, we feel, intersect the
25 faults in the saturated zone, quantify the fault and

1 fractures, obtain geophysical measurements,
2 hydrogeological properties, and allow for future
3 access and long-term monitoring. We think horizontal
4 wells fulfill those requirements. Next slide, please.
5 We'll talk a little bit, and we'll have
6 some slides that are somewhat redundant, but you're
7 going to have a slant well, a vertical well, and then
8 a horizontal well. And the purpose of this slide is
9 just to illustrate the fact how difficult on a
10 vertical well it is to intersect vertical fractures.
11 It's just really difficult to do. A slant well gives
12 you a better chance. The best way to intersect near
13 a vertical or near vertical features is to use a
14 horizontal well. You can also see variations in the
15 lithology bedding also in a horizontal well. Next
16 slide, please.
17 Why go horizontal? You get improved well
18 productivity, you get better connection to the
19 fractures and the vertical features, obtain detailed
20 information over larger scales than you can in a
21 vertical well through the vertical fractures or faults
22 that are poorly identified in the vertical wells.
23 Next slide, please.
24 Are horizontal wells experimental? No.
25 Over the last 15 years, horizontal drilling for the

1 oil and gas industry has exploded. In '87 there was
2 51 horizontals, by '97 it was 4,000, and now it's I
3 think over probably 10,000. Major horizontal well
4 areas include Alberta, Canada; Texas, North Dakota in
5 this part, the hemisphere we're dealing with.
6 Through 2000, there were 23,385 horizontal
7 wells in the U.S., and just about 10,000 in Canada, so
8 it's a very common thing to do in the oil and gas
9 industry. It's not your pushing the envelope by any
10 means from that standpoint. Next slide, please.
11 We could probably skip through quite a bit
12 of this because you guys are obviously very well
13 versed in it. Death Valley Regional Flow System is
14 the regional hydro geologic setting. Yucca Mountain's
15 site scale model is the subset of that. Bounding
16 conditions go into that model. Local hydro geologic
17 setting, we've got the Early Warning Drilling Program
18 wells, and that gives us information on the sediment,
19 the contacts between the different axis. And then
20 information on the water table and the gradients.
21 Goals of the proposed horizontal drilling
22 program - what questions are we expecting to answer
23 with proposed wells? Cross-sections with the proposed
24 horizontal wells will look at some of that. Next
25 slide, please. Here's regional hydro geologic

1 setting. Again, this is the big area that we're
2 looking at. Death Valley is over there. Here's your
3 site scale model. Next slide, please.
4 Most of the ground water flow is fed from
5 the north, in the northeast, the discharge area is to
6 the south and the southwest, and that's the current
7 thinking. Next slide, please. When we get into more
8 localized area, the saturated zone in the lower
9 sections of the upper volcanics, Topopah Spring tuffs
10 and the flow occurs predominantly in the UVA and the
11 lower volcanic aquifer discharge to the alluvium
12 towards the south and southeast. That's the current
13 thinking. Underflow may occur at depth, we don't
14 know.
15 Nye County is concerned primarily with the
16 shallow accessible aquifers because that's most likely
17 what water source is there outside the repository.
18 Next slide, please. Ground water flow is driven from
19 the steeper gradients to the north, the northwest,
20 much flatter in this area, of course, where it dumps
21 into the Forty-Mile Wash area like we discussed,
22 southeasterly flow direction may be intercepted by
23 north-south steep faults. Again, that's suggesting
24 that that's the general flow. What I found, I can't
25 discriminate between southeast, that type of flow,

1 that type of flow, or north-south, with the data that
2 we have.
3 We are planning a natural gradient test at
4 that location dumping tracer into 22PA and letting it
5 drift, and then sampling it at 22S. Again, that's
6 planned for some time this year. We've got some
7 issues we've got to take care of in order to place the
8 tracer and get along with that test.
9 One of the things I forgot to emphasize is
10 that tracer that set off in screen number one,
11 remember, we never did see it. We could see pressure
12 response between Zone One and Zone Two, but we didn't
13 find any mass to that screen number two, so we never
14 saw any tracer show up there. So, apparently, there's
15 some stratification from a mass transfer standpoint.
16 One of the things we're planning on doing
17 for the natural gradient test is opening up screen
18 number one in 22S and doing a sample to see if that
19 tracer moved towards 22S that we placed in that screen
20 number one prior to the natural grading test. Next
21 slide, please.
22 Again, we talked a little bit about the
23 vertical gradients. We had some downward flows, and
24 then we had some upward flows here. There might be
25 some possibilities to sit down and think about some

1 tracer testing and such down in this area, and maybe
2 try to get a sense of are we back-filling into the
3 alluvium from deep carbonates, or does it continue to
4 flow up and then flow out? We don't know yet. Next
5 slide, please.
6 Arrow magnetic. Again, most of this is
7 just trying to display some compartmentalization that
8 we know exists out there. Next slide, please. Again,
9 that's what the purpose of this slide is, to emphasize
10 that we have some evidence of compartmentalization
11 potential out here. We don't know if it exists yet,
12 but we had some information that suggests that it
13 does. Next slide, please.
14 Okay. The major EWDP findings,
15 permeability of the alluvium and underlying volcanic
16 aquifers can be very high. Now the upward hydraulic
17 gradients generally observed from the deeper to the
18 shallower aquifers, local large downward gradients at
19 the paleo spring well sites, focus on flow likely
20 occurs in the Forty-Mile Wash alluvium due to the
21 permeability contrast. Particle-size distributions of
22 the alluvium samples is significantly different in the
23 saturated alluvium drill cuttings and core sample
24 sonic coring is the best. This is what Dale talked to
25 you guys about last time, was the sonic coring. And

1 they got some good information off of that. Again,
2 they had a sonic core in the 22S area. I can't
3 remember which one. Was it PC the did the sonic core
4 on? And looking at that information, I couldn't see
5 anything that would just strike me as to how to
6 populate the tracer model based on that information,
7 so there wasn't anything just wow, that's it. Next
8 slide, please.
9 Okay. Layer cake hydro stratigraphy at
10 Yucca Mountain does not exist at the Highway 95
11 continuity of the volcanic aquifer units complicated
12 by buried older faults in the volcanic units at
13 Highway 95, and several miles north of Highway 95.
14 They're likely to complicate flow paths, longer and
15 more convoluted. We have older growth faults likely
16 to either terminate major ash flow sheets or create
17 abrupt textural facies boundaries. Structures also
18 provide plumbing for large upward hydraulic gradients,
19 and the vertical gradients can be orders of magnitude
20 larger than the horizontal gradients, so the vertical
21 gradients can be pretty important. Next slide,
22 please.
23 Flow in the volcanic aquifers likely
24 occurs in structurally controlled compartments, that
25 the thought process. Flow in the alluvium aquifers is

1 controlled by the textural units, channels, and likely
2 affected by local vertical gradients near the
3 underlying fault. And I guess we can emphasize that
4 that's something that we saw from the tracer testing,
5 that there is that going on. Whether it affects
6 things on a large scale, I don't know. Next slide,
7 please.
8 Okay. Proposed horizontal wells,
9 justification, model flow paths depend on poorly
10 constrained hydraulic gradient information. Flow
11 occurs in areas of variable upward vertical gradients.
12 Model flows apparently unaffected by the large
13 vertical structural features currently. Next slide,
14 please.
15 Our goal is cost-effective method to test
16 large faults within the projected flow paths from
17 Yucca Mountain, determine hydraulic properties of
18 structures for future updates of the models, and
19 better align monitor wells with flow path. Again,
20 we're trying to figure out where things are going and
21 where best we should be pre-positioning some wells.
22 Next slide, please.
23 The method - drill, complete, and test.
24 We're saying here two horizontal wells, actually,
25 we're talking about a total of three locations that we

1 have. We have funding currently for one. We are
2 going to have a meeting, testing program will be a
3 cost-effective test of the larger faults in the flow
4 paths from Yucca Mountain to the Amargosa Valley,
5 program can be completed in a timely manner using off-
6 the-shelf technology. We're not trying to create
7 anything here. Program can be implemented in a
8 cooperative manner with all the interested parties.
9 Next slide, please.
10 Again, these are just different
11 methodologies to go vertical and go down vertically
12 and kick off, go out slanted, kick off. This is
13 mostly, and we'll probably blow through a lot of these
14 slides, just an understanding. I don't know your guys'
15 experience with horizontal wells, so if there's
16 something that you have a question about, ask me.
17 Next slide, please.
18 This is a steering motor. What you have
19 is a mud motor is what they're called, progressive
20 cavity pump, and they pump mud down. It spins the
21 bit, and it allows you to use like a bent sump in
22 order to steer the drill bit. Next slide, please.
23 Here's just a picture of what it would look like in a
24 hole getting kicked off. Next slide, please.
25 How do they measure things? Typically,

1 they send a pulse up the drilling mud to the surface
2 and that tells them information about azimuth,
3 inclination, that kind of stuff. And you can actually
4 get logging information, like gamma ray and that stuff
5 through a pulse backup through the mud system. Next
6 slide, please. And that's all that's showing you
7 there, is they basically send a signal and they get
8 information from that signal about what's going on
9 down hole back away from the bit, probably about
10 anywhere from 20 feet back from the bit, so it's
11 pretty much almost realtime information as you're
12 drilling what's happening. Next slide, please.
13 You get inclination, azimuth, you get tool
14 face and you get these type of things. And then you
15 can get like gamma ray, and you can do formation and
16 valuation measurements as you're drilling. We're not
17 proposing we do that. Those are very costly to do,
18 but you can do them. You have density, sonic pressure
19 information. Next slide, please.
20 Another type of tool that they have, they
21 basically have a little control motor here, and they
22 have basically an actuator that kicks out a pad and
23 directs the drilling bit as you're going down. Next
24 slide, please. That's just another picture of it.
25 Next slide, please. Okay.

1 We talked a bit about this already. Next
2 slide, please. Okay. Drilling and completion. We're
3 going to move in a top drive single drilling rig,
4 drill a 12-1/4 inch hole to 100 feet below the water
5 table. We're going to obtain Nye County standard
6 geophysical logging suite, and then we're going to go
7 ahead, and that's in the vertical hole. It's at 9-
8 5/8ths casing, 100 feet below the water table,
9 approximately 1,200 feet. Next slide, please. You may
10 think that this is what we're talking about for a
11 drilling rig. That is a drilling rig. That is the
12 typically older type of drilling rig. Next slide,
13 please. This is actually the type of rig that can do
14 this work. It's basically a very small footprint. It
15 has hot drive here, and extensible mass so that they
16 can pick up casing, and it's pretty amazing, they can
17 accomplish what they can nowadays with that small of
18 a footprint, which allows them and us to go some
19 places that are somewhat challenging from the
20 standpoint of topography, maybe. Next slide, please.
21 Top drive unit here. Normally what you
22 have is the old style rigs, you have what's called the
23 Kelly bushing and a turntable, and that's down on the
24 rig floor. That's all the pictures, you see the guy
25 spinning chain and that kind of thing. These are much

1 safer. They basically are top drive hydraulics, can
2 actually push the pipe into the hole. It's not just
3 the weight in order to drive the pipe down, so that
4 allows them to do horizontal wells a lot easier. Next
5 slide, please.
6 Here's just a little couple of schematics
7 of what we're talking about. The vertical hole here
8 below the water table. Next slide, please. Drill out
9 with 7-7/8ths bit, under-balanced mud system, so we're
10 trying not to dump a bunch of mud into the fracture
11 system, of course, so we're using under-balanced
12 drilling. Build a medium radius horizontal at 10
13 degrees per 100 feet so, therefore, the curve will be
14 900 feet long, drill 500-1,500 foot of lateral, and
15 final lateral length will depend upon drilling
16 conditions. If you hit a lot of fractures that are
17 very conductive and take your boot away from you,
18 you're done, but that's information you didn't know if
19 you go 500 feet and all of a sudden use circulation.
20 You know you hit a pretty high flow feature that close
21 to where you were.
22 They'll try to do the best they can to
23 keep things going, but that's what's going to pretty
24 much kill it. If you don't hit any high flow
25 features, and you can actually maintain fluid in the

1 hole, we'll go out to 1,500 feet. And maybe,
2 depending how things go, I suppose, you could go a
3 little bit longer than that, but you're going to run
4 out of money. Next slide, please.
5 So here's a schematic what that kind of
6 looks at. You're building your curve here. That's
7 going to go for 900 feet. The next slide, please.
8 Here's the proposed logging program for the horizontal
9 section. Log the well with Wireline tools and drill
10 pipe, run formation micro imaging log FMI, run a
11 platform express which is more your typical logging-
12 type stuff, resistivity, formation density, that kind
13 of thing, Dipole Shear Imager. That's a fancy
14 computerized sonic tool that gives you information on
15 the rock properties and gives you information on
16 fracturing. A couple of other logs basically for
17 determining lithology information. Next slide,
18 please.
19 Basically, that's kind of what it looks
20 like. You basically do drill pipe conveyed logging,
21 because you've got to push the tool out and then pull
22 it back in. You can't do it with a Wireline. Next
23 slide, please. I don't know if you guys are familiar
24 with Formation Micro Imager log. It's basically kind
25 of a dip log on steroids. You end up with a bunch of

1 resistivity pads on a series of arms at high density,
2 and it can give you a resistivity image of the
3 formation, and then you can go - next slide, please -
4 basically tie those back in, that detailed information
5 back into what your fracture system looks like in your
6 lithology, your bedding plains, and that kind of
7 stuff. And it pretty much almost gives you a core-
8 like image of what the subsurface looks like without
9 getting a core, especially on the fracturing side of
10 things. Been very successfully used in the oil and
11 gas industry for looking at fractured systems without
12 trying to take core. And as you well know, coring is
13 costly and difficult, especially in fractured rock.
14 It's even more difficult to do, get a whole sample,
15 come back. Next slide, please.
16 Get strike and dip calculation from fully
17 oriented image. You don't lose anything. Next slide,
18 please. You can develop structural model from the
19 oriented beds and faults. Next slide, please. It's
20 probably the most important log that we'd like to get.
21 Characterization of fractures from the electrical
22 images, you basically see these sinusoidal things.
23 They can be either bedding plains, depending on what
24 they look like, you can determine some aperture
25 information from it, and you can look and do fracture

1 counts and that sort of thing. Next slide, please.

2 Aperture is computed along each fracture

3 trace. That's what they're doing here, calculating

4 some apertures, depending on the size and the

5 coloration. Next slide, please. It has been run in

6 fractured volcanics. That's from the Columbia River

7 Basalts. Next slide, please. Okay. And they've

8 actually run it at Los Alamos in a fractured tuff,

9 also, so it's been proven to be able to image these

10 type of formations. Next slide, please.

11 This is a funny thing. I couldn't figure

12 this one out. Next slide, please. This is the sonic

13 tool basically on steroids, computerized sonic tool

14 with different spacing, and it gives you some

15 information on shear and S&P waves, basically. So you

16 get a full wave form coming out, and they can do some

17 analysis based upon that. Next slide, please.

18 You combine the two together, DSI and the

19 FMI, and you get a better answer from your fracture

20 standpoint. What do they look like, what makes sense?

21 Next slide, please. This is for formation

22 geochemistry. Next slide, please. This just tells

23 you what types of elements it looks at. Next slide,

24 please. Natural gamma ray. Next slide, please. This

25 is their, what they call Platform Express, and it's

1 their standard logging suite, typical resistivity,
2 caliper, gamma ray, that type of thing, single pass.
3 Next slide, please.
4 Completion program - determine the screen
5 and packer configuration. Drill and logging data will
6 be used to determine that. Install six inch screen to
7 blanks in external packer so we can isolate the major
8 flow features that we want to study. The drilling
9 changes to a completion fee schedule at that point, so
10 we're trying to save money. Next slide, please.
11 Initial testing program - individual
12 screen completions are tested for productivity,
13 retrievable packers and plugs are used to isolate the
14 screens. The well is produced with air lift, and each
15 screen is logged with a spinner tool so we can get
16 some rates information out of it. Next slide, please.
17 That's basically the kind of tool that they would use
18 to go out there and look at that. Next slide, please.
19 Long-term pump testing and observation,
20 tracer testing is what we could see happen with this
21 well, detailed production logging with water flow log,
22 detailed pressure transient analysis with multiple
23 pressure transducers and retrievable packer plug
24 combinations so we could set on one side of the fault,
25 put a memory gauge at there, and then pump into the

1 other side or produce out of the other side and see
2 what kind of pressure response, if any, we get, that
3 type of information. And then multiply the impact of
4 the lower cost vertical wells. We could go in and
5 offset the horizontal with vertical wells and use them
6 as like tracer injection, from that standpoint,
7 produce out of the horizontal. Next slide, please.
8 Estimated cost - basically, this is what
9 the cost structure that we're looking at, drilling and
10 logging over 800,000, completion 137,000, testing
11 132,000. Next slide, please. Total estimated cost is
12 roughly a little over one million per well, and that
13 was basically trying to get three wells because demobe
14 cost is a big thing, because there are no drilling
15 rigs of that type sitting in Nevada because there's
16 very little oil and gas in Nevada, especially around
17 there. Next slide, please.
18 Horizontal wells can intersect faults and
19 saturated zone, increase productivity in fracture
20 dominated flow, quantify faults and fractures, obtain
21 geophysical measurements, hydrological properties, and
22 allow future access and long-term monitoring. Next
23 slide, please. That's it. We made it.
24 MEMBER HINZE: We did, indeed. Thank you
25 very much, John.

1 MR. CAMPANELLA: Thank you. Again, I
2 apologize for not having hard copies for you guys to
3 look at.
4 MEMBER HINZE: We've asked a lot of
5 questions along the line here, but perhaps there are
6 some additional questions. Ladies, gentlemen? Ruth.
7 MEMBER WEINER: I'd like to know from just
8 generally, how DOE expects to use these data? I mean,
9 these are very good data, and it seems to me that a
10 model, a good model of anything is based on the data
11 you've got. And I'm very interested in how you expect
12 to incorporate this into the larger performance
13 assessment model.
14 DR. COLEMAN: Yes. I've got my scientists
15 working cooperatively with these guys doing similar
16 analysis on all the work that's shown here, and those
17 analyses, past and present, are being incorporated
18 into our documents. We're revising our AMRs and our
19 saturated zone case. I didn't feel I could come and
20 talk about my saturated zone case under a talk
21 entitled "Nye County Update". I mean, the county is
22 the county and the project is the project, but I think
23 some of our perspectives on it as we might assert that
24 some of these data that he's collected are sort of
25 confirming the ranges that we're using in our model.

1 We have a lot of material in our models and in our
2 documents that incorporate a lot of the work that's
3 been done and associated with Nye County, and that's
4 continuing. We're working with them again this year.
5 MEMBER WEINER: How do you decide what to
6 incorporate and what not to incorporate?
7 DR. COLEMAN: Well, we incorporate
8 everything that it seems reasonable to incorporate.
9 I mean, yes, we don't -- I mean, I guess, what are you
10 talking about? Are you asking if I'm cherry-picking
11 the data or ignoring some --
12 MEMBER WEINER: Well, you just used the
13 term "reasonable", and I wonder what you mean by --
14 I'm a novice in this and I just look at all the data
15 that's been collected. And it seems to me this is
16 very well done, and I just wondered when you decide to
17 incorporate, do you pick some, do you discard some on
18 the basis of some discard criterion that you have?
19 I'm just curious. You used the term "reasonable."
20 What's reasonable?
21 DR. COLEMAN: Well, you might not rework
22 your entire case if the data from a Nye County test
23 confirmed the ranges that you were already using in a
24 model, but yes, we would incorporate all of it, is
25 what I would assert.

1 MEMBER WEINER: Thank you.

2 MEMBER HINZE: Dr. Clarke.

3 MEMBER CLARKE: Just a couple of quick

4 ones. And this wasn't included in either of your

5 presentations, but I just wonder what the current

6 thinking is on the horizontal extent of the alluvium,

7 the percent of the flow path, or how much are we

8 talking about when we talk about transport it through

9 the alluvium? That may not be completely

10 characterized. I don't know --

11 MR. CAMPANELLA: I have not looked at

12 that, so I can't answer that question. I'm pretty

13 much site-specific at this point in time.

14 DR. COLEMAN: In our analysis, we had an

15 uncertainty zone that was kind of a probabilistic

16 sample, the uncertainty zone for the alluvium. And

17 recent drilling has really narrowed that down to the

18 point where we can remove that from the saturated zone

19 case. And I think there's somewhere between a half a

20 kilometer and 1.5 kilometers minimum travel in the

21 alluvium in any scenario to the 18 kilometer boundary.

22 There are some flow pathways that go sort of due south

23 and stay in the volcanics for a large part of their

24 travel, but I don't believe there's any that don't at

25 least have some half a kilometer worth of travel in

1 the alluvium.

2 MEMBER CLARKE: Okay, thanks. Very

3 interesting. Tracer study is very interesting

4 interpretation of the data. Thank you.

5 CHAIRMAN RYAN: Just a quick question,

6 Latif, while you're coming up to the microphone, if I

7 may. I really appreciate the fact that there's a lot

8 of detailed geohydrology in all of this, and it was an

9 excellent presentation. But for me, it's back to the

10 risk-significance of it. Have you optimized your

11 drilling plan based on what you need to know from this

12 risk-significance point of view of performance

13 assessment?

14 MR. CAMPANELLA: I think that's what we're

15 trying to do with the horizontal wells, because we

16 really feel that the major flow features are going to

17 be the faults, are the barriers, baffles, or conduits,

18 and we really don't know that. If they're conduits

19 then, of course, then the travel time is going to

20 really increase because the flow is going to be

21 concentrated along those. And in addition to that,

22 too, when we get down to Highway 95, there's that

23 uncertainty about whether or not the up-welling is

24 kind of almost a hydraulic barrier moving down

25 farther.

1 CHAIRMAN RYAN: I'm asking you to go to
2 the next step back toward performance assessment. All
3 t those questions make sense to me based on what ycu
4 explained this morning, but I'm asking a different
5 question. Do any of those matter?
6 MR. CAMPANELLA: I don't know that I can
7 answer that.
8 CHAIRMAN RYAN: Okay. Maybe that's
9 something I'm offering to others to think about, but
10 I think, to me, that's really where the rubber meets
11 the road in terms of, apart from, not in terms of, but
12 apart from the basic scientific information of high
13 quality to understand the system behavior. That
14 certainly has merit on its own two feet, but I think
15 in terms of performance assessment, really whether or
16 not this will enhance that or you need to get all this
17 detailed information to make a decision, I don't know.
18 I don't see the connection yet, and I think for us,
19 that's helpful for us to try and understand that
20 connection back to enhancement of understanding in the
21 context of performance assessment. So just something
22 to think about. Thanks.
23 MR. CAMPANELLA: All right.
24 MEMBER HINZE: Latif, we have time for
25 just a couple of very brief questions.

1 DR. HAMDAN: Latif Hamdan, staff, and this
2 is an excellent follow-up on Dr. Ryan's latest point
3 and the point he made earlier about assessment.
4 Probably the most important property in the alluvium
5 to the dose calculation and to difference is
6 absorption. And you have these tracer tests that you
7 have, and it was not apparent from your presentation
8 that either DOE or Nye County have used that to
9 determine or to shed light on the absorption
10 coefficient, which is in the different assessment, so
11 the question is will DOE or Nye County use the
12 information from this to shed more light on the
13 estimate for the absorption coefficient in the PA?
14 MR. CAMPANELLA: I think that's going to
15 be part of the work that's going to happen with the U-
16 2 well, if I'm not mistaken. It's supposed to be
17 looking at that. And we did pump Lithium in here, but
18 it appears from a lift response, I didn't show that,
19 that we totally overwhelmed the system with Lithium
20 because we got a fast response time for Lithium that
21 overwhelmed the system, and then we have a slow
22 degrade there that I have not seen the model that
23 we've got to be able to handle that right now.
24 DR. COLEMAN: This is Drew Coleman. I
25 guess I'd say that Rhenium tracer tests were kind of

1 an analog for Technetium and looking at redox
2 conditions that have been discussed in the saturated
3 zone. And you can't get permits for true
4 radionuclides in the field, so a lot of the work goes
5 to doing that work in the lab and looking also at the
6 behavior of permittable tracers, if you will, and
7 making analogous calculations on that. And there's
8 some work going on at Los Alamos to trickle tracer
9 through some of the sonic core sections in the
10 alluvium, so I would say yes, we're looking at the
11 transport characteristics, and that may be more of a
12 project thing than a Nye County thing.
13 MEMBER HINZE: Dave, you had a quick
14 question?
15 DR. DIODATO: Yes, 75 seconds. Dave
16 Diodato, Technical Board Staff. In terms of the risk-
17 significance question, first, the project thinks that
18 the saturated zone alluvium at least is risk-
19 significance. When the MTS did their scoping analysis
20 for peak dose out to a million years, which they
21 represented to the board in February, the saturated
22 alluvium was the only geologic unit included in the
23 assessment. The unsaturated zone was not in there, no
24 volcanic rocks at all were in there, in fact, in that
25 analysis, and that's scoping analysis. But on the

1 other hand, the TSPA in the saturated zone, the travel
2 times range from 20 years to 200,000 years for a
3 conservative species. Now I don't know how
4 hydrogeologists that find that credible. They look at
5 the mean values, that's one thing. But those
6 extremes, again, the realism of that is a matter of
7 question.
8 But with this work that's presented today,
9 I think you can look at the tracer tests and come away
10 with a message that the stratigraphic architecture and
11 the stratigraphic details could make a difference in
12 terms of radionuclide transport, especially if this
13 idea of kind of the buried paleo channels bears fruit
14 and works out to be a conceptual model that holds
15 water in this case, so those are my three comments on
16 that.
17 CHAIRMAN RYAN: I appreciate all of those.
18 I guess what I'm thinking ahead to is this concept of
19 stovepiping. You know, the geologists work on
20 geology, the hydrologists work on hydrology, and
21 performance assessment folks use codes and calculate
22 stuff in a third stovepipe. Somewhere along the line
23 you've got to tie it all together as a system.
24 DR. DIODATO: Absolutely.
25 CHAIRMAN RYAN: And that's what I'm

1 suggesting. We're trying to reach for where's the
2 system view of this.
3 DR. DIODATO: That's a relevant
4 perspective, obviously. And then the only other
5 comment I would make would be to the Nye County folks
6 in terms of the horizontal drilling program. I would
7 say if you're do a horizontal well and you stop when
8 you get to the high permeability feature, then isn't
9 that really the part that you want to test, so why not
10 complete in that zone? That's part of what you'd be
11 looking for. Right? I wouldn't just give up hope
12 when you get to a zone that you start to lose
13 circulation in.
14 MR. CAMPANELLA: No, it's not that you
15 would give up hope when you started losing
16 circulation. It's you're going to reach a point where
17 it becomes so catastrophic you can't continue to
18 drill. You can dry drill. You can go ahead and shove
19 your cuttings into the fracture system, but then
20 you've damaged them, so there's a fine line between
21 having a little bit of leak-off basically of your
22 fluids, and that's why we're going with an under-
23 balance system, is try to prevent that as much as
24 possible. But when you hit large features, you're
25 done.

1 DR. DIODATO: Oh, I think you take my
2 point, though.
3 MR. CAMPANELLA: Yes, but it would be
4 completed then at the end, and we would be able to at
5 least touch into that.
6 DR. DIODATO: Yes. Thank you.
7 MEMBER HINZE: Thank you very much, John,
8 Drew, and Scott. We appreciate the briefings this
9 morning. They have been useful to us. Thank you very
10 much.
11 DR. COLEMAN: Thank you for having us.
12 CHAIRMAN RYAN: It was an interesting
13 morning and good updates all around, so we appreciate
14 it. We are at our appointed lunch break, and we'll
15 reconvene promptly at 1:00. Thanks very much.
16 MR. CAMPANELLA: Thank you.
17 (Whereupon, the proceedings went off the
18 record at 11:34 a.m. and went back on the record at
19 1:01 p.m.)
20 CHAIRMAN RYAN: I guess the appointed hour
21 is here and I would ask everyone to come to order.
22 One small announcement is the designated federal
23 official for the afternoon session will be Neil
24 Coleman.
25 And, without further ado, I will turn over

1 the first part of the afternoon session to Professor
2 Hinze.
3 MEMBER HINZE: Thank you very much,
4 Chairman Ryan.
5 This afternoon, as I am sure we all are
6 aware, we have two distinguished professors that will
7 be making presentations to us on the topic of modeling
8 igneous activity.
9 We will start off with Dr. Andrew Woods of
10 Cambridge University, who we are very pleased that you
11 could finally get over here to make this presentation.
12 We do appreciate that.
13 And we understand that you have been
14 working with the Center for Nuclear Waste Regulatory
15 Analysis on this program. And we will be interested
16 in hearing your comments on modelling the dynamics of
17 simultaneous flank and summit eruptions of basaltic
18 magma.
19 Andy, it's yours.
20 DR. TRAPP: Before we start, just a couple
21 of comments.
22 MEMBER HINZE: John Trapp?
23 DR. TRAPP: Well, first off, one of the
24 great parts of this job is getting a chance to work
25 with people like Andy. It's been a tremendous

1 experience.

2 As you mentioned, he's at Cambridge. He's

3 the BP professor of petroleum science, head of the BP

4 Institute, and professor fellow at St. John's College

5 at Cambridge.

6 The talk today is really what I would call

7 an intermediate talk or an interim talk because if you

8 take a look at many of the eruptions that occur, you

9 do have this phenomenon simultaneously summit and

10 flank eruptions.

11 Before you can get to the point that you

12 can really understand the effects of these things on

13 a repository, you have to understand some of the

14 basics of what causes these things and how they would

15 function, which is really the basis of this study.

16 The phenomena of summit and flank eruptions is not

17 directly how it applies to the repository. That's a

18 later phase.

19 With that, I will turn it over to Andy.

20 DR. WOODS: Well, thank you.

21 Yes. In the next half-hour or so, I want

22 to talk through a talk on the dynamics of simultaneous

23 summit-flank eruptions. And I guess you all got

24 copies of the slides.

25 I will give a brief outline, in which I

1 will sort of introduce the problem, talk a little bit
2 about geology limits for field observations, where
3 there has been simultaneous summit and flank
4 eruptions, talk a little bit about how we can start
5 developing some simple models, concentrated models,
6 that allow us to understand some of the controls on
7 the system, some of the dominant predecessors that are
8 actually controlling the eruption rates and
9 particularly the different eruption rates for the
10 summit and the flank.
11 I will then talk a little bit about some
12 laboratory experiments, where we developed an analog
13 laboratory system to actually simulate some of the
14 effects on simultaneous flay through summit and flank
15 eruptions. And I will draw some conclusions.
16 So the cartoon at the bottom of this slide
17 really -- I guess if I can go back to the previous?
18 Yes. The cartoon at the bottom sort of paints a very
19 simplified picture of what we're thinking about, the
20 deep supply of magma rising up a dike or a conduit.
21 And at some point in the subsurface, this
22 bifurcates into two flow parts, one to the summit,
23 leading to eruptions of the summit, and one to a
24 flank, which will lead to lava flows into a type of
25 eruption on the flank.

1 I am, first of all, going to develop a
2 model to try and quantify the flow through a very
3 simplified picture of this detailed plumbing system.
4 I guess I would emphasize that the detailed structure
5 of the subsurface plumbing system, it's difficult to
6 get detailed geophysical data to constrain that, too.
7 I'm going to develop some very simplified bullets to
8 understand for a given geometry what the controls are
9 on the eruption rates.
10 So, to turn to the next slide, numerous
11 facility systems have evolved both summit and flank
12 eruptions. I've listed three eruptions here. There's
13 the famous eruption in Paricutin, which I guess was
14 described by Krauskopf in 1948. There have been many
15 papers about this since where there were summit
16 eruptions and then there were flank eruptions
17 simultaneously, implying the subsurface system was
18 coupled.
19 Mount Cameroon erupted in 1999-2000.
20 Again, that was a 20 to 30-day eruption. There was a
21 recent account of this in Bulletin of Volcanology
22 talking about high-level events, about 26-50 meters
23 above sea level and low-level events 1,500 meters
24 above sea level, both erupting. And the eruption
25 through both the high-level events and the low-level

1 events evolved over time.

2 I guess an overall characterization would

3 be that there was slightly explosive activity at the

4 high-level events and more lava flow-type behavior at

5 the low-level events, but there was a range of

6 eruptive filament at both events.

7 Mount Etna, which has erupted many times,

8 the 2001 eruption had very complex eruptive activity

9 with both summit and flank eruptions. The slide on

10 the next page shows some data collected by Behncke and

11 Neri during that eruption, and it shows the -- and

12 this is a plot showing the communicative flow rate as

13 a function of time during that eruption.

14 And so the darker line is the total

15 eruption rate. And each of the thinner lines just

16 corresponds to one of the flank vents or summit vent,

17 just showing that there was magma erupting from

18 different vents.

19 And we can look at the sort of cumulative

20 eruption rate but also see that there was behavior at

21 a number of different vents at the same time. So

22 there is a sort of complex subsurface plumbing system,

23 but the observation is that, you know, similar magma

24 eruptions with different events.

25 And we were trying to understand the

1 controls and the dynamics of these simultaneous flank
2 and summit eruptions. The first thing we have done is
3 to develop a very simplified theoretical model, where
4 we are trying to understand what impacts the volatile
5 gases; i.e., the water and carbon dioxide, that exalts
6 from the magma and the magma, what impact the
7 separation of the gas and the liquid phase has in
8 controlling the eruption rate.
9 In a number of situations, in a number of
10 cases, effusive eruptions or lava flow-type activity
11 have characterized the eruptions at the flank;
12 whereas, more explosive-type eruptions, more gas-rich
13 eruptions have been seen at the summit.
14 And so one of the questions we can look at
15 is the impact of the separation of the gas and the
16 liquid. And another issue is how far the flank vent
17 is from the summit. Obviously, the flank vent is a
18 little tight, but it is also at some distance from the
19 main feeder dike. And so there is a different
20 frictional resistance in the flank path to the flank
21 vent as the rest of the summit. And understanding how
22 that can control the eruption rate is also one of our
23 objectives.
24 And then we'll show you some laboratory
25 experiments, just looking at the eruption regimes and

1 seeing how we can see systematic changes in the
2 eruption style.
3 So the theoretical model is really going
4 to start looking at the controls on the gas content of
5 the magma and also looking at the distance of the
6 flank vent from the summit vent. And then the
7 experiments are going to look at a sort of physical
8 analog in which we're going to look at the separation
9 of the gas phase from the liquid phase.
10 So in developing a model, this is a very
11 complex process. So we have developed a very
12 simplified model. And this really follows a number of
13 developments in the literature over the last 15-20
14 years, where a series of simplifying assumptions have
15 been developed and they have been tested with a number
16 of historic eruption in simple erupting geometries.
17 What I have done in this study is we have
18 really taken those model assumptions and extended them
19 to account for having two flight paths to the surface
20 from some deep source.
21 And so we have a deep source of magma and
22 a fixed conduit geometry in the model. And we're
23 going to look at steady state flows. Obviously in
24 real erupting flows, there is a time factor as well.
25 But once a flow becomes established, then

1 typically the time it takes magma to rise from the
2 source through the system interrupt at the surface is
3 short compared to the time of evolution of the whole
4 system.
5 And we saw the data from Mount Cameroon
6 when the eruptions were persisting for tens of days,
7 several days to tens of days. And the actual travel
8 time of the material through the system is more like
9 ours.
10 And so as an approximation, we can assume
11 that we're in quasi-steady flow. And then if we want
12 to understand the long-term evolution of the system,
13 it's possible to build in effects where you can start
14 changing the conditions deep in the system. But we're
15 going to look at steady state flows in this study.
16 One of the key constraints is the exit
17 conditions at the vents. And the exit conditions at
18 the vents really depend on how much of the very high
19 pressure the magma has in the subsurface, is able to
20 be dissipated before the magma reaches the surface.
21 And it's possible of the magma is quite degassed,
22 moving quite slowly, it's possible that the resistance
23 to flow in the work described to you rising to the
24 surface actually dissipates most of the overpressure
25 and the material issues of atmospheric pressure at the

1 vent.

2 But what we find is that as the gas phase

3 or the gas content increases, then the flow tends to

4 rise more rapidly in the conduit. And the pressure

5 doesn't dissipate as rapidly because the density of

6 the mixture falls. And as a result of that, the

7 material issuing from the vent tends to issue at a

8 pressure greater than atmospheric. And it comes out

9 with the speed of sand of the mixture. And so

10 essentially we get choked flow.

11 And so what we see is a change in the rate

12 of change of flow rates as we go through the

13 conditions, but I'll talk about that later. So there

14 are conditions at the vent that are important.

15 One of the main simplifications in this

16 sort of initial model is to assume that the flow is

17 homogenous; i.e., that the magma and the gas bubbles

18 actually rise together as they rise through the

19 conduit.

20 Now, what happens is deep in the system at

21 high pressure, the water phase, the gas phase is

22 dissolved in solution in the magma, but as the magma

23 rises and decompresses, some of that gas phase comes

24 out of solution and produces a bubbly liquid or a

25 two-phase liquid. And depending on viscosity of the

1 magma, the rise speed of the magma, the bubble rise
2 speed through the magma is either greater or less than
3 the actual assent rate of the magma itself.
4 And that determines whether we're going to
5 see primarily homogeneous flow, where it moves as a
6 bulk, or whether we see what is called separated flow,
7 where the gas actually rises more quickly than the
8 liquid.
9 And in this first model, we're going to
10 assume we've got homogeneous flow. And some of the
11 effects of the separated flow will be added in later.
12 But we'll see in the experiments, the experiments
13 obviously lab experiments, in a -- there is an element
14 of separated flow in all the experiments, but
15 obviously it depends on the liquid flow rate in the
16 bubble size, how important that separated flow is, but
17 the experiments do -- I mean, they are physical
18 experiments. So there is no assumption of that. But
19 in the modeling, we are going to assume homogenous
20 flow.
21 We're going to assume the magma is in
22 equilibrium with the gas in terms of the way the gas
23 comes out of solution. And this really follows a lot
24 of the literature modeling basaltic eruptions. And
25 I'm looking at the data about how water comes out of

1 solution.

2 So we have developed a model. And it's a

3 sort of quasi one-dimensional model, where we have a

4 homogeneous mixture rising up the -- there is a sort

5 of feeder dike or feeder conduit, then partitions into

6 the summit and the flank dikes. And so there is a

7 certain amount of gas rising in the summit to the

8 summit vent, a certain amount of gas rising to the

9 flank vent. And a certain amount of the ascending

10 magma rises and erupts at the summit and summit erupts

11 at the flank.

12 And what we are interested in is

13 understanding the partitioning of those fluxes and

14 what some of the controls are within the context of

15 this simplified model.

16 And the dynamics of the flow is really

17 driven by what is called the buoyancy of the bubbly

18 mixture and the overpressure of the chamber. And so

19 I guess the idea here is that there is a feeder

20 chamber or reservoir of magma which has some pressure

21 deep in the crust. And that will drive the magma

22 upwards.

23 Typically the magma itself if it remained

24 as a pure liquid would actually be denser than the

25 material close to the surface, the crust material

1 close to the surface. And so it wouldn't actually
2 ascend unless there was a large overpressure in the
3 chamber.
4 But, in addition to any overpressure in
5 the chamber, as the magma rises and exsolves gas to
6 form bubbles, becomes a bubbly mixture, the density of
7 that bubbly mixture obviously is less than the density
8 of the pure liquid.
9 And so if we look at the weight of the
10 column of bubbly magma from the surface down to the
11 chamber, the weight of that bubbly column is actually
12 less than the weight of the surrounding rock, the
13 surrounding lithostatic pressure, if you like.
14 And so the effect of the bubbly mixture
15 gives us a net buoyancy force, which actually drives
16 the mixture to the surface. And so there are two
17 things driving the flow. It turns out that the
18 buoyancy force associated with the exsolution of
19 bubbles is the dominance, is typically the dominance
20 effect driving the flow to the surface. But we
21 include both effects in our model.
22 As the magma rises, typically in these
23 sort of basaltic systems, the viscosity is a range of
24 viscosities but 10 -- sorry -- 10 up to 1,000 might be
25 a range of viscosities depending on the temperature

1 and the exact composition of the magma.

2 And the typical Reynolds numbers in those

3 flows are quite high. So we're looking at flow where

4 there is turbulent friction on the walls of the

5 conduit. In fact, we have included both the laminar

6 and the turbulent drag law so that if the magma were

7 slightly more viscous and the Reynolds number became

8 more marginal, the band between turbulent and laminar

9 flow, you can actually take a prioritization of the

10 way the effective drag coefficient changes as you

11 undergo that transition, but the flow is typically

12 dominated by the turbulent drag in most of these

13 simulations.

14 And so the equation at the bottom of that

15 page really shows how in steady state flow, the output

16 of momentum of the flow changes because of the

17 buoyancy force, which is really the difference between

18 the first term on the right-hand side, which is the

19 gravitational deceleration, and then we have not put

20 pressure gradient because of essentially the

21 lithostatic pressure. And then we have this drag

22 term. And the term in brackets corresponds to the sum

23 of the diameter in the turbulent drag. And so that is

24 an empirical model, which allows you to map through

25 and model different play regimes.

1 And then, of course, there is mass
2 conservation in each conduit. We are not losing
3 material as the flow rises up each conduit.
4 And so we combine equations for the
5 momentum in the mass conservation of each conduit and
6 combine those with a law for how the gas phase changes
7 with height as the material rises to the surface.
8 And there is a number of different
9 experimental data about how gas comes out of solution,
10 but as a simplifying approximation, we put a
11 parameterized version of this in a form of Henry's Law
12 for the exsolution of the gas. And this is obviously
13 a simplification of any particular magma, but it's
14 representative of loss of experimental data.
15 And then, as I've mentioned before, we
16 have our condition at the vent that the flow either
17 issues atmospheric pressure, which typically occurs
18 with low gas content or the magma is choked at the
19 vent and issues at the speed of sand.
20 DR. MARSH: What is *n*?
21 DR. WOODS: Sorry. *N* is the gas content
22 of the gas content.
23 DR. MARSH: Concentration?
24 DR. WOODS: Yes. It's the mass --
25 DR. MARSH: Yes. I'm just asking -- Bruce

1 Marsh -- Andy what the units in --

2 DR. WOODS: Yes, the mass fraction.

3 DR. MARSH: Mass fraction.

4 DR. WOODS: It's the mass fraction. So

5 typically *n* will vary. Well, it's normal magma, but

6 it's a few percent.

7 Then I guess one of the issues is with

8 separated flow, the tricks would be the same, maybe

9 different to the summits and flank vents. And the

10 pressure may be different at the two vents because the

11 speed of sand depends on the pressure and the

12 compressible mixture. So if the flow rate is

13 different in each of the two vents, we would expect a

14 different speed of sand and a different erupt from

15 pressure.

16 DR. MARSH: Andy, one other question.

17 What is S in there in that --

18 DR. WOODS: This a constant which

19 determines how the gas comes out of the solution as

20 the pressure falls.

21 DR. MARSH: Okay.

22 DR. WOODS: So it's an empirical number.

23 I'll give you an exact number.

24 DR. MARSH: That's all right.

25 DR. WOODS: So in our model, we're

1 assuming there is no gas leak separation, it's
2 homogeneous flow. And what we did, the government
3 equations are sufficiently complex that it's not
4 possible to develop an analytic solution. So we solve
5 the equations numerically.
6 And we have to numerically shoot to
7 actually ensure that we have got the right conditions
8 at the vents. We have to ensure that the materials
9 used at the speed of sand at the vent or with
10 atmospheric pressure. And so there is a need to
11 actually ensure that the band efficients block both
12 vents.
13 And this is a sort of non-trivial
14 numerical integration because we've got two different
15 vents and two different trait conditions. And so we
16 need to search through perimeter space in terms of the
17 eruption rate, give them source conditions to get the
18 consistence eruption.
19 Essentially, the material erupts at the
20 fastest rate possible, consistent with decompressing
21 as much as it can into the surface. And that
22 decompression, the maximum decompression, is the one
23 that takes you to the speed of sand. And so we have
24 to solve that and have it consistent in both vents.
25 And so the next slide really shows, I

1 guess, sort of one of the headline results. And it's
2 really the principles that arise from this that are
3 most important, the qualitative principle.
4 What this graph shows is the eruption rate
5 as a function of the magnetic gas content. And we
6 have a red line, which is the total flow issuing from
7 the volcano. The green line is the flank vent. And
8 the blue line is the summit vent. And this is for one
9 particular fixed geometry of the conduits.
10 What we are looking at here in a
11 parametric sense is how the eruption rates vary as we
12 change the gas content. And so as the gas content
13 increases, we're seeing the overall flux increasing up
14 to about .03. Once we go beyond that, the flow at the
15 vent starts becoming choked. And because it starts
16 becoming choked, it's that the flow rate as we
17 increase the gas content doesn't increase
18 substantially.
19 And what we also see is the partitioning
20 between the flank and the summit vent changes. Both
21 increase for lay gas contents, and the flank vent is
22 actually erupting more in this particular realization.
23 But what we see is once we get to choked conditions,
24 the flank vent actually starts erupting progressively
25 less and the summit vent is erupting progressively

1 more. So the flow is partitioning between the two.
2 And, if you like, the preferred path to the surface is
3 evolving.
4 But these calculations depend critically
5 on a number of other parameters that the actual size
6 of the two flow paths to the surface and the length of
7 these flow paths.
8 So I guess the thing to take away from
9 this is the fact that we're seeing a shift as the gas
10 content increases from eruptions preferring the flank
11 vent to eruptions preferring the summit vent.
12 And then the next graph on the next slide
13 illustrates another key control.
14 DR. MARSH: Excuse me. One thing, Andy.
15 I was just wondering if the flank and summit conduit
16 size are the same in this case.
17 DR. WOODS: Yes.
18 DR. MARSH: Everything is identical?
19 DR. WOODS: In the actual distance, flank
20 vent is obviously at a low elevation --
21 DR. MARSH: Right, right.
22 DR. WOODS: -- from summit vents. So that
23 has a sort of material impact on the eruption rate.
24 So with very little gas contents, what is the gravity
25 erupting from a flank vent is obviously --

1 DR. MARSH: Right.

2 DR. WOODS: -- less than the summit vent.

3 That tends to lead to preferential eruption from the

4 flank vents. Once the flow becomes choked at the

5 vent, then the pressures are actually increasing.

6 And, if you like, the benefit of all cf

7 that, the ease of access to the flank vent relative to

8 summit vent changes. And so it tends to take the sort

9 of straight vertical path.

10 DR. MARSH: So in terms of a drag, for

11 example, at the point of bifurcation, the length of

12 each vent --

13 DR. WOODS: Well, the next slide actually

14 --

15 DR. MARSH: Oh, okay.

16 DR. WOODS: So the next slide is really

17 looking at as we change the solidification, but now

18 what we're doing is we're changing the distance of the

19 flank vent from the main feeder dike, as it were.

20 So we have a main dike coming up going to

21 the summit. And we have a flank vent. But the

22 lateral distance of that flank vent from the feeder

23 dike is actually increasing.

24 And what we see is that as the lateral

25 distance to that feeder dike increases, the

1 partitioning between the summit and the flank tends
2 more towards the summit because that is the shorter
3 flow path.
4 DR. MARSH: What is the summit vent
5 distance, then? If you normalize that bottom axis to
6 the summit distance, let's say, at the point of
7 bifurcation, what would --
8 DR. WOODS: At the point of bifurcation,
9 the summit vent is about a quarter of the height of
10 it. It's about 500 meters.
11 DR. MARSH: Okay. So it's off to the
12 left?
13 DR. WOODS: Yes. And the reason is that
14 because the flank vent is actually lower elevation,
15 there is less work against gravity actually erupting
16 material out of the flank vent and the summit vent.
17 Essentially we have to lift the material another 500
18 meters upwards to get at the summit vent.
19 But obviously that crossover point depends
20 critically on the actual geometry of the system. So,
21 you know, we shouldn't take away our ratio of four to
22 one as a rule.
23 I mean, it depends particularly on the
24 ratio of the whole geometry. This is more
25 illustrative of the fact that there can be a

1 transition from the control beam, the summit vent, the
2 control beam, the flank vent, depending on the
3 detailed geometry of the system.
4 And the other principle that comes out of
5 it in a similar graph is that we changed the width of
6 the flank vent compared to the width of the conduit to
7 the flank vent compared to the width to the summit
8 vent. Obviously the narrow one would have less flux
9 again because there is more resistance to flow. And
10 so you get a very similar flux in that case.
11 So these are some broad principles that
12 allow us to understand that depending on the detailed
13 geometry, it may be the summit vent that dominates or
14 it may be the flank vent that dominates. And it can
15 change depending on the gas contents, the properties
16 of the magma.
17 MEMBER HINZE: Andy, help me here with the
18 diagram going back to page 2.
19 DR. WOODS: Yes.
20 MEMBER HINZE: We're looking at a flank
21 conduit that is at right angles to the dike, then?
22 DR. WOODS: Okay. Yes.
23 MEMBER HINZE: You know, that distance can
24 vary depending upon --
25 DR. WOODS: Absolutely.

1 MEMBER HINZE: -- if you want a --

2 DR. WOODS: Absolutely. This is extremely

3 simple geometry. It's the horizontal path from the

4 main dike to the flank vent. A little bit later on in

5 the talk, I'll show you some graphs where we change

6 the angle of the dike feeding the flank vent.

7 It obviously depends on the point of

8 bifurcation in the master dike, where the two flow

9 paths originate. So the actual path the magma takes

10 in getting to the flank vent could be in a vertical

11 path. It could be in a horizontal path. Just it

12 depends where the dike actually bifurcates into two.

13 So in these calculations, which are

14 deliberately very simple, I'm treating it as a

15 horizontal flow path. But later on I've got some

16 calculations showing it can be 30 degrees as we change

17 it from zero degrees to 30 to 60 to 90. That has a

18 substantial effect on the results.

19 MEMBER HINZE: Can't the flank vent also

20 come directly off from the dike as a separate

21 vertical?

22 DR. WOODS: Yes. It could do. And I have

23 got a calculation showing that a little later on.

24 Yes, exactly. I think what we're trying to do is

25 understand some of the principles because there's

1 obviously a range of geometry.

2 MEMBER HINZE: Please.

3 DR. WOODS: I mean, I would emphasize we
4 are not trying to simulate a specific volcano in this
5 case. We're just trying to understand some of the
6 principles, the physics that we have assumed the
7 beginning actually implies. Okay? So that's all
8 we're trying to do. I think that's the objective of
9 what we're trying to achieve here, is get some
10 understanding.

11 And I think the key understandings from
12 these slides are that the partitioning between the two
13 vents can change depending on the properties of the
14 magma or the geometry of the system. And one may
15 dominate or the other may dominate.

16 CHAIRMAN RYAN: It struck me as you said
17 the same thing that you read before. Can you give us
18 a range in reality of what that might be? I mean,
19 could it be 100, zero in both directions or is it --

20 DR. WOODS: Oh, you mean the ratio of the
21 fluxes?

22 CHAIRMAN RYAN: Yes.

23 DR. WOODS: You know, I mean, it can
24 actually change during the eruption as well. So, I
25 mean, in some of these systems -- well, maybe when we

1 see the experiments, you will see it a bit more, --

2 CHAIRMAN RYAN: Fair enough.

3 DR. WOODS: -- but in some of these

4 eruptions, like in Mount Cameroon, the eruption

5 started at the summit and erupted quite vigorously

6 then. And then the flank vents started a little bit

7 later, but they erupted for 20 days or so. And so the

8 flank vent became progressively more vigorous and the

9 summit vent became less vigorous. So there was a

10 changeover during the eruption.

11 CHAIRMAN RYAN: And for the rookies in

12 volcanism, if you could maybe as you go along give us

13 some or give me some sense of how that might range

14 across different volcanoes or around the world what

15 the patterns might be, that would be helpful. That

16 might be a big apple to bite into, but --

17 DR. WOODS: Yes. I mean, I think if you

18 look at for a minute the data that I showed, if we can

19 just go back to that slide, the slide after that, the

20 next one, the next one, please, yes, if you look at

21 this data, if you look at the thin lines, the thin

22 lines are showing the eruption rate from different

23 vents.

24 So what we're seeing here is this is one

25 of the flank vents that was doing this. This is

1 another flank vent. I mean, there was a series of
2 different vents here. And so the different vents are
3 erupting at different rates. That's the total. Okay?
4 But it's the composition of these different -- so this
5 one here builds up here while that one comes in.
6 So this is the dominance. This is
7 dominant for a while. But then later on, this one
8 becomes dominant. So it can change.
9 CHAIRMAN RYAN: Yes. That helps a lot.
10 Thank you. So it's very dynamic. I don't have a good
11 answer to my question other than it's real dynamic.
12 DR. WOODS: It's very dynamic, yes. And
13 I think what we are trying to do in this is we are
14 trying to rationalize some of the controls that might
15 explain why there can be such variation.
16 CHAIRMAN RYAN: Thank you. I appreciate
17 it.
18 DR. WOODS: So with that sort of
19 theoretical modeling in mind, one of the issues that
20 is very difficult to capture with that model is the
21 partitioning of the gas phase and the liquid phase
22 because we have assumed homogeneous flow. So
23 basically we're looking in the gas and the liquid
24 together.
25 So we can move on a few slides. That's

1 right. So what we found is we actually developed an
2 analog system that allows us to look in a controlled
3 fashion at a very simplified picture of what one of
4 these eruptions might look like.
5 And so in the experimental system -- and
6 I'll show you some in a minute, but in the
7 experimental system, we have a reservoir on the
8 left-hand side of the slide. This reservoir we fill
9 with water. So water is all working fluid. And we
10 have a pipe coming out of the base of that reservoir
11 going along the short section. And then we have a
12 vertical pipe feeding off of that.
13 And, if you like, that vertical pipe,
14 which has "summit vent" written above, at the top is
15 the model of the main feeder dike. And then at some
16 point on that vertical pipe, we put a horizontal pipe,
17 which is a model of the flow towards the flank vent.
18 So it's extremely simple, but it's trying to capture
19 the same geometry as we have in our simple theoretical
20 model.
21 And in the experimental system, we have
22 actually got a series of sections. So on the vertical
23 pipe, just below where the horizontal pipe comes out,
24 we actually have a series of top sections we can add
25 on.

1 So we can change the angle, as Dr. Hinze
2 was asking. We actually have a series of experiments
3 where we change the angle of the pipe feeding to the
4 flank vent. And we can change the height of the
5 summit vent and the height of the vents or the small
6 pipes above the flank vent.
7 And so we can change the geometry of that
8 to model that series of different types of geometry.
9 And what we did in this experiment is, in addition to
10 having this reservoir of water, we actually have an
11 air supply. And we feed the air supply through a
12 controlled valve. And so we can pump in a flux of gas
13 at the base of the summit vent.
14 And so this is a sort of fixed flux of gas
15 that we can control. And we set the system up so that
16 the level of water -- so before we turn the air supply
17 on, the level of water in the reservoir can be above
18 or below the height of the summit vent and above or
19 below the height of the flank vent. Okay?
20 So we can start with a system in which, if
21 you like, the magma chamber reservoir, which is all
22 tank of water on the left-hand side, is actually
23 overpressured or underpressured relative to the two
24 vents.
25 And obviously if it's overpressured and we

1 open the valve, the flow valve, which is along the
2 line AA dashed, as soon as we open up the valve,
3 liquid starts pouring out the vents. Okay? And then
4 we can catch that liquid and measure the flow rate of
5 the liquid.
6 But we can also start the system where the
7 reservoir is underpressured and so, actually, the
8 level in the reservoir is below the level of the two
9 vents, in which case if you open the valve with no air
10 flow, nothing happens. It's all in equilibrium.
11 And then we have this air supply that we
12 have. Adding the air supply allows us to generate a
13 column of bubbly liquid in the main conduit, if you
14 like, that leads up to the summit vent.
15 MEMBER HINZE: Did you ever vary the size
16 of the bubbles?
17 DR. WOODS: Yes, we did. In this
18 particular experimental system, we have one nozzle
19 geometry. There is a whole series of different nozzle
20 systems we have explored. You can get little porous
21 disks, and you can pump the air into a porous disk or
22 you can have a needle where the bubbles come from.
23 It turns out that the bubble -- well,
24 that's a whole interesting other area, but that the
25 surface tension has a lot of control over the sort of

1 size of the bubbles as they are released from a needle
2 or a porous plate.
3 And for the sort of flow rates we're
4 dealing with here, we actually chose a size of bubble,
5 particular size of needle, and had the air come out of
6 that. So we were getting approximately the same size
7 bubbles. But that could be varied.
8 First I'll show you the results to show
9 you the effect here. I mean, the challenge in this
10 analog system is to get extremely small bubbles, where
11 we're going to get exactly absolute homogeneous flow.
12 So the bubble speed is much smaller than the liquid
13 speed.
14 In these experiments, the bubble rise
15 speed based on the bubble size ranged from being a
16 factor of about ten smaller to a factor of ten larger
17 than the liquid rise speed. And so what we were able
18 to do in this experimental system was actually model
19 the transition from homogeneous to separated flow.
20 So you could obviously do what you are
21 saying, but I suppose the question is, what are we
22 trying to achieve with this? What we are trying to do
23 is understand how the eruption might change as we
24 start changing some of the premises? And I think if
25 I show you the results, you will see we have achieved

1 that.

2 MEMBER HINZE: One of those is the bubble,

3 the size of the bubbles, and resulting homogeneity.

4 DR. WOODS: Absolutely. But the

5 homogeneity really depends on the rise speed of the

6 water compared to the rise speed of the bubbles. So

7 I guess we chose these so that we can actually spend

8 that regime.

9 CHAIRMAN RYAN: Right.

10 DR. WOODS: We could change it, but the

11 interesting changes occur as we go through that

12 transition from homogeneous to separated flows. So I

13 think we've captured the principle in a sense.

14 DR. MARSH: One other question, Andy,

15 before you go on. One of the critical measures, of

16 course, is the size of the bubble relative to the

17 conduit size.

18 DR. WOODS: Yes.

19 DR. MARSH: And that bears on what you are

20 talking about. But what in general range are you

21 operating in in terms of --

22 DR. WOODS: All bubbles, they're probably

23 about half to a quarter of the size of the --

24 DR. MARSH: They're fairly significant in

25 size, yes.

1 DR. WOODS: In terms of the -- again, it
2 depends on what question you are trying to explore.
3 DR. MARSH: Right.
4 DR. WOODS: And there's a number of
5 different issues you could explore.
6 DR. MARSH: You can justify it somewhat
7 because in a real system, bubbles coalesce and things
8 like this. So they get big. But that's a huge bubble
9 for a real volcanic system, although, I mean -- or
10 conduit, right? That's a quarter of the size?
11 DR. WOODS: Yes. Okay. Again, it depends
12 on the --
13 DR. MARSH: What you're after, I realize.
14 DR. WOODS: We're not trying to simulate
15 the eruption here.
16 DR. MARSH: Right.
17 DR. WOODS: What we're trying to do is
18 understand some of the principles. And there's
19 obviously a huge number of different variables in an
20 experiment which you can change. And so we have tried
21 to understand some of the controls.
22 And we also tried to understand what is it
23 that we're not simulating what the experiments are
24 doing and do they need to correlate to different
25 deductions, I guess, is the --

1 DR. MARSH: So, in other words, for what
2 you are after, this part of the experiment is not that
3 meaningful?
4 DR. WOODS: Yes.
5 DR. MARSH: You can have big bubbles, for
6 instance, --
7 DR. WOODS: Yes. I think --
8 DR. MARSH: -- or separated flow. And you
9 want to see the transition from that?
10 DR. WOODS: Yes. I think these
11 experiments are fit for this purpose. And yes, I
12 would like to -- by way of context, we have actually
13 got a -- I mean, this is called a small experiment
14 system. We actually have a very big flow leaf, about
15 a six-meter flow leaf as well, which we will be
16 running experiments of the much broader range of
17 bubble sizes. And we see very similar effects.
18 I think the correlative results from this
19 don't change. We do vary that premise, but that's
20 obviously to well-defined experiments. Yes.
21 And I think the sort of interesting thing
22 to do is to, first of all, have a look at the system
23 where we're just looking at eruption from a vertical
24 summit.
25 So the data on the next slide is

1 interesting. And the photographs show -- photograph
2 A is the case where we have a small bubble flux and an
3 enterpriser chamber. So you can see there are sort of
4 quite large slugs developing in the pipe, but we've
5 got a rather small bubble flux.
6 And then B is the case where we have a
7 larger bubble flux. And we see, you know, at the top
8 of the photograph a more vigorous looking -- I know
9 it's a snapshot, but it's a more vigorous looking flow
10 coming out the top of the conduit.
11 What we do systematically is we have
12 varied against flux. And we have measured the water
13 flow rate. We control against flux. The water flow
14 rate is what you get in experiments. And we have
15 changed the pressure of the reservoir feeding the
16 system from being underpressured to neutrally
17 pressured, which means that the water levels at the
18 top of the conduit before we use putting gas in, then
19 we have an underpressured system, in which case the
20 pressure of the reservoir is below the top of the
21 conduit.
22 And the data on this graph show the sort
23 of three cases. So the diamonds are the case in which
24 we have it neutrally pressured. So when there is no
25 gas flow, there is no water flow.

1 So there are the diamonds. And those
2 would be increased against flow. We induce a water
3 flow. The circles are the case in which we have an
4 overpressured reservoir. So even if no gas flow, if
5 we open the flow valve, then flow starts out the pipe.
6 And as we add gas flow, the flow increases and
7 increases from in the circles 30 to about 50 cc a
8 second.
9 And then the triangle data corresponds to
10 the case where we have an underpressured reservoir and
11 we need to put enough finite flux of gas before any
12 liquid flow occurs from the conduit. Before that
13 happens, the bubbles just issue from the top of the
14 conduit. And we get just degassing.
15 I think this data actually provide a very
16 simple analog to interpret some of the behavior you
17 see at summit vents of some volcanoes, the Strombolian
18 volcano in Italy, offshore Italy. You know, you see
19 a range of activities where you get bubble-bursting
20 events at the surface. And other times you just get
21 degassing without any magma issuing from the volcano.
22 I think this provides some insight into
23 how those different play regimes can occur in terms of
24 the source of gas and source of liquid. But the key
25 thing in all the results is the flow increases of the

1 gas flux, which is as you would expect.

2 MEMBER HINZE: What's the line, the open

3 pattern? What is it? Line? The open diamonds, et

4 cetera.

5 DR. MARSH: That's when you have gas flow.

6 DR. WOODS: No, no. Sorry. Yes. The

7 horizontal access is the gas flow. Sorry. So the

8 solid symbol and the hollow symbols correspond to a

9 different mechanism supplying the gas. So we have a

10 valve which allows you -- we have an air supply, a

11 couple of atmospheres of pressure. And the air supply

12 provides a range of gas fluxes for each valve. So we

13 have to use two different values today for low gas

14 fluxes and high gas fluxes.

15 And so we have actually --

16 MEMBER HINZE: So you get the full range

17 of gases?

18 DR. WOODS: Yes. You get the full range

19 of gases. So we actually discussed the data -- just

20 for proper reporting of what we have done. And what

21 you say is there is actually very good consistently

22 between the triangle data, the solars and the hollow

23 symbols, you know, overlapping ag in in the diamonds.

24 I think another thing that is interesting.

25 Just for proper reporting of what we have done, what

1 you say is there is actually a very good consistency
2 between -- it's in the triangle data. The solars and
3 overlapping system symbols overlap -- and this is the
4 two gas fluxes.
5 I think the other thing that is
6 interesting to note here is that there is a degree of
7 scatter int eh data. It doesn't follow a fixed curve.
8 And I think that is sort of history systems operate.
9 And there is a sort of range of fluxes.
10 So we turn to the next slide. What we see
11 We've always done a whole suite of comments. We've
12 included hundreds and hundreds of picture here, but if
13 people order there's a whole series of pictures of a
14 different play regimes. This shows a system if you
15 look at the bottom photograph.
16 It shows a system where the section at the
17 top of the vertical conduit pipe now has a horizontal
18 section as well as the vertical section. And in the
19 center of that horizontal, the flank bent actually
20 gone to that -- you could think of that as a little --
21 and was made by coming out of that.
22 We actually have a system where we have a
23 third flank vendor, but in this experiment, it's
24 sealed up. And so that is passive and has no pot to
25 play the experiments.

1 DR. MARSH: Is that the right-hand --

2 DR. WOODS: It's sealed up.

3 DR. MARSH: Yes. Okay.

4 DR. WOODS: So that's particularly

5 passive. The data with two vents in the data with

6 this external section are identical but within the

7 experiment for error. But I just think that

8 photographs for -- and what is happening as we go from

9 the top photograph to the bottom photograph is we're

10 increasing the gas flux.

11 And so you see in the top photograph the

12 gas flux, it's an underpressured system. And the gas

13 flux is quite small. And so what is happening is the

14 gas is actually causes the liquid in the conduits or

15 the pipe above the main feeder, to rise a little bit.

16 But it doesn't reach the top. And so

17 there is no eruption from the summit for the low gas

18 flux. Some gas is coming out with summit. And so

19 some of the air supply is coming out with summit,

20 then, but there is no liquid coming out. There is

21 liquid coming out the flank vent. And there was some

22 gas taken without liquid.

23 As we increased the gas flux, the height

24 of the liquid in the vertical in the summit increases,

25 but it still doesn't reach the surface. But there is

more gas coming out the surface. But now because the gas flux is increasing, we're actually carrying more gas to the flank vent so that flank vent is becoming more vigorous in this case. So you can see there is liquid flying out hard from that vent.

In the third photograph, the flux has increased sufficiently to actively liquid out the summit as well as the flank vent. And as we further increase the gas flux, we get a shift towards the summit vent.

And the data is a systematic series of data shown in the graph or the chart at the bottom of the page, the bottom right-hand corner. And there are three series of data here. But let's look at the red data, just the different colors of three different experiments. Let's just look at the red data and focus on what we are seeing in that red data.

What we see is the vertical axis shows the liquid flow and the horizontal axis is the gas flow. And it's the gas flow that we are actually controlling. So that is what we are inputting into the system.

What we see is that for very low gas flow rates, the eruption rate, the liquid eruption rate, increases. And it is all coming out the flank vent.

1 The red diamonds are all zero up to a gas flow of
2 about 15 cc a second. Above 15 cc a second, what you
3 see is the diamonds start rising off the axis. That
4 corresponds to a point at which the summit vent stops
5 issuing liquid as well.
6 So up to that gas flux, we have only got
7 eruption from the flank vent. The logic gas fluxes,
8 we're getting progressively more erupting from the
9 summit. So the diamonds are increasing.
10 What you see at the same time is the
11 amount issuing from the flank vent actually starts
12 decreasing because there are obviously two across the
13 surface now.
14 The overall eruption rate, which are the
15 circles, continue to increase. And if we keep an
16 increasing gas flux, that eventually will saturate.
17 That is what we are seeing. We are seeing an increase
18 in eruption rate, overall eruption rate, with gas
19 flux, but we're seeing a drop in the flank and an
20 increase in the summit with the gas flux.
21 And that is consistent. The blue data,
22 the blue symbols, are showing very similar data. But
23 the green data I guess emphasize the point that -- the
24 green data corresponds to the case where the summit
25 vent is a little higher. And so in that case, it's

1 actually harder to divert the flank out the summit
2 vent because we have a much higher elevation of the
3 summit vent.
4 And so I guess the message from this is
5 this is sort of a consistent, sort of consistent with
6 our calculations, but the detailed geometry has a big
7 impact on the quantitative details.
8 I think we're seeing some of these
9 principles about separation of the gas and liquid flow
10 very clearly. I think one of the interesting things
11 these experiments shows is it's possible to have a
12 summit vent that is issuing a lot of gas, especially
13 having bubbles bursting at top of the summit vent,
14 where while you can have vigorous lava-type activity
15 for a flank vent because at the point of connection,
16 a lot of the gas can carry on rising, but the liquid
17 can sort of move down the lateral vent.
18 If you are interested in understanding how
19 this ties into the dynamics of what we were seeing
20 before, if we think about the conduit below the level
21 at which the dike bifurcates, in that zone in the
22 conduit, we have got a mixture of bubbles and liquid.
23 And so the density of that mixture is actually much
24 less than the density of the surrounding crust or in
25 this case the reservoir.

1 Our driving force for the flow going out
2 the flank vent is the buoyancy of the bubbles. It's
3 just that when we get to that bifurcation in the
4 dikes, the bubbles actually separate from the liquid.
5 And so we're getting mainly lava issuing from the
6 flank vent.
7 I think this is discretional as is why
8 it's possible to get any points, large lava flows
9 coming out from flanks when you have actually got
10 quite volatile magma because the bubbles -- some of
11 the gas can separate and come out the summit and the
12 sort of multi-gas magma sort of whizzes at the flank.
13 So I think that is an interesting learning from these
14 experiments corroborated with the data.
15 The next slide if we just turn, sort of
16 goes back to the calculations that addresses the point
17 Dr. Hinze is asking about, just changing the angle of
18 the vents. What we're seeing here is that as we
19 change the flank so that the line at the bottom is
20 where, if you would like, we have got a vertical dike.
21 And as we change the angle of the dike, what we're
22 seeing is the way the eruption changes.
23 So we have got a point of bifurcation
24 where we're mentioning just a dike at different
25 angles. So, again, it's a parametric study. And it's

1 looking at what is the eruption rate as a function of
2 the gas content for different geometries of that flank
3 dike.
4 What you see is that the vertical dike has
5 a harder time erupting for gas content than a lateral
6 dike, essentially because we've got, you know, not the
7 same elevation to lift the magma through. But as the
8 gas content increases, there is a changeover. And the
9 magma prefers to go or it's easy to go on the shorter
10 flow path, which is the more vertically aligned dike.
11 So, for example, if we look at the
12 picture, the black line, the 90-degree, which is a
13 horizontal dike, and the red line, the 30-degree dike,
14 the eruption rates cross over with a gas flux of .03.
15 And, you know, above that gas flux is
16 easier for more of the material would erupt from the
17 30-degree flank dike. And that's really a result of
18 the fact that that is a shorter flow path. And so the
19 resistance to flow is less. And that is what is
20 dominating, rather than the working its gravity.
21 And that's really because as the gas flux
22 increases, the buoyancy of the mixture increases. And
23 so gravity becomes less of an impediment to the flow.
24 And so there are some quite subtle changes in what
25 controls which is going to be the dominant flow path

1 to the surface, which arises from that.

2 So, really, there are sort of headline

3 learnings from this study. And I guess the

4 conclusions are that fluxes are petitioned between

5 summit and flank vents. And we deduce some of the key

6 controls on this from numerical experimental modeling.

7 This is an initial study, and there is a lot more.

8 What can be done is to try and learn more.

9 But I think some of the principles have been already

10 established through the sort of systematic experiments

11 and some parametric studies of the simplified model.

12 And what we're seeing is that with a large

13 gas content, we tend to get greater play from the

14 summit. With larger bubbles, there's going to be more

15 separation. And so you'll tend to get more effusive

16 eruptions in the flank. That really comes from the

17 experiments. And for the small gas content, we're

18 going to expect to see more effusive-type eruption

19 from the flank dominating.

20 On the next page, you know, the distance

21 or the geometry of the system really has a big control

22 over whether the summit or the flank -- which one is

23 important, how far the flank vent is from the summit.

24 And, you know, with low volatile content magmas, we

25 would expect to see more of the material issuing from

1 the flank than the summit.

2 Gas-liquid separation can lead to an

3 explosive degassing behavior at the summit without

4 very much liquid being erupted from the summit while

5 you can have quite a lot of effusion going on in the

6 flank. So this is sort of interesting.

7 This is the geometry I guess of the

8 plumbing system. It can actually do a lot of

9 separation for you and allow you to get

10 Strombolian-type bubble bursting or pops going off at

11 the top of the volcano with vigorous lava flows going

12 out the side. And I guess that seems to be consistent

13 with the separated flow picture.

14 So I think we have learned quite a few

15 things that were in the field data, sheer observations

16 of lava flows from flank vents and the more explosive

17 behavior consistent with more gas going to the summit.

18 But I think we have sort of got the beginnings of a

19 rational basis to try and understand the origins

20 behind that from some of the controls on that from the

21 study.

22 MEMBER HINZE: Thank you very much, Dr.

23 Woods. I appreciate it. You had us all enthralled,

24 I hope. I think we kept coming back to what John

25 stated, that we weren't on the analog, the actual

1 volcanic problem. We were looking at the principles
2 involved. You were looking at the principles
3 involved.
4 Let's ask Dr. Weiner if she has any
5 questions.
6 MEMBER WEINER: I just have a couple. I
7 am really enthralled by your experiments. Did you
8 look at or could you speculate on what would happen if
9 you used liquids of a different viscosity glycerine?
10 DR. WOODS: Yes. We did glycerine
11 experiments, too. Sorry. I forgot to mention. Yes.
12 Really, what happens is it depends on I guess the
13 Reynolds number of the flow. That's sort of the peak
14 control.
15 MEMBER WEINER: Yes.
16 DR. WOODS: And the reason we were using
17 water here was to get -- in these experiments, we were
18 getting Reynolds numbers of a few thousand. And that
19 starts to coincide with the case you would expect in
20 a lot of these basaltic systems.
21 If you move to glycerine, which tends to
22 be -- it depends on if you use water, you can change
23 its viscosity. That tends to get more viscous. And
24 you move to a low Reynolds number flow regime.
25 And when you do that, the dynamics change

1 because it's essentially not the turbulent flow. The
2 bubble rises through the liquid as well as the sort of
3 overall liquid flow rates because much more controlled
4 much more by the viscosity of the glycerine.
5 I guess the broad principles of separated
6 flow persist, but I'm not sure that -- in the scale of
7 our experiments because they're quite small
8 experiments, we need to use a less viscous liquid to
9 simulate the -- to get the Reynolds number regime.
10 With a larger system, where you want to,
11 say, explore the effect of different bubble size
12 distribution, you know, and you have a much larger
13 pipe system in experiments, using glycerine would have
14 been more appropriate because you've only got Reynolds
15 numbers of a few thousand. And you need to make more
16 viscous the water in that case.
17 So I think what we have done is we have
18 tried to scale the experiments so we're in the right
19 -- we have done a similar regime for the volcanic
20 case, albeit we've got a smaller system. And if we've
21 got a Reynolds number flow, we can start moving to a
22 slightly different play regime.
23 MEMBER WEINER: The other variable I
24 wanted to ask about was temperature. I assume you
25 didn't make any attempt to control the temperature.

1 DR. WOODS: These were all at lab
2 temperature.
3 MEMBER WEINER: Just ambient lab
4 temperature?
5 DR. WOODS: Yes, yes.
6 MEMBER WEINER: But as you heat water, you
7 evolve gas from the water also. Now, I don't know
8 anything about magma, and I don't know how that would
9 represent a magma system, but have you looked at what
10 happens if you change the temperature or keep the
11 temperature constant in such a way that you are also
12 evolving gas from the liquid, releasing dissolved gas,
13 basically?
14 DR. WOODS: Yes. So in the model, it's
15 not an experiment, but in the theoretical model, we
16 are actually releasing gas by depressurization. Okay?
17 So we're actually -- so in the experiments, we have
18 the gas by having a compressed air supply. And that's
19 a model for some of the gas flux that you get by
20 decompression exsolution in the magnetic system.
21 Yes. So I think, you know, we're trying
22 to look at the bubbly flow and see how the bubbly flow
23 evolves.
24 DR. MARSH: Well, you are basically
25 simulating that by interjecting the bubbles in.

1 MEMBER WEINER: Interjecting.

2 DR. MARSH: That basically handles that

3 kind of phenomena in this experiment, yes.

4 MEMBER WEINER: Thank you.

5 VICE CHAIRMAN CROFF: Have you tried to

6 use your model to predict the experimental results?

7 You've got data points. Use the model.

8 DR. WOODS: Yes, yes. What we've looked

9 at is what are the critical conditions for -- sorry.

10 I'll step back. In a lot of these experiments, we're

11 actually dealing with a more separated flow regime.

12 So there is some slip velocity between the

13 liquid and the bubbles. But we're able to take the

14 model and try and predict the critical gas flux at

15 which we would expect to see liquid issuing from the

16 summit vent, for example. And you can get a critical

17 gas flux, and we should expect that to occur. And

18 that seems to coincide with the theory.

19 Once you go into the two-phase flow, just

20 say the single conduit flow, trying to predict the

21 actual flow rate, because of the slip that we're

22 getting between the two phases, you have to include

23 that in the model. So the homogeneous model we have,

24 you're probably specially pushing happily you can

25 apply that model to these experiments.

1 It would be possible to do experiments in
2 a bigger conduit with some running at length, but it
3 would be possible to do it in a bigger conduit, where
4 you have small bubbles, which are moving much more
5 slowly than the liquid. And then that model should
6 coincide with the experiments. But we haven't done
7 that yet.
8 VICE CHAIRMAN CROFF: Thanks.
9 MEMBER HINZE: Dr. Ryan?
10 CHAIRMAN RYAN: No. I asked my questions
11 along the way. Thank you.
12 MEMBER HINZE: Dr. Clarke?
13 MEMBER CLARKE: I was going to ask about
14 temperature, too. It doesn't appear explicitly in
15 your equations, but I guess it comes in in other ways.
16 Is that --
17 DR. WOODS: Okay. In the sort of
18 theoretical model, where we're looking at doing the
19 studies, we're assuming that the system has reached
20 steady state. And so the material is issuing at the
21 surface.
22 There will be some temperature change
23 associated with some of the exsolution as the magma
24 rises to the surface, but that will be quite a small
25 change in temperature compared to the starting

1 temperature of the magma.

2 Yes. So we haven't specifically included

3 that in the model.

4 MEMBER CLARKE: As I understood it, all of

5 your scenarios or your experimental conditions

6 resulted in eruptions. Is that correct? Did you look

7 at it?

8 DR. WOODS: In the experiments?

9 MEMBER CLARKE: Yes. In other words --

10 DR. WOODS: No. When we have an

11 underpressure chamber and we have a gas supply, we can

12 just get pure gas issuing from the surface. But yes.

13 So in that case, we're getting eruption of gas, I

14 guess, but not liquid.

15 MEMBER CLARKE: Yes. I was just

16 wondering. Is the point at which the phase separation

17 is complete important to -- you know, I have just a

18 very basic question reflecting my lack of

19 understanding that if you had total separation and you

20 were still below the surface, would that be the end cf

21 it?

22 DR. WOODS: Okay. I think there is a

23 slightly bigger picture. What we have been looking at

24 is the conduit on the surface. And there is a source

25 of material actually driving that flux to the surface.

1 And so if you go somewhere like Stromboli,
2 where you see bubbles bursting at the surface and
3 there is a little gas issuing and not as much liquid,
4 in that sort of eruption style, the gas is still being
5 derived from somewhere. It's still coming from
6 decompression or exsolution of gas somewhere deeper in
7 the system.
8 MEMBER CLARKE: Okay.
9 DR. WOODS: And then you need to have a
10 different mechanism of replenishing or recharging that
11 liquid flux. So in these systems where we're
12 imagining a reservoir builds up somewhere in the crust
13 that then triggers the eruption, that's the source of
14 the liquid and the gas.
15 So in that sort of scenario, which is sort
16 of the scenario we have been talking about with these
17 examples in Etna and Paricutin and so on, you know,
18 we've got eruption of both the liquid and the magma
19 because when we ask that accumulation across the
20 eruption of that chain but to surface.
21 And to get fully separated, experiments
22 show that the summit has fully separated flow, but the
23 flank will still sort of erupt lava, you know, sort of
24 erupt the liquid.
25 I guess it would depend on if you had a

1 chamber that was underpressured sitting in the crust.
2 You know, the question would be, why did it start
3 erupting in the first place? Typically, which is a
4 whole different topic, it does start to erupt.
5 There will be some initial pressure,
6 actually, driving that initiation of the eruption.
7 And that will be driving liquid to the surface. And
8 then what has happened is the bubbles increased, the
9 buoyancy increased. The bubbles are there providing
10 the driving force as shown in the model.
11 So the steady state model is really
12 illustrating that the evolution of the gases is
13 actually key for driving the continuing eruption.
14 MEMBER CLARKE: Any future experiments
15 planned that would look at other conditions?
16 DR. WOODS: What sort? I'm not quite sure
17 what you're --
18 MEMBER CLARKE: Well, I'm just asking.
19 DR. WOODS: I think there is a number of
20 -- I mean, there are a lot of interesting experiments
21 to do to understand Dr. Hinze's question about the
22 bubble size distribution on that dynamics. And there
23 are a number of other questions to look at.
24 I think one of the challenges in
25 experimental modeling is to get analogs that are sort

1 of physically consistent with the system. And so it's
2 necessarily simplified to try and get a handle on some
3 of the processes. But there are clearly other
4 processes there that it would be nice to simulate as
5 well. So, I mean, there are all more experiments to
6 do.
7 MEMBER CLARKE: Thank you.
8 DR. TRAPP: Just a very quick add-on. One
9 of the things that we were doing this morning and we
10 will be doing tomorrow is sitting together with Dr.
11 Woods and talking about our planned experiments,
12 studies, et cetera, for the next year or so.
13 I can't tell you what they are right now.
14 We're still working on it.
15 MEMBER HINZE: Dr. Marsh, did you have a
16 question?
17 DR. MARSH: Yes, a couple of questions.
18 Just so I can get this straight myself, you start up
19 the system, for example. And let's say it's
20 underpressured. So basically it can flow from the
21 flank because it's lower in height. You can set it up
22 so there is some flow.
23 And I'm kind of getting straight why the
24 bubbles know how to go up to the flank. And that's
25 because when the bubbles are small, they're entrained

1 in the fluid and the fluid is carrying them along,
2 basically. And so the fluid is venting up flank. So
3 they go that way.
4 We increased the bubble size and the gas
5 flux. When they get to the corner, for example, they
6 have their own moving faster than the fluid basically.
7 They're rising faster than the fluid. So they want to
8 go straight. And so as you increase the gas content,
9 it becomes a very low-density column. And it starts
10 going out of the gop. And so you have both erupting.
11 Now, I don't know. Maybe Britt can answer
12 this. Have you ever seen a system where the flank
13 actually starts erupting first, shoots some flows
14 before we get the Strombolian phase?
15 I don't know, but, I mean, it's an
16 interesting trade-off here in terms of the -- you
17 know, that critical transition is interesting in terms
18 of I've never known -- usually flank eruptions develop
19 after the main event starts or shortly thereafter,
20 like Paricutin and stuff like this.
21 But the transition also -- there is a
22 major transition also in the flow, then, really, in
23 terms of oleometer flow, which is fluid-dominated
24 small bubbles. And then you increase the gas mixture,
25 gas content, and it becomes, really, a gas-dominated

1 flow --

2 DR. WOODS: I mean, I think we need --

3 DR. MARSH: -- at the corner, to the

4 corner.

5 DR. WOODS: Yes. Then you --

6 DR. MARSH: D gas is at the corner, I

7 guess.

8 DR. WOODS: Yes. I mean, in these

9 experiments, we fixed the geometry.

10 DR. MARSH: Right.

11 DR. WOODS: And so we're in that geometry.

12 And clearly in a real erupting system, the geometry

13 evolving --

14 DR. MARSH: That's fine. I understand

15 that entirely. Sure.

16 DR. WOODS: You're ordering in a real

17 system of which water erupts first. It's going to be

18 controlled by the geometry of the evolving dike system

19 as well as by sort of bubble liquid dynamics.

20 So I am not saying they are similar. I

21 think what I am saying is that if during the eruption

22 the geometry evolves, all of the pressure of the

23 chamber evolves, all of the -- either of these effects

24 can have an effect of changing the balance during the

25 summit and the flank eruptions. The flux is coming

1 from the summit and the flank.

2 And I think what we're seeing from the

3 experiments is very -- it's sort of one physically

4 consistent picture in which we can understand why

5 we're able to see different styles of eruption of the

6 same magma from different events simultaneously.

7 But I think there are obviously other

8 questions to explore. I'm not trying to simulate the

9 eruption here and some of the processes controlling

10 it.

11 DR. MARSH: I appreciate that very much.

12 Thanks.

13 MEMBER HINZE: Our time is fleeting here,

14 but I'm going to use the Chair's privilege to ask you

15 one question. One of the important phrases that to

16 many people's peer review, I'm wondering if you have

17 any plans for publication of this work and what that

18 might be.

19 DR. WOODS: Yes. I mean, this is sort of

20 going through the publication process at the moment,

21 the sort of first phase of this. And so that's

22 basically en route through the journal process and

23 this further work.

24 MEMBER HINZE: What journal is this?

25 DR. WOODS: That's going to be the

1 Bulletin of Volcanology.

2 MEMBER HINZE: Volcanology. Thank you.

3 DR. WOODS: Yes.

4 MEMBER HINZE: With that, your time has

5 expired. And I'm afraid we're going to have to move

6 on so Bruce has his time. We thank you, Dr. Woods,

7 for an excellent presentation.

8 With that, Dr. Bruce Marsh will make a

9 presentation entitled "Magma Interactions with the

10 Repository: The Effects of Solidification." Bruce,

11 I imagine that you will be using the pointer a fair

12 bit.

13 So I would suggest that anyone who is

14 sitting over on this side and wants to see where Bruce

15 is pointing to, that you come around here because you

16 can only really point on what is --

17 DR. MARSH: I'm sorry that this isn't the

18 best, as I'm sure Andy realized, the venue for a

19 university professor who likes to get up and walk

20 around and gesticulate at the board and point, et

21 cetera. But we'll make do with this.

22 I am actually going to talk about -- in

23 fact, strange as it may be, Andy's talks and mine are

24 somewhat complementary. I'm going to talk about

25 what's happening to the liquid phase of the magma as

1 it degasses as it approaches the surface and what
2 happens in terms of its solidification effects on it.
3 And some of what I am going to talk about
4 will be familiar to some of you before, but to get you
5 all on the same page, I will go over some -- and, of
6 course, you have all see that picture. I just cribbed
7 that in from DOE to talk about why we are here to
8 worry about what happens if magma hits the repository.
9 So on the next figure, you see kind of one
10 of the main things I'm going to be talking about. And
11 that is solidification fronts in general. And
12 solidification fronts, of course, we're dealing with
13 a magma. And everywhere that magma is, the boundaries
14 of the magma are going from a solid to a melt and
15 somewhere into the middle, with or without carrying
16 crystals, entrained crystals, and with or without
17 bubbles and vesiculation. And so this is what I am
18 going to talk about in detail.
19 But to show people, really, what these
20 things are in detail, I want to review a little bit of
21 how these things actually work and to show what
22 happens when you actually encounter them in reality.
23 So what we mean by solidification front in
24 the last picture, if you could just go back to that
25 for a second, please, is this is on the left-hand side

1 here -- for example, on the bottom axis, you see
2 crystallinity. This is from a crystallinity fraction
3 from one to zero. And on the right-hand side,
4 basically it shows the melt viscosity content, I
5 guess. This is the viscosity of the interstitial melt
6 in between the crystals.
7 So as magma crystallizes because the
8 crystals are different competition than the magma, the
9 melt evolves chemically. And what we see is a
10 tremendous change in the silica content of the melt.
11 So across the top axis, you actually see the
12 interstitial melt silica content.
13 So starting with a basalt, for example,
14 something like we would see in the western U.S., near
15 Yucca Mountain, 50 percent silica, and after about 50
16 percent crystallization, the interstitial melt has
17 increased to 55 percent. In other words, it has only
18 gone up by five percent in silica.
19 And you can see the viscosity increasing
20 from a value. I can't even see the exponents on it.
21 Maybe it's in the figure here, yes, 100, something
22 like this. But it goes up very, very large, of
23 course, and be 10^8 or so back at the other end of
24 here.
25 I put on words here to describe for those

1 who are of the geological mind this would be a basalt
2 out in here, be some kind of andesitic liquid here.
3 This is a dacitic liquid wave out in here of about 65
4 percent silicon and a rhyolitic or granitic liquid way
5 out in here. And that's interstitial.
6 Now, the interesting aspect of this I am
7 going to show you about is that once we get to about
8 50 percent crystallization, this material is at
9 maximum packing. In other words, the solids are all
10 touching.
11 In fact, because they're crystallizing,
12 they're tacked together. And this thing actually has
13 strength, has a lot of strength in it now. Once you
14 get to 50 percent crystals, it has a lot of strength.
15 So this thing is actually basically a
16 dilatent solid. These are materials that are packed
17 together. And this material is welded. I'll show you
18 more about this in a minute.
19 Now, there is experimental evidence,
20 actually, to show many basaltic systems that have a
21 lot of phals partiture, long, thin crystals that a
22 loose chicken wire network actually sets out, even at
23 25 percent crystals. And this thing has some strength
24 out in there, too. This is the basic feature that I
25 am going to be talking about.

1 If we go on to the next slide, just to
2 show some -- we're going to go to Hawaii and look at
3 Kilauea Volcano here.
4 Next slide. And you will see this is the
5 main Kilauea summit volcano, Halema'uma'u Fit. And
6 right in front of it, actually, is an interesting
7 thing.
8 One of the most difficult aspects of this
9 subject that we work with is the fact that we never
10 get to find a giant pool of magma somewhere in Europe.
11 We all talk about magma chambers. We all talk about
12 conservations of magma. But, in fact, we have never
13 found one anywhere that is accessible to us.
14 We see some perhaps but along the ocean
15 ridges, other places, but we have never been able to
16 have one of any large size that we can do experiments
17 in or do anything significant in that would approach
18 what we think is a magma chamber.
19 In Hawaii, however, there has been a
20 series of lava lakes. And this is Kilauea Iki Lava
21 Lake. Now, this is not a crater, but this is a
22 substance, basically, from a subsistence of the land
23 due presumably to a lava tube that is underneath the
24 area.
25 This pit was preexisting. And, as often

1 happens in topographic areas like this, the eruption
2 that took place in Kilauea Iki in 1959 took place up
3 on this shoulder here on the side. That very much
4 happens. You might think about that in terms of
5 topographic influences where these things come out.
6 This was a fire fountain. You can see how
7 the wind pushed some of the spatter and things around
8 downwind here. This is basically the influence area.
9 And it erupted. The lava effusively
10 flowed down in here. Of course, there was spatter and
11 things from the gas phase, kind of like what Andy was
12 talking about, but mostly why interruptions are very
13 low in volatiles. Maybe they contain a quarter of
14 weight percent.
15 And so it filled this pit up to about 125
16 meters of magma, lava. And some people at the U.S.
17 Geological Survey, Tom Wright and Dallas Beck and Herb
18 Shaw, had the wherewithal actually once a crust
19 started to form to get on it and do some experiments.
20 Next slide. So you can see drilling here,
21 where I was partly involved in this in the '70s. And
22 there is Tom Wright there. And here is the drilling
23 going on.
24 And if you look at the next slide, here is
25 the drill hole. This is an annex core. So we're

1 looking at about two inches across here. And you can
2 see the about 500-degree red spot down there.
3 It's about what your toaster is in the
4 morning, 550 Centigrade or something like this.
5 That's down about five meters or so and rapidly gets
6 -- of course, 550 degrees is well below the
7 solidification temperature. It begins getting into
8 the melt here at about 1,000 degrees. And it gets to
9 the upper end of the solidification front at about
10 1,200.
11 Now, the one interesting thing that I want
12 to tell you about a little bit is that when you're on
13 the drill rig here and you're actually drilling along,
14 it drills, of course, chunking along like a rock. And
15 we're using water as a lubrication.
16 You can drill. You're drilling out. And
17 suddenly you're bringing core up all the time.
18 Suddenly you realize that you're bringing up quenched
19 magma.
20 But you're still drilling along as a rock.
21 It sounds like a rock. It acts like a rock. It has
22 strength. You keep drilling. You get 10 percent
23 liquid, 15, 20, 30, 40, 50 percent liquid. At about
24 50 percent liquid or 55, the whole sound changes
25 entirely, the drilling. It gets a quieter sound.

1 You realize that you could actually stop
2 the drill rig. And you can take the stem. And you
3 can actually start pushing it in a little bit by hand.
4 But before this, up until you get 50
5 percent liquid, this thing drills with great strength.
6 The material has great strength. If you go any
7 further, you can actually push it. It's almost like
8 feeling you're puncturing a membranae. You could
9 actually push the stem right out into the system.
10 So we go through these series that we call
11 the rigid crust out to 50 percent crystals. Now we're
12 in a mushy region out to about 25 percent crystals
13 that we call the suspension zone out in front of that.
14 So the next slide -- and it shows you the
15 sequence. Now, ignore these large crystals. These
16 large crystals are crystals that were carried up in
17 the flow from that depth. So these are phenocrysts
18 that were brought up with the flow.
19 And these are thin sections that we made,
20 of course, from the drill as you're moving from here,
21 where it's totally crystallized in the back end out to
22 the front end, where it has about 15 percent crystals
23 in it.
24 And the brown stuff out in there is glass.
25 Those tiny, tiny little areas are the crystals. You

1 can see, actually, there are little strands of these
2 things that actually hang together, like ganglia, more
3 or less.
4 And they are like little parasitic
5 situations, where all the minerals are crystallizing
6 together. So olivine is crystallized. What olivine
7 doesn't like, plagioclase eats up; and what
8 plagioclase doesn't like, olivine. And we have final
9 pyroxene. So they run in kind of little parasitic
10 relationships here.
11 And you will see whole areas where there
12 are no crystals growing at all, unlike what we have
13 always taught our students, that crystal A grows over
14 here in this corner and crystal B is over here and C
15 is here, and they eventually impinge on each other,
16 eat up all the liquid.
17 No. They grow locally. They grow locally
18 in these little relationships. And out of these come
19 large crystals. You can see the large crystals coming
20 out. We're down at 1,125 now. And so we have cooled
21 down by about 70 degrees. And you see these large
22 crystals.
23 That's from, actually, small crystals
24 hanging together, kneeling together, into larger
25 crystals. So big crystal takes over small crystal

1 because the small crystal is higher, service-free
2 energy. And we go back all the way through this
3 thing.
4 So this is a real solidification front.
5 This is how they actually would look going through it.
6 Now, the key is that this is happening spatially in
7 the system. So this is what we would think of in
8 these systems all the time.
9 Now, we often think in systems that the
10 magma actually flows freely in here and exchanges
11 nutrients with this, but, in fact, in these salacious
12 systems like this, it really doesn't.
13 One thing you will notice is the crystals
14 that grow out that are very, very tiny, these crystals
15 are much less than a millimeter, for example, in size.
16 And the crystal size in abundance really reflects the
17 cooling rate.
18 So high rates of cooling, for example,
19 enucleate lots of crystals. And since the
20 solidification front is progressing inward deeper
21 here, there is only a certain amount of time for these
22 things to grow.
23 So if you imagine yourself sitting in the
24 magma here in this room, eventually the liquid would
25 come through. And you would have a nucleation wave.

1 And that wave would reflect the rate of cooling. And
2 then eventually you would grow a little here. You
3 would have a growing time. And then eventually the
4 solidus would approach, and that would be it. You
5 would be done. And so the population crystals, the
6 numbers and the sizes reflect the cooling regime and
7 how it happens.
8 So next slide, please. So we often think
9 that there are systems like this on the left. This is
10 a dendritic system, where you get metallurgy or in
11 aqueous solutions, where you grow large ice crystals
12 or where you chill the bottle of wine to quickly white
13 wine in your freezer, you know, people coming over,
14 you got it, and you forgot it, you put it in the
15 freezer, and you get it out too late. And you have
16 those great big crystals growing in the middle of the
17 bottle that was brandied. And your significant other
18 is not speaking to you. And these things go on.
19 Silicate systems are a little different.
20 Next slide. You can see what they are, they are very
21 small in the melt because the crystals are very tiny.
22 The chemical boundary there is on the crystals are
23 very tiny. And so the melt is really not moving
24 around. It's also quite viscous in this. So the
25 whole thing is propagating off.

1 Any boundary we have, we have one of these
2 things propagating inward from it in the
3 solidification fronts. And so any process that is
4 going on in here, of course, has to compete with this
5 rate of solidification.
6 Next slide. So this is what we started
7 out with looking at this. I just want to refresh you
8 in terms of keeping this in mind. Now, I'll show a
9 little bit later also if we want to add volatiles in
10 to handle what Andy is talking about, we could ask,
11 even as Jim asked a question, about what is a magma
12 chamber, how is it going to do it, how is it going to
13 pressurize, and things like this.
14 Well, you could have a system that sat out
15 here that was actually under-saturated with water, but
16 as crystallization took place, the water builds up in
17 the melt. And eventually it will generate a volatile
18 phase. And that volatile phase, of course, is a huge
19 change also in volume upon exsolution. And that could
20 drive an eruption, for example, like a start.
21 So in Andy's case, you could start out
22 with something that wasn't much volatiles coming out.
23 And eventually, as solidification proceeded all around
24 the margins of a system, it could generate a gas phase
25 internally and start pushing an eruption. Obviously

1 this does happen. We're going to talk about it
2 dynamically in a little different way.
3 Now, I've been mentioning to you about you
4 can drill this thing out into the middle out here. So
5 this actually is almost ingently viscous out in the
6 middle in terms of the overall. That's the viscosity
7 of the interstitial liquid.
8 But if we talk about the viscosity of the
9 mushy stuff itself, out here, the magma out here, we
10 can calculate. Given this temperature, given this
11 composition, given this water content, we can
12 calculate viscosity very nicely with various models.
13 As we add solids to it, we can use various
14 models also, ones that I put forth in the early '80s.
15 And we can actually get an idea of what this is like.
16 And some of these are shown in the next slide, some of
17 these various models. And so these are various models
18 from chemical engineering and all kinds of people that
19 have been known for a while.
20 So you add solids to any kind of material,
21 and the bulk viscosity goes up. Why does it go up?
22 Well, because they approach maximum packing. And at
23 maximum packing, in a container of a fixed dimension
24 and volume, at maximum packing with any amount of
25 solid material, the material can't be sheared at

1 maximum packing unless it expands.

2 So when you are actually walking along the

3 beach, for example, and you see dry sand around your

4 foot, that's because the sand is at maximum packing.

5 You step on it. You shear it. There's not enough

6 water now. The grains have all moved out past each

7 other. And now we have excess pore space.

8 So what happens in this situation, of

9 course, is the viscosity goes off to -- I put it here

10 at .6. It could be .5. It depends on the ensemble of

11 solids, the packing of solids. And so it goes up and

12 basically is uneruptable. So that stuff off to the

13 right, then, is a very, very rigid rock, even though

14 it contains 50 percent melt more or less.

15 Next slide, please. So when you see a

16 system like this, then, in the Hawaiian lava lakes,

17 another way to look at this is that every one of these

18 systems has if we look at the bottom, it goes from 980

19 or 1,000 degrees up to 1,200, 1,210 for Makaopuhi Lava

20 Lake, for example, the basalt in Hawaii. And the

21 crystal varies like that.

22 It varies across because you start, the

23 liquid has very few crystals. And about in the middle

24 region, a lot of phases are growing very rapidly, lots

25 of stuff growing. So it actually has decided to

1 increase here and grows off to 100 percent eventually.

2 Now, remember, when we're in the middle of

3 this thing, once you're in the middle, the crystals

4 are all touching. They're all tacked together. The

5 whole left-hand side of this thing is a rock,

6 basically. The right-hand side is the magmatic

7 portion. The closer you get to this transition zone,

8 the less chance you have of this thing actually doing

9 anything. It becomes a solid material.

10 In fact, about half of this outer magnetic

11 region you can get like this chicken wire network of

12 plagioclase growing. So it may have some yield

13 strength, actually, out in there.

14 These things are very hard to get at,

15 although there are experiments done by some people

16 where they actually take samples at about 30 percent

17 crystalline. They take a cube of this material, put

18 it in a furnace. And they notice that the melt drains

19 out of it just so you see the network of crystals.

20 Tony Philpotts and people in Connecticut and other

21 places have done this.

22 So, remember, this is the kind of thing

23 you see all the time. And next slide. So a direct

24 reflection of that is you can increase the viscosity

25 of magma by increasing its silica content or

1 increasing its solid content. But you can only put
2 solids in up to a point at 60 percent.
3 And I want to just show you briefly here
4 this no man's land up here, where you get up. Now, if
5 we pump a lot of water in, sometimes we can make it
6 more fluid, move that boundary down a little bit. And
7 that is what you see here.
8 But I show here all the bad-acting
9 volcanos, all the really explosive guys, Maropi and
10 all these. I can hardly read them. Palei and
11 everything are all up near this boundary. So that's
12 the really dangerous one.
13 They get near this. They start flirting
14 with this 50 percent crystallinity. What happens is
15 the volcano gets plugged up, basically, then. And if
16 you're going to do something, then, if magma moving up
17 below and it wants to move, then this stuff won't come
18 out of the top.
19 What's it doing? It explodes. It blows
20 up. That's why these guys are so dangerous, and you
21 monitor these things for crystallinity and dome
22 building and things like that. There's this back and
23 forth.
24 Next slide. Now, another aspect of this
25 is the fact that when we deal with magmas, you will

1 see very many petrologists just deal with phase
2 diagrams.
3 This is a phase diagram. It's a normative
4 diagram that our good friends Dave Walker and Ed
5 Stolper developed more or less. And there is
6 diopside. And here is silica down here in this end.
7 So you can think of this as a garden
8 salad. You know, you can think of this as lettuce up
9 here. And you can think of this as tomatoes down here
10 and maybe carrots over here. These are various
11 mixtures. But there is a line along anything that
12 they all must vary along, trade-off.
13 Now, the very curious thing about the
14 Earth is that the oceanic crust that is here,
15 continental crust that is up here -- and we can't
16 understand why with all the magma being supplied at
17 Hawaii and mid-ocean ridges and things, it all ends up
18 right there at that one point right there.
19 In other words, we can come into that
20 point. Once we hit that, that is dead. The whole
21 oceanic crust sits right there. Hawaii, the whole
22 Island of Hawaii, sits there. And it's been a mystery
23 why because it just slides along this phase boundary,
24 temperatures decreasing all along. There's nothing to
25 stop it on the phase diagram.

1 But if you go into space, into spatial
2 dimensions; in other words, when you move in
3 temperature on a phase diagram, you're actually moving
4 in space in a magma chamber, spatially X, Y, Z.
5 So if you move along this, what you are
6 doing is that composition actually is right at the
7 leading edge of the solidification front. And when
8 you move further down, you're actually in the
9 solidification front. And these liquids all down here
10 are actually the interstitial liquids inside the
11 solidification front.
12 So it shows you how hard those are to
13 extract, that they're uneruptable. And the only way
14 to get these things out is by special processes, and
15 we don't have time to really go into them today. But
16 it's another whole lecture on it to show you how these
17 fronts are very important in explaining quite a number
18 of situations.
19 Next slide. So the other interesting
20 aspect of thinking about a magma before it gets to
21 surface is that magmas have a pressure temperature
22 phase field. In other words, here is pressure on the
23 left-hand side in kilobars.
24 So this goes up to 30 kilobars. For
25 example, it's a high low on the basalt. So that's

1 like 90 kilometers in the Earth. We're talking about
2 great depth.
3 And the phase equilibria is on here, so
4 this temperature across the bottom. So you can see
5 the liquidus of this high low basalt is about 1,275.
6 And beyond that, at low pressures, this is all liquid.
7 The first phase you come in is
8 plagioclase. And you can see we have olivine coming
9 in in other phases, final pyroxene and other things.
10 As we go up in pressure, of course, these phases
11 change. And these things all basically lean off to
12 the right more or less except when a phase becomes
13 unstable, like here, which is like many hydrous phases
14 do.
15 Now, this system is also a dry system,
16 partly bone dry, no volatiles in it whatsoever. So
17 it's very interesting. And all of these systems act
18 like this.
19 All of these silicate systems act like
20 this. You increase the pressure under dry conditions.
21 The effective melting points of the solids goes up
22 with pressure. And so everything leans off to the
23 right. And some of the phases become unstable. And
24 you start getting other phases in it.
25 Next slide, please. So what you see in

1 general and generically look at this is pressure,
2 temperature. In a dry system, then, we're looking at
3 a solidification interval that increases with
4 temperature as we go up in pressure.
5 And, you remember now, part of that is
6 inaccessible to eruption. If a magma travels into the
7 lower half of this range, it becomes a magma that
8 doesn't make it to the Earth's surface.
9 So any time it actually cools -- so a
10 magma is coming up and it is going too slowly. It
11 will actually cool back into this. And it sticks in
12 the crust. And the Earth's crust is full of bodies of
13 magma that have been stuck in the crust. And we see
14 them all over. We call them plutons. We change it.
15 Now, we're interested today in really
16 talking about volcanic rock. So we're interested in
17 things that actually erupt from the upper half of this
18 region here.
19 In Hawaiian systems, for example, lots of
20 systems that we see, the big voluminous systems, erupt
21 often with very, very small amounts of freshly grown
22 crystals in them. And I'll show you why that is in a
23 second.
24 Now, if we add volatiles to this system,
25 next slide, it's a very different kind of system, at

1 low pressures at least. So if we add enough volatiles
2 to saturate; in other words, we add water and CO_2,
3 let's just say water to begin with, it decreases the
4 melting points of these things.
5 So it has an effect of destabilizing the
6 solids. And the melting point, actually, in the
7 solidus liquids interval decreases up to a certain
8 point. As we get to a pressure, the saturation
9 pressure, beyond which there is not enough volatiles
10 to saturate it, it takes on again a situation very
11 much like a dry system that is under-saturated.
12 So if you imagine a magma coming to the
13 Earth's surface now, it comes up. And it's got
14 volatilize in it. And as it comes up and gets to this
15 boundary here, it starts to generate a gas phase, a
16 bubble phase.
17 And that's what drives a lot of the
18 eruptions for, like Andy was talking about,
19 Strombolian-type eruptions, et cetera. And the more
20 volatiles it has in it, of course, the more important
21 that becomes in terms of how fast it's moving, et
22 cetera.
23 And so what happens, we get a
24 fragmentation or we get a heavy vesiculation depth.
25 We get a fragmentation depth, where it starts coming

1 apart sporadically, basically erupting in a
2 Strombolian kind of eruption.
3 Now, it's very interesting now that this
4 thing decreases. And we want to worry about a
5 trajectory of how this actually get to the Earth's
6 surface on this. Okay?
7 So next slide, please. So if we look at
8 something like the Lathrop Wells basalt and we do a
9 calculation and we look at even experimentally --
10 we've checked some of this out experimentally already,
11 but this is for the dry system. The dry system, then,
12 goes up like this. And here are some the phased
13 boundaries on it and things like this.
14 The wet system -- and we have every reason
15 to believe like Lathrop Wells had anywhere between two
16 and four percent water in the system. And so if we
17 look at Mack Rutherford's experimental data that
18 showed what it may be, he said it was right here at
19 about 200 megapascales, 2 kilobars, and that
20 temperature right there.
21 Now, the curious thing about these magmas,
22 one of the dangerous things about them, of course, is
23 that that temperature right there, it only has a few
24 percent or ten percent crystals. What you will notice
25 is temperature is below the one atmosphere solidus

1 temperature.

2 So for that magma to erupt out as a lava,

3 for example, has got to get up in this interval. And

4 it's got to come out in the upper half of this

5 interval.

6 So that's the interesting aspect of this,

7 of these bodies you hear. And that's what makes them

8 so dangerous. The fact is, as we'll see today, they

9 actually can't get up in there. And so they fragment

10 and come apart.

11 So what happens, actually, is as this

12 thing degasses, it moves the solidification interval,

13 moves up to here. And this thing undergoes rapid,

14 enormous solidification.

15 Next slide, please. So to show you what

16 this looks like, here's the compare, MacAvoy Lava

17 Light, for example, with the Lathrop Wells. This is

18 dry at one atmosphere. You can see it is 1,000

19 degrees up to 1,170.

20 There are no surprises in this thing, very

21 similar. It's very similar to a normal basalt except

22 that it's an alkaline basalt, not a tholeitic basalt.

23 Okay?

24 Next slide, please. So this just shows a

25 little bit of what I was mentioning about volatiles.

1 You will generate volatile in this thing back in here,
2 even though it's not saturated at depth.
3 In the solidification front, you can
4 generate volatiles. And these volatiles can escape
5 and get back into the system, et cetera. That is
6 another aspect of the story.
7 Next slide. So here we have now two
8 different systems that we're going to tell about the
9 different aspects of this. One is that these systems,
10 these wet magmas on the left that have to try to get
11 up and if they're going to erupt as lava, they
12 dewater, and other systems, like Hawaiian systems,
13 that are very hot. And they have very low amounts of
14 water.
15 Next slide, please. And I show this.
16 Now, the one interesting thing about the Hawaiian
17 systems, systems that are very dry to begin with, is
18 that if they want to ascend, basically we can do the
19 ideal situation, where these things do not lose any
20 heat to the walls at all. We call that adiabatic
21 ascent. In other words, it keeps all its internal
22 energy. And all we do is we undergo any cooling due
23 to pressure to volume change due to pressure release.
24 And if we actually do that calculation, it
25 drives the magma out into the region, burn it up as

1 crystals and drive it out into a region where we have
2 no crystals.
3 And I'll show you briefly that once a
4 magma gets out in here and it's super heated, it will
5 undergo rapid convection. It will pump out that heat.
6 And it will go back and forth on this system, back and
7 forth. And it will come out near the Earth's surface.
8 We always see these magmas. Hawaiian
9 systems and systems like this in general always erupt
10 right near the liquidus. We have never seen a super
11 heated magma on the Earth unless it's something
12 generated by an impact or something like this. But
13 any magma that comes out is super heated.
14 Now, these are big, effusive, very hot
15 flows. And they are at low viscosity. So if we're
16 going to calculate how this would actually work as a
17 lava flow, we could take the lava, the magma before it
18 got to the Earth's surface. We would say, "Okay.
19 It's at 1,200 degrees. It has" such and such a
20 competition, such and such a crystal content. We
21 could calculate the viscosity for it. And we could
22 then predict what it was going to do as a lava.
23 These guys over here are very different.
24 As this approaches your surface, of course, it
25 degasses. And if it just goes straight up, the big

1 question is, what is its trajectory as it goes towards
2 the Earth's surface? In other words, what is the need
3 of 80 abating consent path for this?
4 So if it goes straight down, for example,
5 it becomes a complete solid very, very rapidly. So if
6 we took, for example, the analog situation of this
7 magma, basalt, we took it with crystalline and deep
8 temperature, et cetera, we put in four percent water,
9 we could calculate a viscosity.
10 And then if we were going to calculate
11 what that would do as a lava, that would be really not
12 a very accurate calculation because that's what it is
13 when it has all of its volatiles in it.
14 And as it approaches the Earth's surface,
15 of course, it loses all of those volatiles. And if it
16 degasses through some kind of a Strombolian eruption,
17 where all the gas collects at the bottom of a column
18 while you're shaking up a beer bottle and letting all
19 the froth go out and the stuff left at the bottom of
20 the beer bottle is the degassed magma, once you degas
21 that, it goes to this phase diagram on the right.
22 Well, if you hold the temperature the
23 same, you notice that thing is totally solid there.
24 It's not going to go anywhere. It's going to be solid
25 in place. Obviously these things do ooze out and

1 things. And we'll see what happens with that.

2 Next slide. Now, this is a summary -- and

3 I have gone over it, really, before with some people,

4 but it just kind of summarizes what our understanding

5 of how magmas actually give up heat.

6 We don't know exactly from magmas, but all

7 crystallizing systems that we have looked at so far,

8 we know when they have super heat, they convect

9 vigorously. As soon as they get down to the liquidus

10 and all their super heat is gone, it goes stagnant.

11 And so we're in basically then a situation where it is

12 conductive.

13 So that's what runs the Hawaiian systems,

14 like when they actually generated a little bit of

15 super heat, they go in a rapid convective mode. It

16 pumps that heat out and keeps buffering it, then, at

17 that upper liquidus.

18 Next slide. And these show some

19 experiments that we have done over -- this is a super

20 heated melt. I'll run through thee rapidly. And this

21 is after about a half-hour in a super heated melt of

22 paraffin. The upper solidification front is coming

23 down.

24 Next slide. And, as you can see now, this

25 is about an hour, hour and a half, two hours. You can

1 see the bottom of it is actually becoming stagnant,
2 and it's not thermally stratified. It's actually
3 isothermal as the front is coming down. And you can
4 see plumes still dropping off, still has some super
5 heat.
6 Next slide. This is about two hours into
7 it. Convection is almost ceased into it. We can
8 actually calculate the temperature loss very well by
9 conventional methods. It uses a paraffin with a small
10 solidification interval in it. And so this is what we
11 are talking about with that.
12 Next slide. This is the isopropanol
13 system, where Andy's colleagues and I were in heated
14 debate because it is magma. So we have to be in a
15 heated debate on what happens with these. And this is
16 the same kind of system except that it's more
17 difficult in many ways to do these experiments.
18 And this is ice. As you know, ice
19 increases in volume as it pushes alcohol around. In
20 the later stages, you can see also when it loses super
21 heat, this becomes stagnant, too, in terms of it.
22 Next slide. So this is the situation,
23 then, we're involved with. With magmas that don't
24 have any volatiles or very low volatiles, this thing
25 comes right down near the liquidus depending how much

it tarries as it's near the Earth's surface. It comes out as temperature. And there's usually low crystalline except for crystals that pick up transit sludge and other materials. And we're faced with the other guys that are these wet guys.

Okay. So the good question is now, what is the trajectory of this as it comes to the Earth's surface? And you heard Andy was mentioning he is using exsolution models for what you get for how the gas has come out of solution. And this is an important issue. In his model, for example, he would use a model in the theoretical model for how the gases solve out of the magma.

This is basically the same kind of issue except he is interested in how much stuff comes out with the mass fraction of stuff coming out. And we're interested in here with what the temperature trajectory is in terms of the remaining liquid, what it's like, the melts, how it is coming out.

Next slide. So these are some of the more earlier calculations we did on some of these. And this is -- and by other folks, too -- showing this is the pressure. This is the volatiles in the melt and how it approaches the Earth's surface. And this is the crystallinity.

1 So we don't show temperature exactly here.
2 We show how the crystals build up. So you can see
3 that something that has a lot of volatiles in it has
4 great depth. This is pressure. So we're down at
5 great depth. This thing runs in, and it solidifies at
6 depth.
7 As we get to lower volatiles, we can come
8 closer and closer to the Earth's surface. You will
9 notice when we talk about Lathrop Wells, it's two to
10 four percent. So we're talking about flirting,
11 really, with this boundary here about getting either
12 not to the Earth's surface or at the Earth's surface.
13 So it's a very interesting trade-off. And so it's an
14 important issue.
15 Next slide. So this is an important
16 issue, of course, for the whole idea. So this is some
17 calculation of the most recent. A whole number of
18 people have worked on these. And this is Mastin and
19 Ghiorso. Is this what you used, Andy, for your model
20 for degas and inert solution?
21 DR. WOODS: I'm using a sort of simple
22 Henry's model.
23 DR. MARSH: Okay.
24 MR. HILL: Britt Hill, NRC staff.
25 We were using the one that was developed

1 in Sparks.

2 DR. MARSH: So this is a model. It's

3 thermodynamically very, very comprehensive Ghiorso

4 with his NELTS program and Mastin put together. And

5 this includes gravitational effects also. It

6 satisfies potential energy constraints. And they put

7 that into viscous dissipation and things like that.

8 Be that as it may, this just shows a

9 system, Albite-water, which is a more soliciting

10 system but analog that a lot of people use because we

11 know a lot about the solubilities. To make a

12 long-story short, the 80 abating consent paths are

13 right here, you can see. So this is starting at 200

14 megapascales, about the area where Mac Rutherford

15 thought the Lathrop Wells would reside in equilibrium

16 before it got to the Earth's surface, when his 200

17 megapascales, 1,000 degrees.

18 And you can see this is the 80 abating

19 paths. They all have a huge amount of cooling taking

20 place. This is isoenthalpic, where you actually use

21 some other method, but the best you can come up with

22 here, really, is a lot of -- there's cooling, of

23 course -- is the exsolution comes out of

24 volatilization.

25 With crystal growth, you add lavidium,

1 but, actually, you could add in some latent heat.
2 But, of course, latent heat comes from you don't get
3 latent heat unless you're cool, your crystal growth.
4 So basically the best you can come out is that these
5 things would come up isothermally. In other words, it
6 wouldn't heat up at all, but it wouldn't cool any more
7 than it was before.
8 So if you go back now, next slide, the
9 issue is then that this thing originally when we
10 thought that we could move over here a little bit
11 through perhaps heat of volatilization, but now it
12 looks from Ghiorso's modeling and Mastin there that
13 basically this stuff is isothermal.
14 In other words, as you come up and you
15 degas it, the solid part of it, the liquid part of it,
16 basically you start undergoing quenching to a glass
17 perhaps or to something that's a super cooled magma.
18 In other words, this is a very serious
19 issue. And this is probably why these volcanoes, of
20 course, are so explosive, because they start moving up
21 and they crystallizing or going to a glass, basically.
22 And they frighten that very rapidly and start breaking
23 apart in this. Okay?
24 So keep in mind now when we calculate how
25 a lava flow moves, the whole ions situation or

1 something like this that has intrinsically low
2 volatiles or none at all is a very watery type of
3 material; whereas, this material is undergoing a huge
4 amount of intrinsic solidification due to the
5 depressurization.
6 Next slide. So when we go to a place like
7 Hawaii, for example, look at lava flows and we look at
8 lava tubes and we look at any kind of flow, it is
9 fairly straightforward to do those kinds of
10 calculations in terms of how the lava would move
11 because we know very well what is coming out. And the
12 crystal growth that is going on inside dealing with
13 solidification fronts, et cetera, is due to cooling.
14 It's not due to depressurization. Okay?
15 Now, the other thing, though, you realize
16 is that magmas when they're in the upper part of the
17 Earth's surface, they're in a very to them hostile
18 environment. They've come from a distance of great
19 depth, where they have come up from an environment
20 where they are about 1,200 degrees, very low
21 temperature gradients. And as they get to the Earth's
22 surface, of course, there is no generation of heat in
23 here. These things are just cooling. They're in
24 their solidification interval. So anything they touch
25 they actually quench against at all.

1 So if you stick your hammer into this,
2 which people commonly do, -- the way to get a sample
3 of one of these magmas is as a geologist in Hawaii is
4 you take a wire. And you have a good geologic hammer.
5 And you throw your hammer into it. It quenches out in
6 a big glob on the hammer. And you pull out the
7 hammer, and you have a sample of this going by. So
8 quenching is absolutely phenomenal.
9 Next slide. So you can see, even where
10 you get spatter flying in the air, it quenches on
11 trees. You can get this stuff small. It's like
12 pancake batter quenching on a tree.
13 Now, this is the key for this is because
14 it's in its crystallization interval. And so anything
15 it touches, it crystallizes out, either as a glass or
16 as a crystalline material.
17 Next slide. So this is where you actually
18 see it go around trees in Hawaii. It goes around the
19 tree. It quenches out all around the tree. And the
20 lava because it quenches out and sometimes the lava
21 keeps on moving or deflates around it, the tree, of
22 course, burns up and leaves a hollow in the inside,
23 but these are casks from trees. And you could see
24 these things very, very commonly.
25 The next one at the bottom here, this is

1 an alkali basalt module. This is a piece of mantle
2 material.
3 Next slide. You can see the quenched rind
4 around it. This is actually a spinelle prototype from
5 probably 30 kilometers down. It has a quenched rind
6 around it. It's an alkaline basalt.
7 Next slide. These are not typical nodules
8 that you would see thrown out. These are very heavy
9 ulcerated nodules, having cut them open, of course,
10 because the beautiful quench all around them on the
11 outside, you can see the quenched batter over on the
12 outside.
13 Next slide. This is at very high super
14 heated where Sandia did their experiments with their
15 probe trying to extract energy from a basically
16 55-gallon drum of super heated material magma. Then
17 they put this probe in, put material gases through it,
18 water basically through it, steam, but you can see
19 they've always got this quenched rind. They broke it
20 apart here so you could see their probe underneath.
21 But it has a quenched rind of they call it lava crust
22 on it.
23 Next slide. Here it is in Pompeii. You
24 can see how even an ash flow would quench around human
25 beings. And what happens, of course, it burns the

1 humans up, leaves a cavity. And when they find these,
2 they inject plaster into these things and then chip
3 away the material. And these are very dramatic, of
4 course, with these and sometimes too dramatic.
5 So next slide, please. I'm not going to
6 go through in terms of the essence of a lot of the
7 time, but when we're talking about quenching, we can
8 do an energy balance basically between a canister, for
9 example.
10 We want to worry about how much quenching
11 would take place on a canister. We basically can
12 equate the amount of basically enthalpy in the
13 canister and equate it to the lava around it, and we
14 can calculate the rind thickness here, basically. And
15 we come down. There are a couple of them. And I saw
16 for the contact temperature I just show on here.
17 For example, it comes out about
18 equivalently about -- just like we find in many, many
19 models, it's the average of the two temperatures, et
20 cetera. But the bottom line is those red things that
21 you can hardly see here, and that is that the
22 quenching thickness will be about a half the radius of
23 the canister depending on exactly what the internal
24 thermal conductivity is to about one radius of the
25 canister.

1 And so on the next slide, you'll see a
2 dramatic sort of verification of this kind of thing.
3 This is an Eocene conifer in the Western Mull region
4 of Scotland. It's called MacCulloch's tree. And it
5 was encased by a giant lava flow. And this tree is
6 over a meter, a couple of meters across.
7 There is Henry Himalayas, who gave me the
8 picture, standing on it from Durham University on the
9 ground there. And you can see the quenched rind
10 around it.
11 Next slide. I'll just show you you can
12 see there is the quenched rind. In fact, it's so
13 clear because the clubner jointing, which tells you
14 the cooling interface is vertical in most places, but
15 around the tree, you can see beyond the quenched rind,
16 it's horizontal. And it's of the radius you see it
17 just over the radius of the tree itself, that conifer.
18 That's an unusual thing because that tree is about 55
19 million years old, and it's basically carbon.
20 Next slide, please. Now we want to ask
21 ourselves, how long will this take to happen, really?
22 And this is a cooling of lava lake data in square root
23 of time in the bottom in days and the thickness on the
24 top. These are the data, and those are some of my
25 calculated lines going through. It's no surprises

1 here.

2 And these are the lava flow data from

3 Hahn, *et al.*, down at the bottom -- they all fit on

4 the same trajectories -- for different isothermal

5 advancement rates in the solidification for about 800

6 degrees, 1,070, et cetera.

7 Next slide. So here is what you would

8 get. In the bottom is the quenched thickness. And so

9 we're going out to about ten centimeters. And so we

10 go up ten centimeters, and this interval I've got of

11 quenching now. And you see it's within a minute or so

12 you can get a ten-centimeter rind of quenching.

13 This is very, very typical of what you

14 see, really, in dikes or in flows, lava flows, and

15 things. The first quenching is very, very rapid, of

16 course, since the diffusive process it slows down. Of

17 course, it's one over distance that you go into this

18 thing.

19 So in terms of now calculating how lava

20 would move, actually, next slide, how a lava that

21 entered the drift would actually move, if we look at

22 the lavas, for example, around Lathrop Wells, next

23 slide, and look at -- that's a picture of the flow

24 front -- you will see how these things are. It went

25 out about a kilometer at Lathrop Wells. And you can

1 see these big very, very step flow fronts on this.

2 If we go to the next picture, just put

3 this on for reference, you can see here's the flow.

4 Here's a scale here. One of the things that it's hard

5 to do in terms of modeling the flow in a drift is that

6 if you take the conditions of the magma when it was at

7 depth, it's very hard to use those because it's been

8 degassed and you would like to calibrate yourself. So

9 what you can do is figure out what is the effective

10 viscosity of this lava flow you see here.

11 So the first instance is, next slide, here

12 is a two-day flow. And if you look at that flow that

13 came out, looking at the nature of it and things, it's

14 probably a month-long flow more or less. Although no

15 one was around 75,000 years ago, it looks in terms of

16 its character it was a month-long flow. There are 2

17 days at 10^7 poises basically CGS units. It's well

18 beyond it.

19 Next slide. There's ten days. It's well,

20 well away from it. So what we want to do is increase

21 the viscosity. This is just spreading of a gravity

22 current by various methods, Griffis and Fink or

23 Herbert Hubberts, equations you can use.

24 And the next slide, then, is for 10^9. So

25 there are two days.

1 Next slide. There's ten days.

2 Next slide. Then there's 20 days. And

3 that's at 10^9, effective viscosity of 10^9, of it.

4 Next slide. So if we use that kind of a

5 viscosity, you can see the variations on this in terms

6 of time and radial extent. And I put on there the red

7 line up there, showing basically what it would be with

8 Lathrop Wells. And you can see how you could get to

9 a number of something like 10^9 for this eventually.

10 Here they are for different volumes on the

11 bottom, different volumes that you would use. And the

12 .03 cubic kilometers is about the volume of that.

13 Next slide. So when we are going to do

14 that calculation, then, next slide, we worry about

15 this thing and what happens to it. Well, evidently

16 when it degasses, we're blowing all the gas off of the

17 top.

18 The bottom part of it, then, is reaching

19 down into the system somewhere. And it doesn't have

20 enough time to crystallize. That's the important

21 thing. So it probably goes to a super cool situation,

22 and it goes to what would be kind of a glassy, hot

23 glassy material.

24 Next slide. So we get rapid quenching,

25 and we get to a hot glassy material.

1 Next slide after that. So this is what
2 glass looks like. This is Dingwell and Webb's
3 rheological measurements of viscosity. This is the
4 strain rate. And, of course, a straight curve on this
5 would mean a Newtonian effect. If you divide, take
6 the stress divided by the strain rate gives you the
7 effective viscosity.
8 And you can see here I pulled these apart
9 because they basically, interestingly enough, all lie
10 on top of each other more or less. There's Rhyolite,
11 Andesite, Tholeite, Basalt, and Nephelenite. They're
12 all very similar for the most part. And their
13 temperatures are a little bit low for us. They're 670
14 to 818. These are at the glass transition
15 temperatures. These are glasses.
16 But the interesting thing is if you divide
17 one side into another, you will see the values are
18 around 10^{10}, very interesting numbers. They're about
19 10^{10} CGS. If we heat this thing up a bit, I'm talking
20 about 1,000 degrees, it probably is about 10^{9} or
21 somewhere in there. So these are more or less driven
22 by glassy rheology.
23 Next slide, please. So if you took
24 something like this, then, and you followed on this,
25 in other words, we basically calibrated ourselves with

1 these kinds of flows, and we took into effect the
2 cooling and crystallization and we had flow in a pipe
3 -- this is a little involved because it's not only the
4 flow in a pipe but it's the cooling and it's also the
5 flux integrated over time divided by the volume per
6 length of tube.
7 And you can see this is the flow duration,
8 very slow durations. This is the viscosity. And
9 you'll see this in the range we're looking at in terms
10 of 10^6, ^{7}, ^{8}, ^{9}, and stuff. You can see how
11 drastically the flow shucks down if you get up into
12 the range that we're talking about and things.
13 On the right-hand side, you see how far
14 the flow would go for those viscosities. Here's the
15 flow of duration in time and hours. And then you'll
16 see. And I'll show you this is in meters on this
17 thing and meters on the side. This is one meter, and
18 it's the flow duration in hours, up to about ten hours
19 on the right.
20 So you can see, in the curve for 10^6 is
21 way down here. These are various diameters of the
22 edit. I've taken for the drift the effect of the
23 canister being in there, which would plug partly the
24 drift.
25 So the bottom line, then, is that if we

1 actually try to make a consistent idea of this magma
2 coming up, degassing, coming out, why does the flow
3 only go so far? Why does it not go very far? Well,
4 it's because it very much probably is quenching
5 rapidly, and it won't go very far.
6 If we use those for the rheological
7 properties for the lava entering the drift, it gives
8 us another *n* member, really, for consideration of
9 this. Instead of using a number based on the magma at
10 depth under ambient conditions with four percent water
11 and stuff that makes it very, very fluid. And do it
12 would be the wrong road to take.
13 Next slide, please. So I just show here
14 this is the flow front at Lathrop Wells.
15 Next slide. And it shows schematically
16 what one of these things would look like on it.
17 Now, I just wanted to end with a couple of
18 -- next slide, please -- ideas for where we could look
19 at more information, how to get at this kind of thing
20 more.
21 And this is a sill in Antarctica. This is
22 in the Finger Mountain area. This is about 1,000 feet
23 thick we're looking at right here. If you look at
24 these sills, of course, they're very, very fine
25 grained in the margins. And they're coarser grained

1 in the middle because they cooled instantaneously,
2 basically enquenched on the margins. But in the
3 middle, the crystals are larger.
4 So we could actually go into these, not in
5 this place, of course. We can't sample it. But we
6 have sampled some other places like this. And you can
7 go into this and sample it all the way through. And
8 we can measure what we call crystal size distribution.
9 Next slide. So what we see in the -- I
10 guess part of it didn't show up on your guy's diagram.
11 So please look at the thing up here. So this is what
12 the margin looks like: very, very fine grained; very
13 chilled very rapidly; large numbers of crystals; very
14 small crystals. And there's a millimeter size up
15 there.
16 And in the middle is a -- that's the
17 middle, what the texture looks like in the middle,
18 much coarser grained. And we can actually with a
19 cooling model and with a kinetic model and with these
20 CSDs, we can actually model these very nicely.
21 Next slide. So what we do is we actually
22 go in and image analyze all those crystals. We
23 measure all of them, and we make what we call a
24 population density.
25 So here is a population density versus

1 length. And if I had those data, those data would
2 show up on kind of a log-normal curve here. And the
3 slope of it is S here.
4 The important thing is that we can go
5 through. We can measure various things. In other
6 words, there is what the function looks like. And if
7 we look at the first moment of that function,
8 integrate the numbers over, we get the total number of
9 crystals.
10 It turns out that it's the intercept
11 value. Basically the inverse to the log of the
12 intercept divided by the slope gives us that. And the
13 total length of crystals is the -- that's the zero at
14 the moment, the first moment, gives us the total
15 length of crystals. So we can get all of this
16 information. The next moment up gives us the total
17 area of the crystals, masks the crystals, et cetera.
18 And we can couple these together with cooling to tell
19 us really what was going on.
20 Next slide. And so these are various
21 relationships, parametric relationships, that we can
22 actually get at with these. In other words, the
23 characteristic size that I just showed you actually
24 scales with the growth, characteristic growth, divided
25 by the characteristic nucleation rate to the

one-fourth power. The total number, characteristic number, of crystals goes with the nucleation divided by the growth to the three-fourth power. And we can combine these together, of course, in various fashions here to get other measures on things.

Next slide, then. So, for example, in that we just showed you, that fine grained one, that's about 6 million crystals per cubic meter. And in the middle of that, that's down to 4,400 per cubic centimeter. And the mean length changes and things like this.

So next slide, for example. So these are the CSDs for those. The CSD for that, of course, is enormously steep. And this is where the information comes from, of course. And in the middle, it's like this.

So this is the kind of information that we can actually extract. And when we do these in environments where we know the cooling rate has been and the crystal growth rate has been due to temperature, we can actually -- this is the kind of relationship we get. And we can predict these very, very accurately.

So we can actually get at the models of something like I am showing here and talking about, if

1 it got glassy or whether or not the rheology at
2 Lathrop Wells, why the flow didn't go very far. Is it
3 due to cooling or is it due to depressurization in
4 glassy growth of crystals? We get not a large number
5 of crystals, but we get a glassy matrix.
6 Next slide. So this shows you a small
7 sill in Antarctica. This is a tiny, little sill.
8 There is granite on each side, horizontal sills off
9 the tip of one. And you can see what happens in these
10 situations. We can even go on this.
11 We can even see tiny variations and even
12 fracture fronts that go in this. We can see tiny
13 variations. That tells us this thing cooled in a
14 couple of minutes or in a few minutes across. Okay?
15 Next slide. So the thing I wanted to
16 leave you with, then, is that when we look at a
17 magmatic system and it's getting staged for an
18 eruption, the system itself has all kinds of different
19 thermal regimes in it in terms of relaxation rates for
20 cooling, but it also has in terms of staging, in terms
21 of what its volatile contents are the kind of magma it
22 is.
23 Now, if the Yucca Mountain area had a
24 Hawaiian type magma, it would make our life a lot
25 easier in some ways. We wouldn't have to worry about

1 explosivity as much. However, we would have to worry
2 about fluidity a lot more. This stuff could get in
3 the drifts. It could go a lot further.
4 But we would be misled if we actually did
5 a calculation where we combined the Hawaiian rheology
6 with a gas-rich magma, which is at depth because the
7 magma that gets up near the surface, of course, is
8 going to be gas-poor if it's giving up its gas in an
9 eruption and it's going to be quenching out remarkably
10 fast. And so it's very, very much more viscous.
11 So we have to be consistent. We have to
12 understand the fact that what we're dealing with is
13 magma. It's not a magma that we're looking at in
14 depth under its native conditions, but when it reaches
15 up close to the surface, it's in a dramatic
16 environment. Especially if it's giving off material,
17 degassing, the material is quenching rapidly.
18 Thanks very much.
19 MEMBER HINZE: Thank you very much, Dr.
20 Marsh, a very excellent presentation again. Take a
21 breath, if you will.
22 We want to leave time for the Committee to
23 ask questions, but we have a lot of expertise here in
24 terms of volcanic activity and igneous activity at the
25 table and in the audience. And I would like to have

1 a little time for some discussion, if we could.

2 So, with that, Dr. Clarke?

3 MEMBER CLARKE: Bruce, as I've been

4 listening to all the complexities that have been woven

5 into this, I'm wondering if there's a way to --

6 DR. MARSH: If there's hope for us?

7 MEMBER CLARKE: I'm sorry? No. I was

8 wondering if there's an experiment along the lines of

9 what Dr. Woods did that could incorporate some of this

10 because I'm thinking of carbonated brandy. It makes

11 me shudder just thinking.

12 (Laughter.)

13 MEMBER CLARKE: By the way, that doesn't

14 happen with vodka when you put it in the freezer, not

15 that I would know.

16 But you have a liquid with crystals, if

17 you will, at certain temperature, and gas going into

18 an open area. I mean, is that a realistic thing to

19 think about or --

20 DR. MARSH: Well, one of the real

21 problems, as anybody whose subtitle Andy was talking

22 about, actually, is that these experiments, even in

23 their barest bones, are very, very difficult to do.

24 But when you involve solidification in these things,

25 it's even more involved.

1 However, I think there are things to be
2 done. For example, by combining --- we do paraffin
3 experiments. Paraffins are very interesting. They
4 have a latent heat and other characteristics, crystal
5 sizes that are very similar to silicates. And they're
6 quite watery at their molten self, when they're
7 melted.
8 So, for example, if you did Andy's
9 experiments, I mean, I would hate to suggest to Andy
10 that he puts his molten paraffin in this system
11 because, I mean, you know, we do these things all the
12 time.
13 And most of them blow up in our faces
14 because of the fact that if something happens, we have
15 to wait a few minutes for this or that. And by then,
16 it's solid somewhere in the system. And we're
17 screwed.
18 Basically we have to go in and clean out
19 the whole thing and we've done all things like this.
20 But that's what, really, the kinds of things -- now,
21 the different aspects of it are the fact that we're
22 talking about something, on the one hand, solidifying
23 just purely due to a temperature fact, but we're
24 talking here about depressurization, devolatilization,
25 crystallization. And that is a whole other level of

1 complexity.

2 I mean, these things are all different,

3 but the next step would be just to do it with a hot

4 paraffin, for example, and looking at what happens in

5 the analog system, when it goes into these systems

6 like this just right, what kind of overpressures you

7 need to move it, et cetera. Maybe you could even put

8 some gas into the system, like Andy does.

9 MEMBER CLARKE: Okay. Thanks.

10 MEMBER HINZE: Dr. Ryan?

11 CHAIRMAN RYAN: No questions at this time.

12 I'm happy to listen.

13 MEMBER WEINER: Just one. In magma, since

14 you have crystallization as well as devolatilization,

15 is just using the Reynolds number really a good

16 analog, as Dr. Woods did, really a good analog to look

17 at behavior or are there other considerations, other

18 ways that he could experiment? I would just like to

19 compare the two.

20 DR. MARSH: Well, no. I think let me put

21 this in context. Let's say we're looking at a

22 vertical column, just to be simple here, a vertical

23 column of a gas-rich magma arising up and it's

24 starting to erupt.

25 So there is an interface somewhere where

1 it is actually below that depth. It's under-saturated
2 because it's at a higher pressure. Above that, you're
3 getting X solution of volatiles.
4 And then above that somewhere, the
5 volatiles are so numerous and they're going together,
6 that they actually have more or less a fragmentation
7 interface where the expansion, in fact, if you do some
8 of the calculations on the gas coming out in some
9 magnetic form, the volatiles can expand up to 10,000
10 times their -- in other words, they grow from nothing
11 up to very, very large, large factors. So you have to
12 characterize it by something. So the Reynolds number
13 is fine, I think, in terms of where you are in the
14 system in terms of it.
15 Now, one of the things that Andy didn't
16 touch on, but I'm sure, in fact, he does this or
17 thinks about, is that the walls of these conduits --
18 of course, people worry about how Perryville they are.
19 Where does the gas go? Does it all come off the top?
20 Does it leak out the walls, et cetera?
21 But no one puts in or we start thinking
22 about what happens when you put up a little bit of
23 quenched magma on the walls. What does that do?
24 Well, that seals this container. That seals the
25 conduit and keeps the volatiles in the conduit.

1 So an approximation like Andy was doing in
2 that context is a pretty good approximation. In other
3 words, you have got 100 percent of the volatiles.
4 Other people -- there's a lot of work
5 being done nowadays on how much gas leaks out through
6 the walls. Now, I don't know exactly what we have
7 for, you know, ground truth on that.
8 So yes. So the short answer for a lot of
9 words is the Reynolds number is perfectly fine. Among
10 other things, I mean, you have to go that way.
11 MEMBER HINZE: Since my watch is five
12 minutes fast, before I turn this back to Chairman
13 Ryan, I would like to open up discussion to either of
14 these very fine presentations among the group of you
15 or whoever.
16 DR. FLACK: I just have a quick question.
17 CHAIRMAN RYAN: Tell us who you are first.
18 DR. FLACK: John Flack, ACNW staff.
19 I hate to steal the words off of a book,
20 but it's called "The First Three Minutes." Does it
21 look to you like everything is determined within the
22 first three minutes of this event when it occurs or do
23 things evolve during the course of the event that may
24 change it after that?
25 DR. MARSH: Well, in my way, I mean, a lot

1 could happen in the first three minutes. I mean, in
2 terms of --
3 MEMBER HINZE: Are you talking about in --
4 DR. MARSH: He's talking about, yes.
5 MEMBER HINZE: -- the repository, the
6 magma-drift interaction?
7 DR. FLACK: Yes. From the occurrence of
8 the event, from the initiating conditions, the first
9 three minutes of the eruptive conditions. That sort
10 of set the stage for everything else afterwards. I
11 guess that's --
12 DR. MARSH: Not necessarily, but, in other
13 words, the geometry of the dye, how it's set in terms
14 of the geometry of the repository and what the
15 eruption starts out as, if it vents out somewhere else
16 within a shorter time if it gets into the repository.
17 These are all factors. But there are more than three
18 minutes involved.
19 In other words, three minutes gives you a
20 little bit of the inclination, but we're talking about
21 something that's probably a month-type thing, wouldn't
22 you say, Britt, before we could get the full
23 character?
24 MR. HILL: Yes. Britt Hill, NRC staff.
25 Yes, I would agree that the duration of

1 the entire igneous event could last on the order of
2 anywhere from days to weeks. But I think the specific
3 question here is the initial magma-drift interaction
4 if that potentially occurs. And that in our models
5 and our view and our understanding would occur very
6 rapidly.
7 DR. FLACK: And then presumably stay fixed
8 in the sense of the geometry more or less. I mean,
9 nothing that dramatic would change afterwards.
10 MR. HILL: Well, what we have modeled in
11 a number of reports is that because these are
12 pressure-driven flows that if the magma rises up and
13 intersects a drift, that inflow between highly
14 pressurize confined flow to essentially an unconfined
15 drift, that inflow would occur rapidly on the order of
16 minutes.
17 And so by the end of on order of minutes,
18 you would have a filled drift and the eruption would
19 continue to progress. And there are a number of other
20 processes that, of course, would go on. But in terms
21 of the relevant concern for that initial inflow, we
22 would say and we have said in a number of reports that
23 would occur in the first five minutes.
24 DR. MARSH: But let me add something. I
25 think, you know, in a subtlety in parsing a little bit

1 of what Britt says, I would differ, we would differ,
2 in details in terms of filling the drift. I think
3 Britt would think it fills the drift, wherever it
4 goes, and I would think it fills the short segment of
5 it and depending on exactly the character of the
6 material coming out, and would plug off itself or
7 rapidly keep on going in terms of what it was doing
8 into the dike. So in other words, Britt might say it
9 might fill a kilometer or so of drift, but I would say
10 it might only fill ten meters or something depending
11 on exactly the character of the erupted material.
12 MEMBER HINZE: Further comments or
13 questions? Latif.
14 DR. HAMDEN: Latif Hamden, ACNW staff.
15 The question I have is once we reach a point with your
16 model, Andy, that we are happy with it and we want to
17 apply it to a particular site and the question is how
18 we go about it specifically in a way of inward data.
19 Do you go to the three cases of summit and flank
20 mountain for chemicals that you cited and get data
21 from there as input to your model and in the way of
22 outward, do you hope to get a range of scenarios as to
23 what might happen? Is that the best you can hope for
24 or is it much better than that?
25 DR. TRAPP: Just a sec, Andy. I think

1 you're getting into stuff that's past anything we want
2 to talk about today because you're talking about
3 things as far as scenario development as it goes to
4 the repository. We aren't there yet.
5 MEMBER HINZE: Fair enough. So be it. We
6 have a question back here.
7 DR. COLEMAN: This is Drew Coleman, DOE.
8 I was just wondering why the Amargosa Farms is drier
9 than Hawaii. It seems to counterintuitive to me, but
10 is there an explanation or is that just an
11 observation, just briefly?
12 DR. MARSH: Do you mean the climate or you
13 mean the magma?
14 DR. COLEMAN: The magma.
15 DR. MARSH: Well, it isn't. Hawaii is
16 very, very dry. Lathrop Wells is very wet.
17 DR. COLEMAN: Right, and I would wonder
18 why that was. It seems like --
19 DR. MARSH: Oh, why that's so?
20 DR. COLEMAN: -- by the climate or by any
21 regular observation at the office.
22 DR. MARSH: Okay. It's the nature of the
23 magma and the source of the magma. The magma that are
24 coming up in these cinder cones are alkali basalts and
25 alkali basalts are alkaline rich obviously, but

1 they're also volatile rich in general. In the
2 Hawaiian system, they're at a very high temperature,
3 low degrees of melting, but they're deep melting and
4 they're very dry magma. It's like the ocean ridges
5 are. So these are intrinsically different kinds of
6 bodies.
7 MR. HILL: Do we have time for a quick?
8 MEMBER HINZE: Sure.
9 MR. HILL: I'd like to ask Bruce when we
10 have a basalt, a Lathrop Wells type or Crater Flat
11 type basalt, that has originally four weight percent
12 water dissolved in it, we get up to about 300 meters
13 at depth. We have a volatile phase, but certainly not
14 all of the volatiles are in the bubbles. There are
15 still volatiles, water, dissolved in the melt. Do you
16 have a sense of how much, what the proportion, would
17 be for that total mass of water?
18 DR. MARSH: That actually is really in
19 those calculations for the adiabatic ascent. That's
20 exactly what's come out of that also. There's another
21 whole graph for how the water is partitioned as you
22 devolatilize. So that's a byproduct of the
23 calculations. I didn't put that in, but I can show
24 you that exactly. So it's partitioned. So the fact
25 that Mac Rutherford can actually get a number of

1 phasic equilibria that shows 200 megapascals in that
2 temperature means that the phasic equilibria was
3 quenched in which is a very interesting thing.
4 That was preserved and to preserve that
5 and not destroy, for example, all the amphibole and
6 everything else and he shows what the reaction rates
7 are to do that, but that has to be quenched in. So by
8 and large, depending on how fast the magma moves, you
9 can partition this. Most of it can go into it, almost
10 all the volatiles can go in, but it's progressive. If
11 you move it up slowly and keep it under equilibrium as
12 Andy was using his model, if it keeps under perfect
13 equilibrium, of course, it eventually all goes into
14 the gas phase and there's no overshoot of it.
15 But if the magma starts coming up and does
16 go by equilibrium, it starts coming out and all of a
17 sudden it quenches. So if you look at people who have
18 looked at like these rinds around these alkali
19 basalts, Rutherford has, he says that almost all these
20 rinds they find has quenched in volatile
21 concentrations that are larger of course than they
22 find in the quenched class because they quenched when
23 that Xenolith got into the body earlier on. So you
24 can actually see a progression of degassing in the --
25 The ones that are least degassed are the quenched

1 rinds around these things and as you go up, they degas
2 more and more. And, of course, as it appears on the
3 surface, if you take some of those spatters that come
4 up, they virtually have no volatiles in them at all.
5 MR. HILL: I think the point we're trying
6 to get to is that the reality lies somewhere between
7 the wet solidus and the dry solidus. That you still
8 have some measure of dissolved volatiles in the magma
9 when you're down at 300 meters depth and so you don't
10 instantly go from a saturated magma to a completely
11 dry magma when you depressurize it.
12 DR. MARSH: Well, of course not. But if
13 you look at the phase equilibria there, it has to go
14 up on the surface. It's already -- If you run back on
15 that slide, I mean this is a very important point.
16 You have to --
17 MR. HILL: It does make a difference
18 because that's one of the reasons why when volcanos
19 erupt there's molten lava at the surface even when you
20 have say four weight percent water in the melt.
21 You're at atmospheric pressure, but you haven't
22 completed degassed the magma. You've partially
23 degassed the magma.
24 DR. MARSH: One of the very, very long
25 hold --

1 CHAIRMAN RYAN: Excuse me, Bruce. Could
2 you tell what slide it is?
3 DR. MARSH: Yes.
4 MEMBER HINZE: Can you give a number?
5 DR. MARSH: It's 15. Page 15, the top
6 one. One of the very, very long held difficulties in
7 generating magma, understanding how much water was in
8 magma before they erupted, is the fact that all sub-
9 aerial, meaning that all lava flows that erupt on the
10 earth's surface have virtually zero percent water in
11 them, the only time we've ever been able to find any
12 flows whatsoever. In fact, early on before people
13 could do water solubility measurements, we wanted to
14 find magmas quenched at high pressure so that we would
15 know how much volatiles they have in them.
16 The only place this can actually be done
17 is on the sea floor. Stuff erupts on the sea floor at
18 3,000 meters or so. So you can actually get a
19 pressure on it as you go down the right -- ridge. For
20 example, in Iceland in the Midatlantic Ridge, you can
21 start out at real low. You can go to 50 bars, 100
22 bars, 200 bars, 300 bars for example and you can see
23 then the water finally gets up to its background
24 concentration. But as you get on the surface of the
25 earth, it's degassed entirely. There's nothing in it.

1 There's zero in it.

2 MR. HILL: I disagree with that because

3 when you go out on lava flows especially in lava flows

4 from magmas that have high water content, there's

5 still degassing. When you look at the lave itself,

6 you find textures that show that there has been

7 significant amount of gas escape. For example,

8 diktytaxitic textures are incredibly common and they

9 don't preserve a flow regime. They're degassing after

10 the fact.

11 DR. MARSH: This is exactly the case of

12 Andy's experiments. It has degassed on its way up.

13 The glass does not contain volatiles. It contains

14 tiny little bubbles that are entrained in it. The big

15 bubbles have escaped. The little bubbles are held up

16 in the flow just like in Andy's experiments where

17 early on when the bubbles are small, they're traveling

18 with the liquids. So the melt is actually bringing

19 the bubbles with it.

20 As this thing moves along the ground, the

21 bubbles escape. They come out of it. It's still

22 molten. The bubbles move up because now the magma is

23 going horizontally. The bubbles go up vertically and

24 so they slowly move up and it surely degasses, but

25 they're degassing not coming out of solution. They're

1 all out of solution already. They're coming by the
2 loss of bubbles.
3 MR. HILL: Okay. I think we would have --
4 We just want to make sure that we're clear that we
5 would a different view that not all of the volatiles
6 have escaped from the melt and that this is a very
7 complex process of trying to understand what is
8 happening in these systems over a very short period of
9 time. We don't have the answer to that, but I don't
10 think that we're really going down between a wholly
11 wet magma to a wholly dry magma and I'd come back to
12 the simple observation that you see molten rock
13 flowing from high volatile content scoria cones and it
14 flows not just for a moment, but for some amount of
15 time.
16 DR. MARSH: Well, that's exactly what
17 we've seen. We've seen that at glass that a viscosity
18 of 10^9 can flow for kilometers.
19 MEMBER HINZE: Dr. Melson from the NWPRB.
20 DR. MELSON: Yes, Bill Melson. I would
21 just like to kind of enter this not as a voting
22 member, but I've done lots of studies on matrix
23 glasses, very fresh glasses, with crystals at Mount
24 St. Helens. That matrix glass has no water in it.
25 We've done -- Even FTIR work shows it, whereas a melt

1 inclusions can have up to seven percent and every time
2 I've used this technique where you have a good matrix
3 glass and good melt inclusions, I see pretty much the
4 same thing Bruce was talking about.
5 Now when I did this, it was by sums with
6 a microprobe and I was highly criticized for this.
7 They said you couldn't do it that way. Well, it turns
8 out in Mount St. Helens you could. But this is what
9 we see, even the deep sea cases of Canis Ridge.
10 Bruce, it doesn't go up. You have to go to very
11 sensitive methods to see the water in these deep sea
12 basalts. They're almost anhydrous. So my experience
13 is that the degassing happens quick and nearly
14 complete just in what I've done.
15 The other thing that's kind of confusing
16 is a kind of obsidian like rock called a pitchstone
17 and our collection at the Smithsonian are full of
18 these things. They can have up to three to four
19 percent water and they're perfectly black glass. But
20 this is a secondary phenomena we believe whether it's
21 been taken up by weathering.
22 So the work I've done would support the
23 view that these things once they start degassing at --
24 pressure it goes very fast. If you look at phase
25 equilibria calculations or you can look at -- melt

1 data, just a few percent of water in a melt generates
2 one heck of a lot of pressure and I don't have a phase
3 diagram to show you but it's extremely high. -- the
4 same thing. The matrix is degassed. The crystals can
5 have quite a bit of gas in the melt inclusions.
6 MEMBER HINZE: Thank you, Bill. Britt,
7 did you have a comment back from that?
8 MR. HILL: Well, I think we're getting
9 right to the point of kinetics. How fast is fast?
10 What is rapid may be occurring on the order of a day.
11 That might be viewed as a very fast degassing rate.
12 DR. MARSH: I don't think anyone's ever
13 found a glass in the earth's surface in a lava, active
14 flow, a glass, they looked at in the lava that has any
15 amount of volatiles in it at all. It's a serious
16 issue and it's very definitively known.
17 MR. HILL: Again, you are not looking at
18 a lava that's solidified in the first five minutes.
19 You're looking at something that has sat at the
20 earth's surface until a volcanologist could come up
21 and collect a sample from it.
22 DR. MARSH: If there's gas in it, it's a
23 bubble. It's a bubble. The pressures are too large.
24 The X solution, the solubility is zero so they come
25 out as a bubble. So if there's gas in the chunk, it's

1 in a bubble or in a melt inclusion like Bill was
2 saying. That is really well known. It's one thing
3 that's very well known.
4 MEMBER HINZE: Further questions? This is
5 the chance. If not, we thank you, Dr. Woods and Dr.
6 Marsh and your colleagues, for a very interesting
7 afternoon. It's been really great for the Committee
8 and I think I can speak on behalf of the entire
9 committee. So, Mr. Chairman, it's back to you.
10 CHAIRMAN RYAN: Thanks, Professor Hinze.
11 Let me add my thanks too. I think this kind of open
12 discussion in presentations is helpful to the
13 Committee. I think it's helpful to everybody in the
14 room to hear the range of views and I'm a big fan of
15 exploring the range of views so we can somehow get
16 that documented in our role of giving advice and
17 information to the Commission. So we really
18 appreciate the open exchange and good ideas and
19 different views and audience participation as well.
20 It's helpful to us and, Dr. Woods, thank you for being
21 over here from a long way away for a short visit with
22 us, but it's been very informative. Thank you for
23 being with us. We appreciate you making time. And,
24 John, thanks to you for getting it organized and,
25 Britt, for your participation as well and, Dr. Marsh,

1 thank you very much. So thank you all.

2 We'll take a short break. We're a little

3 bit behind schedule, but well worth every minute and

4 reconvene at 3:30 p.m. and take up our agenda from

5 there. Thank you very much. Off the record.

6 (Whereupon, the foregoing matter went off

7 the record at 3:19 p.m. and went back on the record at

8 3:33 p.m.)

9 CHAIRMAN RYAN: On the record. The next

10 presentations will be directed by Dr. Weiner. So, Dr.

11 Weiner, go ahead and lead us off.

12 MEMBER WEINER: Our next presentation is

13 on the NRC Staff Activity on Performance Confirmation

14 and it will be presented by Jeffrey Pohle and Randall

15 Fedors and please go ahead, gentlemen.

16 MR. POHLE: My name is Jeff Pohle and

17 I'll start it off this afternoon and then bring in

18 Randy a little bit later on in the presentation. Just

19 for some background, the Section 63.74 of Part 63

20 requires DOE to perform those tests the Commission

21 considers appropriate or necessary for administration

22 of Part 63 and specifically in 63.74 it says, "The

23 test required in this section must include a

24 performance confirmation program carried out in

25 accordance with Subpart F of 63."

1 I have some back-up slides on the back of
2 this presentation which kind of gives you a quick
3 summary of the specific requirements in Subpart F. I
4 really had no intention of going through all of those
5 today, but they are available for you to look at and
6 reference if needed. Now NRC will have some oversight
7 responsibilities clearly for DOE's performance
8 confirmation program and now that gets us to Slide 2.
9 So over the past year, the NRC has worked
10 in terms of performance confirmation. We had three
11 areas of activities. You could define them as partly
12 reactive and partly proactive and the three we'll talk
13 about today, first will be the continued development
14 of the XFlo computer code. Just quick information to
15 let you know that we started the literature review on
16 minoring technologies and we'll be coming out later
17 this year with a couple of reports and lastly and the
18 thing you're perhaps most interested in, we initiated
19 a preliminary review of DOE's performance confirmation
20 plan. So it will be these three activity areas that
21 we'll cover. Next slide please.
22 As I mentioned earlier, there is partly
23 reactive work we can do in terms of PC and proactive
24 work. In terms of reactive work, it would be things
25 like reviewing DOE's performance confirmation plan,

1 eventually reviewing DOE's detailed test plans related
2 to the activities presented in the performance
3 confirmation plan and in the future, now this is
4 looking ahead, we would expect to be doing inspections
5 subsequent to issuing construction authorization and
6 I would expect that part of inspections we would have
7 some technical experts along and part of our task
8 would be to have some ability to review the technical
9 data or information derived by the performance
10 confirmation program. This is out in the future if
11 budgets allow.
12 So in 2003, discussions with the Center,
13 was there anything we could do to prepare ourselves
14 for that time when let's say a lot of data could be
15 coming in, you know, particularly from the accelerated
16 thermal drifts. A lot of sensors, a lot of
17 information, how can we ourselves do an independent
18 analysis of that information? So at that time, we
19 initiated the task and this is funded not at a very
20 high level and it's stop and go whenever. Near the
21 end of the year, if time and money allow, we'll do
22 more work on it.
23 Develop the XFlo code and this is
24 basically a next generation code coupled, thermal,
25 hydrological and chemical code. The idea was to have

1 a flexible, adoptable code that can be easily modified
2 to analyze new information during the performance
3 confirmation period and this could be all during the
4 period of operations that DOE will be implementing the
5 plan, their performance confirmation program.
6 Currently, we use MULTIFLO and we use that
7 for the licensing review. We were just trying to
8 position ourselves for the longer term view of changes
9 that could happen in the future, perhaps new ideas or
10 concepts be incorporated into the code easily. So
11 basically most of the work is developing the design
12 and it's modularized so you can bring in the different
13 physics if you so desire. I mean to date we've done
14 a comparison with MULTIFLO on a dual continuum model.
15 I think the activity now when it's active is to bring
16 in the active fracture model. Chemical modules can be
17 added in as time goes along.
18 So it's kind of a long term program. When
19 time and money is available, we kind of get back to it
20 and do some more work on it. Obviously, it's not the
21 position that we really have never used it at this
22 time. And I really don't have a lot more to say about
23 that.
24 MEMBER HINZE: Let me ask you a question
25 then.

1 MR. POHLE: Certainly.

2 MEMBER HINZE: How about the chemical

3 aspect of the PC?

4 MR. POHLE: I could ask BJ to give you a

5 quick answer on that aspect of it. It's BJ Jain.

6 BJ Jain, Center for Nuclear Waste. Our

7 plans include --

8 CHAIRMAN RYAN: Pull the microphone

9 towards you please.

10 MEMBER WEINER: Who don't you sit up at

11 the table?

12 CHAIRMAN RYAN: Have a seat.

13 MEMBER WEINER: And talk into the

14 microphone.

15 DR. JAIN: BJ Jain, Center for Nuclear

16 Waste. We do have plans to include the chemical

17 aspect in this code in the long term, but currently

18 for this fiscal year, we don't anticipate having a

19 chemical C part of the code built into this particular

20 code.

21 MEMBER HINZE: Thank you. That was brief.

22 Thank you.

23 MR. POHLE: We really don't have the funds

24 for that. It's not a program priority at this time.

25 The whole effort on PC, what obviously is the program

1 is that would increase in priority through time.'

2 Let's see. Page 4 or Slide 4 rather, also

3 to help educate the staff when we review particularly

4 when we get into the detailed testing plan review for

5 all the activities in DOE's PC program. Last year, we

6 initiated a literature review looking at the types of

7 methods and instruments that are available. In this

8 case, we broke it down into the Vadose Zone, the

9 unsaturated zone, or for tools and technologies to

10 monitor repository excavations. Construction

11 monitoring will be a big aspect of DOE's program and

12 generally this would include the thermal test too to

13 the extent that we could look at instrumentation on

14 that. Do you have anything to add?

15 DR. JAIN: These reports are basically

16 we're examining if the sensors, the instruments and

17 the techniques and tools can be adaptable to the

18 repository condition especially during the thermal

19 stress test where you have radiation fields as well as

20 high pressures. Some of the tools, they require high

21 maintenance, and we are examining if there are tools

22 that can be adapted to repository environments and

23 that will help us review what DOE is going to present

24 to us. It will help us understand monitoring systems

25 and so on.

1 MR. POHLE: Right. We want to have enough
2 knowledge so we can whether your plan, your test
3 objectives, are even practical. We need to be in a
4 position to know that and express an opinion if
5 necessary on it. So as I said, this is part of the
6 staff education background.
7 And the report should come out this year.
8 Basically, the only hang-up on them is we're waiting
9 for some copyright releases. Once you do the
10 literature review and manufacturers and
11 instrumentation, you want to use some charts and
12 figures. You have to get permission and that's been
13 a slow process.
14 CHAIRMAN RYAN: Sure.
15 MR. POHLE: Next slide. The third
16 activity area was our preliminary look at DOE's
17 performance confirmation plan. You've been briefed,
18 I think, last month on DOE's plan.
19 CHAIRMAN RYAN: Maybe back.
20 MR. POHLE: The Las Vegas trip.
21 CHAIRMAN RYAN: Yes.
22 MR. POHLE: So basically it's DOE's
23 activities to meet Subpart F. Activities are
24 monitoring, field investigations, laboratory testing
25 and use of data to confirm assumptions, refine process

1 model and a lot of the objectives. The next slide.

2 Now the important thing is what context we

3 used to review the plan. Certainly we used 10 CFR

4 Part 63, Subpart F which contained all the

5 requirements for performance confirmation program. A

6 lot of acceptance criteria are laid out in the Yucca

7 Mountain review plan. We considered NRC's risk

8 baseline report certainly about what the key

9 attributes of a repository system are and their

10 significance to waste isolation, important assumptions

11 and uncertainties in those models and parameters that

12 are used to represent these attributes.

13 And the last item I really think I need to

14 emphasize. It was certainly emphasized by DOE on

15 their comments on the rulemaking that the context has

16 to be tied to the post closure performance assessment.

17 Unfortunately at this time, we've never seen TSPA/LA.

18 So there's a lot perhaps we don't know and that's

19 probably changing somewhat today. So we don't know

20 what we're going to get in the future and I think DOE

21 themselves may to relook at the sensitivity studies or

22 whatever the final TSPA/LA is and look at their plan

23 in the context of those sensitivity studies and decide

24 whether they need to make any changes or not. So

25 that's purely a TBV.

1 There was a lot of discomfort on our
2 people's part in trying to do a review without having
3 that because that's really the context of the whole
4 thing. But even at that, we took a stab at it and
5 there are some certain comments one could make. I
6 suppose they would be considered universal which would
7 be on the next slide.
8 So going through this process, it's
9 shipping it out to the appropriate technical staff.
10 At the end, we decided we could kind of bend as
11 comments came in, bend these things into four
12 different categories where there are uncertainties and
13 barrier attributes that we felt weren't addressed.
14 The second one would be activities that we thought
15 might not be practicable with current technology. The
16 third category could be activities that may not
17 provide useful data and the fourth one is activities
18 that may conflict with other activities.
19 At that point, Randy was certainly heavily
20 involved in looking through the plan and I'll let him
21 express a few of the comments under these categories
22 on the following slides.
23 MR. FEDORS: Yes, this is Randy Fedors and
24 that's Jeff's payback for when I was at the Center for
25 eight years, contributed this to some of the comments

there. There are five examples that we chose to put in here and I'll just go right down the line. They cover the four bends or categories or comments or whatever you want to call them.

The first comment deals with unsaturated zone transport issue and it's flow through the non-welded tuff, the vitric portion. We're not dealing with the zeolitic portion here. What we're saying is the vitric is capable of carrying a lot of the flow. So if water is approaching it, it's going to go through the vitric material. The zeolitic we're not. There's a much smaller amount if any going through the matrix of the zeolitic.

There are two assumptions we looked at here. One, that there's no fracture flow and I should caution you that what we're doing is based on our current knowledge of what DOE is doing. So that's reiterating the point that Jeff just made a couple minutes back that we don't know what in the -- yet. But based on our current knowledge, the DOE has eliminated fractures in the vitric at Calico Hills in non-welded tuff. Literally, that's not part of the flow. That's the only unit in the repository that has that distinction. So that's an assumption.

The second assumption, they looked at an

1 analog site at Busted Butte and the assumption is that
2 it's a good analog site. There might be some
3 questions there to look deeper into but that's another
4 point. It's a distal portion of the Calico Hills.
5 I guess one thing that makes it kind of
6 difficult to assess whether this is a good analog site
7 for Yucca Mountain is that we have a Yucca Mountain
8 core base knowledge for the repository of just a few
9 core holes in it and of course your core hole sample
10 size is quite distinct from a tunnel through the
11 distal Busted Butte site. So going on with anything
12 to do with Calico Hills and cores, you might look at
13 poor core recovery because it's friable rock and
14 there's cavity dissolution and so on. That's some of
15 the things that make it difficult to understand. The
16 comment then to sum this up is at the bottom of the
17 slide there because retardation in the Calico Hills
18 non-welded is of some significance. It's not clear
19 why there weren't any confirmatory activities related
20 to verifying the assumptions I would put forth.
21 Going to the next slide, No. 9, the
22 comment on activities not practicable with current
23 technologies, we're dealing with activities mentioned
24 in the performance confirmation report about
25 monitoring drifts, both ambient and accelerated and

there are some plans for in-drift and near-drift measurements in the thermal tests, monitoring of seepage and measuring hydroelectric properties in the fractured rocks.

And our comment would be that some of these technologies are not well developed. They're not well established yet and in of itself, that's not something that we should say "So don't do it." It's something that should introduce some program risk. What if the technology is not there when you plan to do this? But certainly we would wholeheartedly say "Go ahead and try." That's how a lot of advances have been made in the past.

MR. POHLE: Yes, I suppose I could add one point. There are probably some, what's a good word, an opportunity here for some research and development on just how would you measure these observations you plan to make.

MR. FEDORS: Was that the Oste (PH) Program comment? But you didn't want to stay that, huh? So in other words, we don't want to convey that as a criticism. We just want to acknowledge that there is some program risk. If the technology is not there, the technique is not there to do things. And the comment, the major bullet there, there's a couple

1 of things that are mentioned, collecting in drift
2 water when you're near boiling conditions. It's not
3 something the staff sat around and said "I know how to
4 do that" and I don't think it's been done yet.
5 Another one is the example of both in the
6 ambient and the thermally-accelerated drifts. How do
7 you segregate seepage, diversion, along-wall flow and
8 evaporation and drift redistribution and moisture
9 through convective patterns? Something not as a
10 bullet there but alluded to in the introductory bullet
11 was the fracture of flow properties and active
12 fracture model. There's not clear path for how to do
13 that other than in a modeling exercise sense.
14 Slide 10. In the category or bin of
15 activities that may not provide useful data, in Rev 5
16 DOD noted that there were two options for thermally-
17 accelerated tests, a one-drift option and a two-drift
18 option. To clear that up, I'll start with the two-
19 drift option where you'd have a thermally-accelerated
20 drift that had the objectives pointed towards in-drift
21 processes. The second test would be one that's
22 focused more on the near-drift, the host rock,
23 processes.
24 Rev 5 described the two-drift option in a
25 little bit more detail. An earlier rev of the

1 performance confirmation report described a lot of the
2 details of the one-drift option and fundamentally,
3 what we need to take home from here is that there are
4 some differences in the management of these thermally-
5 accelerated tests that seem to preclude both being
6 satisfied by a one-drift option and the three examples
7 that I want to mention are constraining the peak
8 temperature. For the near-drift experiment, they want
9 to constrain the peak temperature to be at that
10 expected during the repository and the emplacement.
11 So a much higher temperature.
12 For the in-drift thermally-accelerated
13 test, they want to look at things that are going on
14 around boiling temperature. So they would go just
15 above a little bit and be able to come back down and
16 focus on processes occurring at that place. So that's
17 a contradiction there.
18 The ventilation, when they ventilate and
19 how they get to micromanaging the heat in these, the
20 in-drift is not going to use ventilation after peak
21 temperature is reached. For the near-drift, they're
22 going to have to ventilate to bring that temperature
23 down from the peak temperature which could be just,
24 don't quote me on numbers, but we're talking 50 or 60
25 degrees above boiling or possibly a lot more. So they

1 need to bring that temperature down within for sure
2 100 years. They will have to ventilate and why is
3 that important? Ventilation has a pronounced effect
4 on moisture in the test.
5 The presence of dip shields, the near-
6 drift test would have them and the in-drift test is
7 not going to have them. That may affect how the
8 processes are working inside the drift.
9 The next slide, that would be Slide 11, a
10 comment categorized as activities that may not provide
11 useful data. In their performance confirmation plan,
12 they talked about looking at metals, looking at
13 environmental conditions in those metals, and actually
14 putting these in thermally-accelerated tests and
15 looking at gas compositions, water quantities,
16 chemical composition of the water, radiation, things
17 like that, monitoring that. Our comment here is that
18 it may be difficult to tease out the mode or not tease
19 out the modes, but replicate the conditions expected
20 during an actual in-place drift when you're
21 micromanaging here and then tying that to the modes of
22 corrosion. Different types of corrosion might be a
23 worry under different environmental conditions and the
24 concern is that they may not be able to provide useful
25 information if you can't tie those to the modes.

1 Slide 12, the category of activities that
2 may conflict with other activities, DOE plan to
3 photograph the drifts as they were going and use that
4 to help them map out the fractures in particular and
5 some other things, but they plan to wash those so they
6 can get high enough quality pictures. It can be very
7 difficult to map based on photographs if your eyes do
8 such a great job. You lose information in
9 photographs. So washing the tunnel walls would be
10 helpful. But our comment here is that this may impact
11 other activities especially if the other activities
12 deal with hydrologic or chemical, geochemistry of the
13 samples of the waters around the drift.
14 So the summary I'll throw that back at
15 Jeff and let him summarize.
16 MR. POHLE: Sure. You know, in retrospect
17 a lot of these comments when you start getting down to
18 the methodologies and making sure DOE's program is
19 integrated correctly so one group is not stepping on
20 the feet of another, I would anticipate a lot of that
21 could be handled during the review detailed test
22 plans. Now DOE did make an attempt to put in the
23 anticipated methodologies in there and we applaud them
24 for that which gave us an opportunity to raise a few
25 comments. Thank you.

1 Certainly the only comment of the nature
2 on GAPS and their program was our comment on the
3 Calico Hills, but that was the one area that we were
4 particularly uncomfortable with not knowing what's
5 going to be in the LA, the fluidity of potential
6 engineering design. I don't know. All I hear is talk
7 and that's nothing for me to base comments on which
8 makes it difficult.
9 Now my current knowledge is that DOE is
10 nearing the point where they can release two detailed
11 study plans. One is on precipitation and one is on
12 construction monitoring. Now the precipitation is
13 certainly not technically challenging. It would be of
14 interest because the study plans will contain the
15 baseline dataset.
16 So if you get something like the precip,
17 you would have all the baseline precipitation for the
18 site as well as the process and the plans for
19 monitoring and that and it will be probably be a good
20 exercise for us when the opportunity, get copies of
21 those for in this fiscal year, to look them over. I
22 don't know what degree we could have comments on them
23 or not. You don't know what you're going to get, but
24 a lot of it will be educational looking at form and
25 format, what's the process.

1 Now these are two particularly complicated
2 ones when you get into things like, you know, at some
3 point when you're dealing with parameters that are
4 deemed of high significance and there will processes
5 for notifying the NRC of significant deviations. It's
6 probably not a critical element of rainfall. I
7 wouldn't want a phone call in the middle of the night
8 that we had three hundredths of an inch more than the
9 mean 24 hour or maximum rainfall. But I think DOE is
10 working through this process. So it will be
11 interesting to see those.
12 And construction monitoring is kind of an
13 interesting one too. It's required by the regulation
14 and just exactly. That could be a lot of stuff just
15 observing. That are always surprises underground once
16 you get underground and what that means.
17 In the long term reiterating back some day
18 in the future we'll be involved in inspections and
19 some technical expert analysis on incoming data. Part
20 of that will probably be updating our own performance
21 assessment as well as DOE updating theirs for future
22 licensing decisions. So if the budget is available,
23 we would keep a hand in that.
24 MEMBER WEINER: Thank you. Because we're
25 behind schedule, I'd like to limit questions to

1 members of the Committee. Dr. Clarke?

2 MEMBER CLARKE: No questions. Thanks,

3 Ruth.

4 MEMBER WEINER: Dr. Hinze.

5 MEMBER HINZE: What kind of plans are

6 there for monitoring the activities during the time

7 after the repository is filled but before it is

8 permanently closed in the period of retrievability I

9 guess? That's the problem.

10 MR. POHLE: By regulation, performance

11 information continues until the permanent closure. I

12 don't know. I don't have a clue if it's full, but

13 we're going to keep it open. I have no idea what time

14 frame we're talking there. Unless you've heard from

15 DOE, I haven't communicate on that level and then

16 there's the issue of detail, what monitoring is after.

17 The rule requires they come in with plans for that.

18 That's not performance confirmation anymore.

19 MEMBER HINZE: Okay. Thank you.

20 MEMBER WEINER: Dr. Ryan.

21 CHAIRMAN RYAN: Thank you. A couple of

22 comments. I think we'd recognize as you did that

23 DOE's last presentation showed a much higher level of

24 detail and information than their previous one. So

25 they have thought a lot about it and I think we agreed

1 with your comment there.

2 The one thing I keep thinking about when

3 I hear people talk about performance confirmation in

4 an heavily instrumented program of any kind is data

5 management. Data will migrate. I'd hate to try and

6 reload a paper tape camera spectroscopy report onto

7 any gamma spec system today. So have you guys thought

8 about or has DOE given you an indication about how

9 data management, data migration, things of that sort

10 will be addressed?

11 MR. POHLE: Mostly when we did the review

12 plan, we were mostly thinking in the practicability of

13 doing experiments, things like replacing sensors, kind

14 of account for those things in the detailed test plan.

15 Data management on a broader level is a good thought.

16 Frankly, I haven't thought much about that. I've

17 looked at it from the sense that what's DOE's process

18 that data comes into DOE. There will be procedures

19 for analyzing that and assessing is this significant

20 in the context of the performance assessment. If so,

21 what do we have to do about it, bring NRC into it,

22 update the performance assessment, even make design

23 changes. I can see that.

24 CHAIRMAN RYAN: Yes, let me just give you

25 a little insight. I mean you're talking about sensors

1 and so forth and how they may or may not fail or
2 operate I'm going to guess longer periods of time like
3 decades. You could end up in a situation where the
4 probe is just fine but nobody eliminates the box
5 anymore to take the data.
6 MR. POHLE: That happens.
7 CHAIRMAN RYAN: That kind of thing and I
8 just throw that out as something to rattle around
9 about because these technologies evolve all pretty
10 rapidly --
11 MR. POHLE: I had it happen last month
12 with the home irrigation system. The timer went out.
13 That's only three years old. Don't make that anymore.
14 You have to get one this big.
15 CHAIRMAN RYAN: Yes.
16 MR. POHLE: And it has to be sitting like
17 this and there's no room between the electrical box.
18 CHAIRMAN RYAN: So the good news is you
19 have an option.
20 MR. POHLE: Right.
21 CHAIRMAN RYAN: But the bad news is it's
22 not an easy one. But I don't think this is a real
23 trivial question.
24 MR. POHLE: No.
25 CHAIRMAN RYAN: It might need some thought

1 to think about how not only will the technology evolve
2 but how will my ability to handle data evolve with it.
3 MR. POHLE: It brings back memories from
4 back in the '80s when at least one site at Yucca
5 Mountain, I think, it might have had telemetry to that
6 area where the sample management facility was, at
7 least on one weather station. That's going back
8 awhile.
9 CHAIRMAN RYAN: Sure. Thanks.
10 MEMBER WEINER: Allen. I want to thank
11 you all very much for a brief pointed presentation and
12 it looks like you're focused very well on what DOE is
13 doing on performance confirmation. So all I can say
14 is keep right on doing what you're doing.
15 MR. POHLE: Thank you. Enjoyed it.
16 MEMBER WEINER: And thank you very much.
17 I think we are, in the interest of time, going to move
18 directly to the next presentation which is John
19 Kessler and friends will present the Electric Power
20 Research Institute preliminary analysis of the maximum
21 disposal capacity for commercial spent nuclear fuel in
22 a Yucca Mountain repository.
23 DR. KESSLER: Thank you, Ruth. I will
24 attempt to keep it as brief as I can.
25 CHAIRMAN RYAN: Actually, we're in pretty

1 good shape.

2 MEMBER WEINER: Actually, we've made up

3 the time.

4 PARTICIPANT: In that case, we'll take as

5 much time as we want.

6 MEMBER WEINER: There you go.

7 DR. KESSLER: Right. And we again

8 appreciate the opportunity to share some work that's

9 definitely in progress in this case. The second view

10 graph please.

11 I'd like to start with some

12 acknowledgments. What I'm going to talk to you about

13 today is currently in the form of a draft report of

14 some preliminary work. We have the report in

15 preparation and the intent is to get it out the door

16 and publicly available by the end of next month. I

17 would like to acknowledge the authors. Mick Apted

18 from Monitory Scientific LLC is sitting here to my

19 left who is the lead author on that draft report.

20 Other authors, John Kemeny from the University of

21 Arizona on rock mechanics issues, Fraser King on

22 corrosion, Alan Ross on regulatory, Ben Ross on

23 hydrothermal issues, Frank Schwartz on really a rock

24 characterization and Wei Zhou on some of the tuff

25 modeling I'll talk to you about.

1 The purpose and an approach. What we're
2 going to show you again is a preliminary, and I want
3 on preliminary, analysis of the maximum physical
4 capacity radiologic repository at Yucca Mountain and
5 in this case we looked just at the disposal of
6 commercial spent nuclear fuel. We understand that the
7 current Nuclear Waste Policy Act of 70,000 metric tons
8 has been divided between 63,000 for commercial spent
9 nuclear fuel (CSNF) and the rest for other kinds of
10 wastes. So what we focused on was really the
11 commercial spent nuclear fuel potential expansion.
12 What we also wanted to do in terms of
13 criteria on ourselves is if we're going to look at
14 expanding Yucca Mountain, we want to assure that there
15 were minimal impacts on the cost or schedule of DOE's
16 current 70,000 metric ton design. So what we did was
17 we considered only the Yucca Mountain areas that have
18 been currently characterized or considered by DOE. We
19 have started with DOE's current line load, high
20 temperature operating mode repository design which
21 I'll review real quickly and we applied many of their
22 same thermal constraints along with a few others that
23 are somewhat different on the natural and engineered
24 barriers. For this first pass, we tried to use
25 conservative convection only thermal modeling which

1 I'll describe and we did a little bit of work on
2 identifying alternatives that could further optimize
3 CSNR disposal capacity.
4 The next view graph is a quick review of
5 DOE's current line-loaded high temperature mode
6 operating repository design. That results in maximum
7 waste package temperatures of that 160 to 180 degree
8 C range. What I'm showing, the next bullet talks
9 about the 81 meter pitch which we know about between
10 the drifts and that maintains sub-boiling of the
11 pillar of the tuff for drainage of condensate water.
12 What I have in the lower left-hand corner
13 there is a CCDF of really how much of the pillar will
14 stay below boiling and what you see is that DOE is
15 anticipating that only something like five to maybe
16 fifteen meters of the rock around the drifts will dry
17 out leaving a significantly large pillar in their
18 design that's below boiling. At present, it's unclear
19 how much exactly of that pillar they need.
20 The next view graph talks about the
21 thermal constraints that we put on ourselves in this
22 preliminary analysis. We kept sort of the 350 C
23 cladding limit. I have "optional" there because in
24 some cases, for example in NRC's TPA, they don't take
25 credit for cladding and if cladding is not going to be

1 taken credit for, then one may not need to apply any
2 particular limit to it.
3 In terms of waste package surface
4 temperatures, we've analyzed up to 309 C already and
5 we think we could easily go higher without
6 significantly effecting the lifetime of the alloy 22
7 material.
8 For the rock wall, we did assume 200 C.
9 Again if you wanted to sharpen your pencil, you could
10 go somewhat higher than that and still avoid the low
11 crystabolite to high crystabolite phase change that
12 occurs in like the 225 to 250 C range that really
13 causes the significant damage to rock due to thermal
14 expansion of that phase.
15 We did look, and you will see, that we
16 relaxed the goal of maintaining those pillars below
17 boiling at all times in the future. We did entertain
18 the possibility that the pillars could dry out or at
19 least get up to boiling for some short period of time
20 without deleterious effects.
21 The next view graph talks about the
22 options. I'm going to talk to you about three
23 different options that we looked at. Option 1 is
24 simply looking at more real estate, expanding the
25 footprint, looking at some other areas in addition to

1 the primary area that they are considering right now
2 for disposal. Option 2 is looking at a multi-level
3 repository. So Options 2 and 3 are really increasing
4 the density per square foot essentially of waste that
5 could be disposed. Option 2 is essentially a shacked
6 repository design that I'll talk about. Option 3 is
7 a grouped single level emplacement where we have
8 groups of drifts all at that same elevation.
9 What we were after was to determine the
10 range and the expansion factor that we could attribute
11 to each one of these options, expansions factors, you
12 know, what factor over 63,000 to 70,000 metric tons
13 each option might afford. Then at the end, I'll talk
14 about some combination of those options and what that
15 might mean. Next view graph.
16 Again, a quick review of the real estate
17 that's out there and what the Yucca Mountain project
18 is considering. What is really hard to see for
19 anybody else except perhaps the ACNW members is that
20 roughly at that white fold, that horizontal line that
21 runs through the strata there in that picture, is
22 where DOE is proposing to put the drifts and I think
23 Mick is pointing that out on the view graph there.
24 It just so happens that that folded line
25 roughly represents the actual diameter of a drift and

1 the message there along with the first bullet is that
2 the Topopah Spring Tuff unit is relatively thick
3 especially compared to that single elevation drift and
4 if we're considering stack repositories we do have
5 quick a bit of Topopah Spring Tuff there to consider
6 using.
7 There is major northwest trending faults
8 that of course don't show up in this particular cross
9 section that define suitable rock blocks and one will
10 have to consider respect distances from those faults,
11 you know, with solitary Oak Canyon shown to the left
12 and the Sundance and Ghost Dance off more to the
13 right. We do believe that even with a multi-level
14 repository one could maintain something like 200 to
15 400 meters of rock cover and 200 to 400 meters of
16 water table below and I'll show you some options we
17 looked at there in a few minutes.
18 Okay. On to Option 1 which is to look at
19 more real estate, the extended footprint, if you go
20 back to DOE's Final Environmental Impact Statement for
21 the low temperature operating mode, they showed in
22 addition to the primary block which is really that of
23 the three that are in the yellow color there. It's
24 the upper left of the three. That's their primary
25 block. They looked at expanded blocks both to the

1 south and to the east, the other side of the Ghost
2 Dance fault. So there is some characterization of
3 those and DOE has already considered those as
4 potential expansion areas. Certainly those could be
5 considered not for low temperature operating mode but
6 potentially for high temperature operating mode with
7 expanded capacities.
8 MEMBER WEINER: Excuse me, John.
9 DR. KESSLER: Yes.
10 MEMBER WEINER: When you said that low
11 temperature operating mode, this was the mode where
12 there was more space between the -
13 DR. KESSLER: There was more space.
14 Right. Essentially the thermal density was lower than
15 the current -- At least what I understand is at
16 present still DOE's plan for this high temperature
17 operating mode, the 11.8 kilowatt maximum package, the
18 1.45 kilowatt per meter maximum line load which is
19 what we understand is still the current design. Next
20 view graph please.
21 So what Frank Schwartz did and really
22 summarizing very quickly our report here, is he went
23 through the literature on who's looked at what kind of
24 available area in the Yucca Mountain region. He went
25 back to Mansure and Ortiz which is the original '84

1 report that was used to kind of identify initially the
2 blocks. He looked at other studies done by the M&O
3 and Science and Engineering report, the final EIS, as
4 well as some recent work by Pair Peterson (PH) all of
5 which looked at different kinds of extended areas.
6 And what you see in the right column is the expansion
7 factor again, how much bigger are these areas in
8 proportion to what DOE is proposing to use for 70,000
9 metric tons in the HTOM approach.
10 And what we concluded was that we're quite
11 confident that we could go to an extended area of
12 about 13 square kilometers or roughly double the
13 footprint that DOE is planning to use and potentially
14 with additional characterization work and study, one
15 could go to 2.6 to as much as 3.5 times the available
16 real estate for potential repository expansion.
17 Okay. Moving onto Option 2 now, this is
18 increasing the density for the same unit area. The
19 first option was the multi-level repository and on the
20 right, it's just a simple cartoon of what a multi-
21 level repository might look like. This was certainly
22 not a cartoon specifically developed for Yucca
23 Mountain but just an example of what we're talking
24 about. What we considered were additional drifts 30
25 to 50 meters above and below the current HTOM design

horizon. We looked at the same or lower line loads than DOE has used. The same line load would be the 1.45 kilowatts per meter. We lowered that down to 1.0 kilowatts per meter to see what effect we got. Next view graph please.

I just want to point out that especially for ACNW a multi-level repository designs aren't new. DOE has considered them in the past for Yucca Mountain. I'm thinking of at least the Ladds era studies that were done. Several European nations as well as the Japanese are considering a multi-level repository and back in '99, Charles Fairhurst when he was part of the ACNW provided a report to the ACNW called "Engineered Barriers at Yucca Mountain" where we borrowed the figures on the right. Again it's just a simple example to show that at that time Charles looked at a three level repository. In this case, he was focused on the Richards Barriers, but he did consider a three level repository with Richards Barriers as well. Next view graph.

Okay. So the other way to stack is that group disposal drift concept and again, what I have here is a very simple cartoon of grouping those drifts where again we're preserving the 81 meter spacing between the groups of drifts with 20 meter spacing

1 within a group and that would leave roughly a 41 meter
2 pillar between the groups. Again for this group
3 disposal drift design, we looked at 1.45 and the lower
4 1.0 kilowatt per meter line load.
5 The next view graph shows the two unit
6 cell models for Options 2 and 3 that we pulled into
7 the TOUGH2 Code. TOUGH2, a multi-phase heat and mass
8 transfer code where as you'll see in the top of those
9 figures we allow infiltration in from the top which we
10 assumed in this particular model 15 millimeters per
11 year of net infiltration and gas movement could be
12 either up or down through that top boundary.
13 We did calibrate our models against some
14 DOE results to make sure we were on the right path.
15 We picked parameter values for the different strata
16 that you see in this particular figure that were
17 within the range of what DOE is considering to do that
18 calibration.
19 And again, what you see is just one
20 example of each one of those options. On the left,
21 I'm showing one that happens to have that 30 meter
22 spacing between the upper, you know, each of the three
23 levels. We also considered a 50 meter spacing. Next
24 view graph please.
25 So that multi-level repository, we

1 considered really six cases or six permutations. In
2 that second column, that shows that we looked at
3 either the 30 or the 50 meter spacing, the third
4 column initial loading. Again I can conservatively
5 say we assumed that 100 percent of this expanded
6 repository got loaded at once with a 1450 watt per
7 meter or 1,000 watt per meter line load. You combine
8 the fact that we're tripling up the number of drifts
9 with either the same line load or two-thirds of the
10 line load. That gets us our next column which is that
11 expansion factor of either two or three times
12 essentially per unit area what we could get for this
13 design.
14 We looked at some different ventilation
15 durations and efficiencies. We considered ventilation
16 that would only go on for 50 years and maybe 50 to 300
17 years with an increased efficiency as the rock dries
18 out and things cool off. Again those efficiencies, we
19 took right out of existing DOE, I think, AMRs in this
20 case.
21 MEMBER WEINER: Were you looking at forced
22 ventilation?
23 DR. KESSLER: Yes. Forced ventilation.
24 The next view graph is quite busy. I just wanted to
25 show you one example of a kind of output that we have.

1 What I'm showing you in the three sets of paired
2 figures there are outputs from the TOUGH case, TOUGH2
3 model for Case 1. The left set is temperature
4 profiles versus time at 55, 100, and 1,000 years and
5 the right is gas saturation.
6 What you might want to keep your eyes on
7 is that gas saturation. You can see that at about 100
8 years the gas saturation has risen to one nearly all
9 the way through the pillar which means that the pillar
10 has just about dried out in its entirely there. But
11 you see that by 1,000 years we're well past the point
12 where that pillar is dried out and we've already
13 started to increase the saturation to allow flow
14 through that pillar.
15 I want to point out again that these units
16 cell models we looked at are conservative in the sense
17 that while we included convection, we did not include
18 any of the 3-D edge effects that might cause the
19 temperatures to be even lower than what we're
20 predicting here or the pillars to stay open for either
21 longer or forever. So we wanted to be a little
22 conservative there. Next view graph please.
23 Again, another busy one, really all I want
24 to point out here in addition to commenting that in
25 this top one we show that our peak temperatures at

1 various positions don't exceed the limits for what we
2 had for our waste package cladding or tuff. The
3 bottom one is the one I want to focus on. Mick is
4 showing you the light blue, innermost curve there.
5 That is for the center line of the pillar and what you
6 see there is that that gas saturation rises to one,
7 meaning it's dried out for only a very short period of
8 time on this semi-log plot such that we're really only
9 drying out the entire drift pillar for maybe a few
10 hundred years at most. I have in terms of details how
11 long they're dried out for each one of these cases for
12 in a back-up view graph.
13 DR. APTED: Also the --
14 MEMBER WEINER: Identify yourself and use
15 --
16 DR. APTED: Mick Apted. Just adding and
17 compare the narrow range -- with this larger dry-out
18 which is the dry-out in the drift area itself and so
19 the pillar do dry out for a short period, but that's
20 very short especially compared to the duration in
21 which no water can reach those packages.
22 DR. KESSLER: Exactly. Right. And if you
23 just back up one for a quick second in the view
24 graphs, again you can see there that we do have dry-
25 outs right around all three drifts for quite a long

1 period of time and that's reflected as Mick's showed
2 in the next view graph going on back to that. How
3 wide the dry-out is right around the drifts versus
4 time in that lower curve.
5 Okay. Moving on to the grouped repository
6 options, again we looked at six permutations which we
7 labeled Cases 7 through 12 where again in that next
8 column we looked at in all cases three sets of drifts
9 that were 20 meters apart giving us a 41 meter pillar.
10 Again, we looked at initial loadings of in some cases
11 1450 watts per meter, the 1.45 kilowatts per meter.
12 But we also considered just loading the two side
13 drifts to half that thermal loading or 725 watts per
14 meter such that we go expansion factors in the next
15 column of either two or three again in terms of
16 increased density. And again we looked at some
17 different ventilation durations and efficiencies that
18 in terms of considered durations and efficiencies are
19 out of DOE AMRs.
20 The next view graph again is one example.
21 In this case, it's Case 10 of temperature and gas
22 saturation at 55, 100 and 1,000 years. What you see
23 for the middle set that Mick is pointing out is that
24 at 100 years we have temporarily dried out the entire
25 pillar, but a few hundred years past that and

1 certainly by 1,000 years in that lower right-hand
2 figure you can see that the pillar has now resaturated
3 and that we again have sub-boiling in the pillar for
4 almost all times still with just a temporary blockage.
5 Again, that's highlighted in the next view
6 graph please. If you focus on that inner curve on the
7 bottom one, you see the relatively short period of
8 time when the entire pillar is dried out for this
9 particular group drift repository design as well.
10 Okay. Finally, getting to the conclusions
11 on the next view graph, so what we have to summarize
12 is derived expansion factors for the extended
13 footprint or just increasing the real estate something
14 like two to three and a half times the current
15 legislative limit of 70,000 metric tons. I should
16 just be focusing in the CSNR. They should all say
17 63,000 metric tons because that's what we focused on
18 and assumed that all the heat was coming from the CSNR
19 and that the other waste wasn't contributing much in
20 the way of heat.
21 For Option 2, that multi-level repository,
22 we again think that we can go to two to three times
23 the current 63,000 de facto limit for CSNF as well as
24 for the group drift. We think we can get up to that.
25 Next view graph please.

1 So of course what one can do is combine
2 Option 1, the increased real estate, with Options 2 or
3 3, the increased density and we considered that and we
4 reached the conclusion that we're confident that we
5 can get at least four times the existing CSNF limit
6 that we can emplace at Yucca Mountain with current or
7 limited additional information and when we do the
8 math, that roughly means we can get up to about
9 260,000 metric tons.
10 Now we do think that with additional site
11 characterization and/or design optimization, a
12 combination of approaches, we think that possibly
13 upwards of nine times that limit could be achieved
14 using more of the square footage, using maybe some
15 additional cooling methods as well as certainly
16 sharpening your pencil. One could go up to maybe
17 570,000 metric tons that's theoretically emplaceable
18 in the Yucca Mountain region.
19 So summary, next view graph, again our
20 preliminary EPRI analysis of the maximum, this is a
21 preliminary analysis. We intend to do some more work
22 throughout this year to explore the options in more
23 detail. Bottom line is we think we can get with
24 confidence four times and perhaps up to nine times the
25 existing limit for CSNF in the Yucca Mountain region.

1 The options that we kept ourselves to we think have
2 minimal impacts on the cost or schedule for DOE's
3 current 70,000 metric ton design. We're starting with
4 our HTOM. They are high temperature operating mode
5 line loader design. We're using current site
6 characterization information.
7 And we would argue that additional
8 information that would be required to expand the
9 repository can be collected in parallel with DOE's
10 proceeding with the license application and
11 development and maybe even loading of the first 70,000
12 metric tons. This additional information and proving
13 the bases for expansion could all occur while the
14 first 70,000 metric tons is being licensed and loaded.
15 And with that, Mick and I will take questions.
16 MEMBER WEINER: Jim.
17 MEMBER CLARKE: John, thank you. Just a
18 quick one. Any anticipated or estimated significant
19 cost differences between these approaches?
20 DR. KESSLER: We did not look at cost. We
21 understand that anything that would expand this is
22 going to involve cost. We haven't looked at that yet.
23 At present, we just wanted to focus ourselves just on
24 the simple question of is it possible.
25 MEMBER CLARKE: I was just looking between

1 options.

2 DR. KESSLER: Right. In terms of

3 expansion versus stacked versus side-by-side, we

4 haven't looked at cost on those, between options yet.

5 MEMBER CLARKE: Thanks.

6 MEMBER HINZE: What is the significance of

7 the physical properties of the units both in a

8 horizontal and a vertical manner? Have you evaluated

9 the physical properties of the rocks there in terms of

10 their stability for construction as well as for drift

11 stability over time?

12 DR. KESSLER: We've taken a quick look at

13 that. At the Appendix A I believe of this draft

14 report that will be available to you by the end of

15 next month, we do discuss some constructability

16 issues. We've had some informal discussions about

17 them. At present, we see no impediments to

18 construction even if the first 70,000 metric tons was

19 loaded.

20 MEMBER HINZE: Is there sufficient amount

21 of information to make that statement or is that just

22 a wishing kind of thing?

23 DR. APTED: Let me add to that. This

24 doesn't show all the units, but the blue and the

25 purple are the Topopah Springs and of course, that's

1 divided into the non-lith and then these four
2 lithophysal units.
3 MEMBER HINZE: Right.
4 DR. APTED: From top to bottom, that
5 pretty much covers a huge part of this that the
6 program has already developed extensive rock mechanic
7 information, thermal, conductivity measures,
8 mineability estimates and so on. When you look at
9 where they're planning to put the repository, of
10 course, it sort of skips across many of these five
11 different units.
12 MEMBER HINZE: So it stays sloped.
13 DR. APTED: Of course, they do step it out
14 and slope it in some of the designs. So, yes, they
15 are in terms of even the 50 meter spacing for three
16 drifts. So it's 100 meter, 110 meters, total. That
17 110 meters spans the region that the project has
18 currently characterized these four lithophysal and one
19 non-lith units.
20 MEMBER HINZE: A second question. You
21 mentioned the need for additional characterization.
22 You went through that rather rapidly. Please expand
23 for us if you will.
24 DR. KESSLER: Yes. I think it's really
25 going to repeating partially what Mick said that the

1 project has already done a lot of characterization of
2 the Topopah Springs Tuff unit up and down. We think
3 that a lot of that could be used. The project has
4 also as part of their EIS for the low temperature
5 operating mode taken a look at least some of that rock
6 off to the east in some amount of detail. Yes, in
7 that figure, what figure is that, Bill?
8 MEMBER HINZE: It's eight.
9 DR. KESSLER: Figure 8 please. That shows
10 not only the ones in yellow which they considered for
11 the low temperature operating mode, but you see that
12 there's other areas up to an area eight there. They
13 have significantly west of the Solitario Canyon where
14 there is some information available. Now here is
15 where it's the factor of too confident in the factor
16 of 3.5 with more work.
17 Okay. We think that there's a good chunk
18 of information that's available to get us up to about
19 a factor of two. We recognize that one would need to
20 do more site characterization work on some of these
21 blocks out there that go out to Area 8 to get up to a
22 higher expansion factor.
23 MEMBER HINZE: Maybe I missed it in your
24 presentation, but Option 1 includes through Area 8.
25 DR. KESSLER: It can. Where's the table?

1 DR. APTED: That's right after. Nine.

2 DR. KESSLER: Yes, Figure 9. Thank you.

3 This is where we looked at different studies that

4 looked at different extended area and that Option 8 --

5 Excuse me. The eight areas that you see in Figure 8

6 come out of the FEIS. Mansure and Otiz when they

7 first sort of did their study of the area looked all

8 the way up to 37 square kilometers. In early studies,

9 the M&O looked at about 11 square kilometers. The

10 Science and Engineering Report looked at 23. So the

11 point is there are data out there for those larger

12 amounts, but we admit that more data would need to be

13 collected to expand well beyond the factor of two to

14 do that.

15 DR. APTED: The 23 number comes here and

16 it was also bantered about in the FEIS but that

17 certainly includes this Area 8 and so on, those whited

18 areas you see in the previous slide.

19 MEMBER HINZE: And that would be where

20 you'd really have to focus on additional

21 characterization.

22 DR. KESSLER: Yes.

23 DR. APTED: But even at that time, they

24 considered they had adequate information to go forward

25 with putting or at least planning to put waste in

1 there. Those weren't areas they had no information.
2 They had maybe less information but confident enough
3 to go forward in terms of considering putting waste in
4 those areas.
5 DR. KESSLER: Right, but we're not
6 disagreeing with you that additional information would
7 need to be collected out for those other areas. Just
8 that we're not starting with a blank slate here out on
9 those areas by any means.
10 MEMBER HINZE: Have you considered the
11 additional risk by decreasing the vertical distance
12 between the repository and the water table for Option
13 No. 2?
14 DR. KESSLER: Yes. The stack repository
15 design.
16 MEMBER HINZE: Right. And what is that
17 minimum distance? What is the minimum distance
18 between the level and the water table?
19 DR. KESSLER: Again it ranges across the
20 site as you know.
21 MEMBER HINZE: Sure.
22 DR. KESSLER: The number typically quoted
23 is on the order of 300 meters from where this
24 repository horizon would be. So we would be as little
25 as 50 meters into that in terms of the UZ Zone.

1 MEMBER HINZE: So you have 30 meters
2 between the centers.
3 DR. KESSLER: We looked at both 30 and 50
4 meters between centers.
5 MEMBER HINZE: Both. And you were having
6 a double so that would then be anywhere from 60 to
7 100.
8 DR. APTED: Right. We put a layer on top.
9 See it's not all both under.
10 MEMBER HINZE: A layer on top. Okay. All
11 right. So have you looked at the risk significance of
12 this?
13 DR. KESSLER: We've looked at it
14 indirectly in the sense that we have looked at maximum
15 temperatures both for the rock, for the waste package
16 and asked ourselves is this within our envelope of the
17 performance that we've already modeled and the answer
18 is yes. So we think there is not a major risk
19 significance for the stack design or the side-by-side
20 design at least for the models that we're looking at.
21 DR. APTED: I think that UZ zone doesn't
22 have a tremendously long hold-up time in terms of the
23 transit across it from the bottom of the repository
24 until it gets there and again if we're looking at
25 radionuclides with half lives of 17 million years and

1 2 million years and 250,000 years --

2 MEMBER HINZE: We have Chloride 36 too.

3 DR. KESSLER: Or its significance.

4 DR. APTED: Right. So that loss of 50

5 meters is not going to unduly compromise the peak dose

6 that would come out of this repository. Another point

7 to add to some of the things that John said and that's

8 contained in Professor Fairhurst's analysis is

9 especially with the stack repository, there's a

10 certain amount of additional water diversion that

11 would be occurring for the subsequently lower

12 repositories.

13 So it's not simply taking the performance

14 of one repository and its release rate and multiplying

15 by three. It wouldn't necessarily track

16 proportionally. It could actually though second and

17 third levels based on some of the comments he's made

18 and we've considered but not yet calculated lead to

19 less than proportional increase. So three times the

20 waste wouldn't lead to three times the peak dose.

21 PARTICIPANT: Rick shared a wealth of --

22 DR. APTED: Exactly. You know that well

23 then.

24 MEMBER HINZE: A final question. Jeff

25 Pohle a few moments ago reminded us of the supposed

1 effect of the Calico Hills upon the absorption of
2 radionuclides. Have you looked at the enhanced
3 temperature effect upon the zeolites in the Calico
4 Hills and what that might mean in terms of the risk?
5 DR. KESSLER: No, we haven't. We do take
6 credit for sorption in that Calico Hills zone. We
7 take credit for sorption in the lower zones, mostly in
8 the saturated zone. Again, we don't think that
9 changing the sorption of the zeolites under the Calico
10 Hills is going to make a huge difference in the
11 overall performance of the repository.
12 MEMBER HINZE: Means doesn't know it.
13 DR. KESSLER: Yes. Well, I think that
14 we've looked at those studies where we've looked
15 already years ago at the ranges of potential KDs for
16 each one of the layers and we found some sensitivity
17 but not that much.
18 DR. APTED: You're going to find and this
19 doesn't quite go down, but look at these temperature
20 profiles. I mean the zeolite phases in geology go up
21 to what, 200 degrees Centigrade or so. The type of
22 temperatures in the Calico Hills never get above about
23 120 degrees and even that's for a very short time
24 geologically speaking here. So I think with some
25 confidence -- And they're going to be dry. Again,

1 water would mediate a rather potential phase change,
2 but I think in dry temperatures 120 degrees, these
3 zeolites are very robust.
4 MEMBER HINZE: I think we would all feel
5 more comfortable if that was really looked at more
6 closely.
7 DR. KESSLER: Again, I think we would go
8 directly to establish geologic science. Again the
9 metamorphic bases for zeolite clay is 200 to 250
10 degrees.
11 MEMBER HINZE: Right. Thank you very
12 much.
13 MEMBER WEINER: Mike.
14 CHAIRMAN RYAN: You addressed the
15 performance assessment question and I recognize this
16 is a work in progress. I had an early given view of
17 it which I appreciate. It sounds like except for heat
18 you're really looking at these from PA point of view
19 as independent. Is that right?
20 DR. KESSLER: No, we're not looking at
21 that. That's why we were talking about the dip shadow
22 effect is potentially the upper one protecting the
23 lower two.
24 CHAIRMAN RYAN: Depends on the
25 arrangement.

1 DR. KESSLER: Yes. Go to just the next
2 figure from this one. Look at that bottom curve and
3 what you see is that we have the zone right around the
4 drifts dried out for a very long period of time. So
5 we get some benefit there. Again peak temperatures of
6 the waste package are such that we don't expect to
7 kick in any additional or significantly more rapid
8 degradation mechanisms for the alloy 22 for these. So
9 we have considered them separately and together, again
10 mostly subjectively at this point, Mike and formally
11 gone through all the work.
12 CHAIRMAN RYAN: No, I appreciate that and
13 --
14 DR. APTED: Let me just add we're looking
15 at showstoppers on the thermal side and the water flow
16 and so on. We haven't done our own TSPA on this type
17 of group drip.
18 CHAIRMAN RYAN: And you're working through
19 all this.
20 DR. APTED: Yes, that's right.
21 CHAIRMAN RYAN: This may be a silly
22 question but why are you doing this?
23 DR. KESSLER: There is --
24 DR. APTED: Careful.
25 DR. KESSLER: Let's just say that there is

1 some interest in looking at options and all I can tell
2 you is that my members asked EPRI to take a look at
3 what might be the capacity of Yucca Mountain just to
4 provide an independent estimate. So that's what we
5 did.
6 CHAIRMAN RYAN: Okay.
7 DR. KESSLER: We just looked to see what
8 it could hold and we'll see how this develops for us
9 as the year proceeds in terms of flushing this out.
10 CHAIRMAN RYAN: We'll look forward to your
11 report. Thanks.
12 VICE CHAIR CROFF: For the times where the
13 pillars dry out, where does the water go?
14 DR. KESSLER: Some of it goes right out
15 the top of the mountain. We increase the saturation
16 a little bit in the strata above but not very much.
17 Can we go to Figure 24 please. That's one of the
18 back-up slides. Thank you.
19 It's busy. I appreciate that. What I
20 want you to focus on, Allen, is the last column for
21 these 12 cases you looked at. This shows us where if
22 you have a stack design. It's the lower two drifts
23 that dry out. At least it's at that same horizon that
24 the pillar totally dries and for how long and you can
25 see that we're talking about a few hundred years here.

1 Given that we have some water moving out the top and
2 that the time period is fairly short, we don't
3 anticipate a few hundred years of total dry-outs to
4 present any problems for the long term performance of
5 the repository.
6 VICE CHAIR CROFF: So you're not creating
7 a huge umbrella here.
8 DR. KESSLER: Heavens no.
9 DR. APTED: Let me add just a couple more
10 to that. The analysis that we showed today, the top
11 level performance just like the current one level
12 design meaning that, the pillar always persists at
13 sub-boiling conditions. Okay. So what really
14 develops is like a V-shaped trough possibly between
15 vertical sets of emplacement drifts.
16 The other thing we're going to work on and
17 extend or two things, one we're going to look at what
18 happens in terms of any instability of gas rising
19 behind hot water at that interface where condensate
20 water is. But we're also going to look at the third
21 dimension and I think the more this is looked at and
22 in terms of even the project studies now is that most
23 of the condensate water, 50 percent or more, is
24 actually in their modeling being formed and condensing
25 at the cool ends along drifts in this third dimension

1 we have not yet simulated.

2 So a good bit of the water, this sort cf

3 umbrella idea that people have, really most of that

4 water, 50 percent or more, looks to be condensing at

5 the cooler end of drift and then disappearing from the

6 system. So we're not creating a lake above the

7 repository that will later flow down, but when you

8 include the third dimension along edge effects, the

9 evidence to-date so far is that a lot of the

10 condensate water will form there and then leave the

11 system. So it won't return.

12 VICE CHAIR CROFF: Okay. Second, in doing

13 your thermal calculations, do you account for decay

14 during repository loading and heat levels going down?

15 DR. KESSLER: Yes and no. We assume that

16 it's instantaneously loaded to either the 1.0 or the

17 1.45 or in some cases 0.725 kilowatts per meter

18 loading. In terms of decay with time, I don't know

19 what Wei assumes.

20 DR. APTED: It's a real good question. I

21 think, I believe, we're using the decay curve from the

22 projects.

23 DR. KESSLER: We have to. We're using the

24 decay curve.

25 VICE CHAIR CROFF: The reason I bring it

1 up is when you start talking about 3X, 4X loadings,
2 you're talking 80 years to load it.
3 DR. KESSLER: At least probably. Yes.
4 VICE CHAIR CROFF: And the first canister
5 to go in is seeing some half lives of cesium and
6 strontium.
7 DR. KESSLER: Right. That's why I mention
8 that we think we have potentially a conservatism, it
9 depends on how you choose to load it, but a potential
10 conservatism in that initial loading in the sense that
11 if you put it all in initially at 1.45 kilowatts per
12 meter and you're ventilating by the time you've closed
13 of course you're less than what we've assumed here.
14 So that could mean you could increase the capacity or
15 that you've added some conservatism.
16 DR. APTED: Allen, one of the things we're
17 thinking of doing, and this is the vertical stack, is
18 right now all three of these line loads are switched
19 on at the same time.
20 DR. KESSLER: Right.
21 DR. APTED: In terms of the assumption.
22 Obviously, the first thing is to possibly say okay put
23 in maybe one horizon and then in 50 years begin to
24 place in the next horizon and then in 50 years after
25 that for example, start looking. But we don't want to

1 get into too much of steering logistics and so on, but
2 we do want to examine system sensitivities to exactly
3 what would be a real world situation that all three
4 drifts would not be loaded at the same time, but
5 sequentially.
6 VICE CHAIR CROFF: Okay. Thanks.
7 MEMBER WEINER: I just have a couple
8 questions. Now in the FEIS when DOE consider
9 alternative cooling times, a cooler repository, they
10 also had the repository open for 300 years. Did you
11 consider that or was yours closed after it was loaded?
12 DR. KESSLER: When you take a look at
13 those two figures that had the cases 1 through 6 and
14 the other figure cases 7 through 12, you'll see quite
15 a few options on there where in addition to zero to 50
16 year ventilation we have some all the way out to 300.
17 MEMBER WEINER: Yes. So you --
18 DR. KESSLER: So we did consider out to
19 300 like the project did.
20 MEMBER WEINER: Did you also look at the
21 option of aging at the surface?
22 DR. KESSLER: Not yet. We've mentioned
23 that as an option. We are going to think about doing
24 that for the next phase of this report.
25 MEMBER WEINER: That was my next question.

1 DR. KESSLER: Right.

2 MEMBER WEINER: And you looked at forced

3 ventilation. You didn't --

4 DR. KESSLER: Yes. These ventilation

5 efficiencies that Mick is showing you in addition to

6 the times there take into account the forced

7 ventilation, the ventilation rates that the project is

8 considering and one of the things then that obviously

9 would have to be done if you're going to triple or

10 double this would be you're going to have to add some

11 more ventilation in addition to what DOE's already

12 planning for. From a constructability standpoint,

13 that means yes, you'll have to add some more shafts,

14 but again we don't see any fundamental showstoppers

15 there in terms of adding more ventilation capacity

16 within the same footprint.

17 MEMBER WEINER: And finally, one of the

18 options that is considered in the EIS is for natural

19 ventilation and just separating the drifts.

20 DR. KESSLER: Yes.

21 MEMBER WEINER: You also considered that.

22 DR. KESSLER: Well, we --

23 MEMBER WEINER: Or did you all consider

24 that?

25 DR. KESSLER: We thought about it. We

1 have not modeled it. We've thought about it. We've
2 discussed whether we want to do that in our phase two
3 of this work. Is that a fair statement, Mick?
4 DR. APTED: Yes, I think right now we call
5 it preliminary and there are numbers down there that
6 I'm sure are draining the blood out of the faces of
7 many people saying "Wow, that's a lot." I just want
8 to stress that while we're looking at logistics and
9 costs and schedule impacts and trying to do it with
10 the least interference, we also have an eye on safety.
11 I mean we're not looking at this as trying to simply
12 lead us down a road where we're not also considering
13 what might be the safety impacts on this, but that's
14 really the next phase.
15 Right now, we're just looking at do we
16 lead to some sort of thermal conditions or results
17 that would really invalidate sort of the current level
18 of knowledge that would say, "This is no-go right
19 now." We haven't seen that in this preliminary
20 analysis. It gives us confidence and I'll try to
21 refine it to consider some of the other aspects
22 including safety.
23 MEMBER WEINER: Thank you. Staff
24 questions? Anyone else? Please identify yourself for
25 the record.

1 MR. MALSCH: Marty Malsch for the State of
2 Nevada. Just a comment and then a question. One
3 comment would be that an obvious purpose of this
4 project would be to support legislation currently
5 pending in the Congress to remove the current
6 statutory limitations. That's kind of an obvious
7 purpose here.
8 I did have a question though and that is
9 did this study consider retrievability of 600,000
10 metric tons and whether that would complicate the
11 obligation to retrieve the waste in case something bad
12 happened.
13 DR. KESSLER: We haven't formally
14 considered retrievability. Yes, it would take longer.
15 Again, fundamentally we would see no problem doing it.
16 It could take longer. It just depends on the level of
17 effort you would also want to make in terms of how
18 much parallel retrievability, how much surface
19 facility you would need to bring it back up to the
20 surface. But formally we haven't consider it. No,
21 Marty.
22 MEMBER WEINER: Thank you and thank you
23 very much for an excellent presentation. I'll turn it
24 back to the Chairman.
25 CHAIRMAN RYAN: Thanks, gentlemen. We

1 appreciate it. It's interesting. With that, I think
2 we've finished our formal presentations and we can
3 conclude the record at this point. We will just take
4 up letter writing which does not need to be in the
5 record. We'll take a very short five minute standup
6 and let everyone that wants to exit exit and then
7 we'll come back quickly and begin our letter writing
8 at 4:55 p.m. Off the record.
9 (Whereupon, at 4:48 p.m., the above-
10 entitled matter was concluded.)
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CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Nuclear Waste 169th Meeting

Docket Number: n/a

Location: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Katherine Sykora
Official Reporter
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