Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title:	Advisory Committee on Nuclear Waste 173rd Meeting
Docket Number:	(not applicable)
Location:	Rockville, Maryland
Date:	Tuesday, September 19, 2006
Work Order No.:	NRC-1254 Pages 1-286

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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW)

173rd MEETING

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TUESDAY,

SEPTEMBER 19, 2006

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VOLUME II

ACNW WORKING GROUP MEETING ON USING MONITORING TO BUILD MODEL CONFIDENCE - DAY 1

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The Advisory Committee met at 8:30 a.m. in Room T-2B3 of the U.S. Nuclear Regulatory Commission, One White Flint North, 11555 Rockville Pike, Rockville, Maryland, DR. MICHAEL T. RYAN, Chairman, presiding.

MEMBERS PRESENT:

MICHAEL T. RYAN, Chairman
ALLEN G. CROFF, Vice Chairman
JAMES H. CLARKE, Member
WILLIAM J. HINZE, Member
RUTH F. WEINER, Member

NRC STAFF PRESENT:

DIANE DeRICCO
DAVID ESH
LATIF S. HAMDAN
JOHN T. LARKINS, Executive Director, ACRS/ACNW
JAMES SHEPHERD
MARK THAGGARD

ALSO PRESENT:

TOM BURKE, Brookhaven National Laboratory
MICHAEL FAYER, PNNL
MIKE HAUPTMAN, Brookhaven National Laboratory
DR. GEORGE HORNBERGER, The University of Virginia
VERNON ICHIMURA, Energy Solutions
MATTHEW KOZAK, Monitor Scientific, LLC
BRIAN LOONEY, Savannah River National Laboratory
DAVID SCOTT, Radiation Safety Control, Inc.
STEVE YABUSAKI, PNNL Hanford

I-N-D-E-X

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

(8:34 a.m.)

4) OPENING REMARKS AND INTRODUCTIONS

CHAIRMAN RYAN: The meeting will come to order, please. This is the second day of the 173rd meeting of the Advisory Committee on Nuclear Waste. During today's meeting, the Committee will conduct a working group meeting on using monitoring to build model confidence.

The meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. Latif Hamdan is the designated federal official for today's session.

We have received no written comments or requests for time to make oral statements from members of the public regarding today's sessions. Should anyone wish to address the Committee, please make your wishes known to one of the Committee staff.

It is requested that speakers use one of the microphones, identify themselves, and speak with sufficient clarity and volume so they can be readily heard. It is also requested that if you have cell phones or pagers, you kindly turn them off. Thank you very much.

I might also add there is an overflow

room. And this presentation, what we hear at the table, will be broadcast to the room next door so folks there can hear and also some of the conversations picked up on the microphone. So those of you in the audience recall that what you say will likely be transmitted next door.

I think we have a bridge line open for participants from PNNL. However, it being 5:30, nobody is on that line as yet. And we'll announce them when they arrive on the telephone.

Without further ado, I'm going to turn over the meeting to Dr. James Clarke, who is going to run this session and tomorrow's session as well. Dr. Clarke, take it away.

MEMBER CLARKE: Thanks, Mike.

SESSION I: ROLE OF MODELS AND MONITORING PROGRAMS IN LICENSING

MEMBER CLARKE: Welcome, all of you, and thank you for attending this ACNW working group meeting on using monitoring to build model confidence. Monitoring and modeling; in particular, the monitor and modeling interface, are of great interest to the Commission and to the Committee.

Our focus for these meetings is to answer the question, how can we use monitoring to not only demonstrate compliance but to build model confidence as well?

Also, in a related area, the Committee will be looking at the use of monitoring and modeling to evaluate the reliability and durability of institutional controls. And we would appreciate any thoughts you have on this challenging area as well.

The Committee worked very closely with the Office of Research, Tom Nicholson and Jake Phillip in particular, to organize the sessions and select the speakers and panelists. As all of you know, Latif Hamdan of the ACNW staff has played a major role.

Our meetings have been organized around four sessions. Today we will look at the role of models and monitoring programs and licensing. And this afternoon we will look at case studies for evaluating radionuclide releases and groundwater contamination.

Tomorrow's meeting will include two additional sessions on field experience and insights and opportunities for integrating modeling and monitoring.

We have invited a very capable group of presenters and panel members, including representatives from the Department of Energy and the national labs, private consulting firms, and waste management companies, U.S. Geological Survey, the U.S. Environmental Protection Agency, and the Nuclear Regulatory Commission.

We have a very tight schedule. And, in fairness to all of the participants, we need to stay on schedule. I will do that as needed. So everyone please stay within your allotted times.

And on that note, we will hold questions until after the speakers have made their presentations and the panel has had an opportunity for discussion.

Professor George Hornberger has agreed to lead the panel discussions. He is, as you know, a former member and Chairman of the Committee. And we greatly appreciate his participation and leadership role in these meetings.

Our first speaker is Vernon Ichimura from Energy Solutions-Duratek-Chem Nuclear, who will talk about the role of modeling in licensing.

5) THE LICENSEE'S PERSPECTIVE ON THE ROLE OF MODELS AND MONITORING IN DEMONSTRATING COMPLIANCE WITH LICENSING CRITERIA

DR. ICHIMURA: Good morning. I am here to talk about a little different perspective, coming from the side of being a licensee. And I would like to thank the ACNW for this opportunity.

My goal is to kind of give you kind of an overview of what kind of models we use and how we use models to demonstrate licensing, compliance with licensing requirements.

What I wanted to do is begin with an overview slide and tell you a little bit about what I would like to talk about. I'm going to talk a little bit about the Barnwell site, where I'm employed at, and give you kind of general statistics and, in doing so, talk a little bit about some things that we do about monitoring and modeling. I'll do a quick review of the regulations.

And what I tried to do today is focus on the measurements and, finally, in the use of models. And I'll try to integrate all these topics together to the extent that I can. And hopefully in making a generalization, I'm trying to focus on the two bottom criteria, where we focus on measurements in the use of models.

About the Barnwell site, it was basically licensed in 1971. The initial license area was approximately 13 acres. The current license area is about 235 acres.

Approximately 12 million curies of

radioactivity have been received. And after decay, there are about 3 million remaining today. The current area for disposal is 105 acres. There are ten acres of the site remaining, of its capacity, of the area that we can dispose of waste.

Much of the area of the site is composed of buffer area in ancillary facilities. There is approximately 28 million cubic feet of waste disposed. And the remaining capacity is somewhere in the neighborhood of about 2 million cubic feet.

Of the 105 acres, since people are going to be talking about capping in the afternoon, about 96 acres of the site is capped with enhanced cap. The area that is not capped is basically called with what they call minutial clay cap.

We are located in the south central section of South Carolina, adjacent to the Savannah River site. It is in the County of Barnwell. I use that term "BWMF," which I won't use much in this talk. It refers to the Barnwell waste management facility.

It composes of a number of ancillary facilities, including the burial site, which we will focus on today. It is in what we call a coastal plain geologic province, and it is composed of primarily sand, clay, a little bit of cobble. Towards the coast, there is a little bit of limestone in the area of the site. There are little pods of limestone, but there aren't any beneath the site.

This is an interesting slide. This is an air photo of the facility and the ancillary facilities. What I wanted to point out is this is north to the top of the page. The groundwater flow beneath the facility basically goes from north to southwest beneath the facility. There are ponds, water management ponds.

The facility is managed so surface water runoff from the facility is minimized. All water is collected on site and perced or evaporated back into the atmosphere.

The supporting facilities are located towards the south side of the facility itself. The area that is kind of the shaded grass, the dead grass area, is actually completed or finished cap.

Groundwater basically recharges this facility and eventually daylights in the creek on the bottom, which is off the screen. And I'll show you that in a follow-up talk. What I'm going to try to do is relate how groundwater leaves the facility, enters a creek, and enters what we call a compliance area or compliance location.

This is a photo of a trench. This is trench 86, the largest trench we have ever built. And it's located on the south side of the facility.

What is interesting about this trench, it was open in 1996. So it's fairly old. And it's almost near the end of its life. What I wanted to say here is in the south, when you look at this in terms of a model or in terms of someone who manages radioactivity in general, this is a very big challenge because you have waste packages within vaults, many vaults, various different kinds of waste packages, waste packages from different sources.

So the source term when you think of modeling in itself is a challenge from the modeler's standpoint, from the focus on the microscopic side of modeling.

To give you kind of statistics, the cylindrical vaults are roughly eight feet in diameter, nine feet high. The rectangular vaults are roughly ten by ten by ten, in that kind of a magnitude. The cylindrical vaults weigh approximately 40,000 pounds. For rectangular vaults, they are somewhere on the order of 70,000 pounds full.

In the foreground, these are reactor pressure vessels. And at the bottom of the screen, this is what we call the monitoring pipe. This is a pipe by which we monitor fluids beneath the trench itself.

Regulations. I just thought I would focus and spend a few minutes on this slide. It's very important from our perspective that we demonstrate by measurement or by model during operation and after site closures that concentrations of radioactive materials that may be released to the general environment generally is less than 25 millirem to any member of the public.

So to demonstrate by measurements and/or model implies that in some cases where we cannot make the measurements or we have to make projections, we almost have to model.

What I thought here, I would bring up a slide to put it in perspective, what we are focused on as a facility. We have tried to operate the facility, first of all, do it safely and within regulations.

The other thing that we always focus on to do this work within regulations is we have to focus on the real dose to workers. We always bring this up because the average radiation dose to a worker in 2005 is somewhere on the order of about 241 millirems.

In the environment, on the other hand,

we're focused on the hypothetical dose to the public. And what I want to point out here is the average annual hypothetical dose to the public is negligible because the scenarios that we construct for modeling do not exist. The hypothetical dose at the compliance location is five millirem. And I will expand more about that topic later on this afternoon. My focus, again, this afternoon would be on the groundwater and surface water.

Okay. At our facility, we focus on measurements. And measurements are important because they are easier to defend. They are almost very concrete. Models have a lot of parameters that take measurements upstream to a compliance location or to a compliance number.

We measure at various locations. We measure around the disposal site. This is an operational type measurement, not an environmental type measurement, during operations.

We monitor around enclosed and open disposal trenches on the disposal site at boundary and compliance location and at far afield off-site locations. And in the most distant location, we monitor background for our facility at distances up to six miles away. We currently make about somewhere on the order of about 10,000 measurements a year of various types.

We focus on all pathways. And I have one exception to this. We don't have animals on this slide. We do not analyze animals. We analyze direct exposure, like open trench with direct gamma. We look at airborne by air samplers. We monitor surface water stalls, plants, and groundwater.

The most important radionuclide from our standpoint, as it would well be for most people who operate facilities like this, happens to be tritium.

Our tendency, at our facility, we tend to use very simple models or well-documented models that have been checked. From the operations standpoint, the operations folks have a tendency to use calculator-based, very simple models that are based on theoretical principle. And I'll expand a little bit by giving you some examples of what they might be.

When we use complicated models, we have a tendency to use commercial or public domain models or simulated. We always run validations. We check the model results when we can with measurements.

In very important cases where the models involve what is perceived to be very important; for example, in the groundwater and surface water pathway, we have independent peer review. And I'll give you some kind of time frame on what it takes to do this work.

Okay. What I am going to do now is going to talk a little bit about some examples, some models that we have used, and talk about them in general. Hopefully in generalizing I don't come up with a wrong perception.

In the case of operating a trench, like I showed you, trench 86 before was a very big trench. And it's wide open and has many, many waste packages.

At some times there are opportunities to place waste packages in various locations. And what we try to do is in particular cases where waste packages are questionable, we estimate boundary dose as a result of placing these packages at various locations in the trench or constructing trenches at various locations on site.

So the question that we always ask ourselves, you know, what kind of shielding is required or in the process where do we place the waste in the trench or the configuration of the waste? In these cases, the tendency would be to use very simple inverse square law models or Microshield.

The bottom line is about the direct gamma radiation. Using these types of models, we always verify with measurements at compliance locations by TLDs.

This is one. We estimate radionuclides at the site boundary in surface stall and surface water. In cases where we have traces of amount of radioactivity on the land surface, a question that we ask ourselves is, can we leave it there and is it safe?

So an exercise of this type would be done by analyzing this concentration of what is in the soils. We do erosion calculation and measurements. And we use runoff calculations and erosion measurements to estimate what the radionuclide concentration might be at the boundary. And, of course, we always verify by measurements.

Finally, this is one that we use. We estimate radionuclide concentration in groundwater and surface water from information that we receive on site. In this particular case, we're looking at tritium. And we're trying to project radionuclide concentrations at the compliance location.

Here we make measurements of radionuclide concentrations near the source. We use measurements of hydraulic data to develop a model. And we perform groundwater and transport modeling. And, finally, we verify with measurements.

Finally, I would like to say that we believe that the role of models is needed to demonstrate compliance from our perspective. We always remember that models are a simplification of reality. Because models have coefficients which lump a whole bunch of processes together, they contain numerous assumptions.

We, finally, feel that the models need to be checked by measurement to the extent possible. And as new information becomes available, we update thee models or we update the methods we use to model and demonstrate compliance.

MEMBER CLARKE: Thank you, Vernon.

Moving, David Scott, Radiation Control, also talking about the role of monitoring from a licensee perspective.

MR. SCOTT: Good morning. What I would like to talk about this morning is our experience with monitoring groundwater in support of license termination at the Yankee Nuclear Power Station in Rowe, Massachusetts.

Briefly, the operational history at the plant is a pressurized water reactor that operated from 1960 to '92, was built adjacent to the Sherman Reservoir in the Northern Berkshires of Massachusetts using a vapor containment design. Power output was initially 485 megawatts. And that was updated in 1963 to 600.

The plant permanently ceased operations in 1992. And we know that early in plant history, operational history, there was a significant leak in the ion exchange pit.

The fuel cladding for the first 14 years was stainless steel. And during the period from 1960 to '80, the spent fuel pool did not have an interior stainless steel liner. These are some factors that may have led to the contamination that we see in the groundwater.

This is a picture of the site shortly after decommissioning began where the facade of the turbine building was removed and most of the plant structure still remained. That was in the midst of removing the vapor containment. Here is a shot of the cooling water, Sherman Reservoir.

And this is as the site looked a couple of weeks ago. All the structures are removed. Large excavations have been backfilled. They're just accomplishing final site grade as we speak.

The potential groundwater-contaminating events that we are aware of, as I said, the spent fuel pool was unlined from 1960 until '80. And we first identified a leak in the ion exchange pit in 1963, which was repaired in early '65.

There was outside storage of contaminated materials earlier in the plant operating history. There was some redistribution of soil contamination related to removal of snow and over-land flow from precipitation events.

There was one incident of the reactor head impacting the site of the containment during a refueling outage that resulted in some outside soil condemnation. And there was an underground drain pipe leak in the radwaste warehouse, which was unearthed and repaired, but there was some residual soil contamination that was left to be dealt with at decommissioning.

A couple of criteria for license termination at the plant. All pathways need to be less than the total effective dose equivalent of 25 millirems per year. And all residual radioactivity as well is reasonably achievable.

Tritium concentrations in the resident farmer's well must be less than 20,000 picocuries per liter with the average yield of that well serving a family of 4 averaging about .665 gallons per minute. And then there are other groundwater contaminants that must be less than limits that are defined in the LTP license condition.

The first ten monitoring was redrilled at the site in 1963, shortly after decommissioning began. Twenty-four wells then were added during four additional drilling campaigns throughout the '90s. Virtually all of these wells were in a shallow outwash aquifer that's 25 to 30 feet deep.

And then there are two additional monitoring points: Sherman Spring, which has been monitored as part of the RENT program since 1965; and the plant potable water supply well, which is completed in bedrock, beneath the surfacial deposits.

These initial monitoring wells and sampling points were sampled periodically, not quite on a quarterly basis but generally a couple of times a year, and analyzed for tritium, gamma emitters, and chemical constituents.

One round of analysis was completed for strontium-90. And the results of these analyses identified a tritium plume, the maximum concentration of which was about 5,000 picocuries per liter. And it was centered more or less on the spent fuel pool ion exchange pit, which were two adjacent structures, and extended down gradient from there.

This plume doesn't show very well, but here is the IX pit. And the hottest part of the plume is there and extends practically 600 feet down gradient from there.

In 2003, we did a comprehensive review of the groundwater monitoring activities to date and came up with several recommendations. They included we thought we needed to drill some additional wells to fully characterize the deeper aquifers beneath the outwash and improve several procedures, those for drilling, sampling, and analysis of the resulting samples.

We wanted to do a better job of defining the data quality objectives. We wanted to use a new method of drilling, rotosonic drilling, which gave us more control over sealing of aquifers as we proceeded deeper and gave us better core samples so that we could better characterize materials we were encountering.

We changed from bailing groundwater samples to a low-flow sampling technique. And we instituted a regular quarterly sampling program. We also standardized and expanded the list of radionuclides for which we analyzed to 22.

The suites of radionuclides that we looked for were determined by location on the site and the historical site assessment and what we believed were reasonable contaminants to look for.

The new locations for the wells were based on the site geology. There are intermediate sand depths within a lodgment till that underlies the stratified drift. And then we also completed several wells in bedrock. Some are as deep as 300 feet beneath the lodgment till or, I should say, the thickness, total thickness, of unconsolidated material, which includes the stratified drift and lodgment till and glacial acustern deposits beneath that in some cases is 300 feet. And so we had to penetrate as much as 300 feet before getting into the bedrock in some places.

We completed several wells in nests at several locations across the site to give us a vertical profile of contaminant levels and vertical groundwater flow potentials.

So in 2003, we installed 17 additional wells with the rotosonic method. And using this method, we telescoped numerous casing so that each time we encountered a different water-bearing zone, we would seal that off so that we were sure that we were not causing any cross-communication between various units as we proceeded deeper. This method allowed us to characterize the complex stratigraphy and determine the vertical distribution of tritium.

We explored the entire thickness of sediments and shallow bedrock down to a maximum depth of 295 feet to the top of rock. And then typically we would drill into rock only 15 or 20 feet. And the bedrock surface is fractured enough that it was water-bearing and we could derive a sample from that.

The results of the 2003 investigation confirmed that tritium was the only plant radionuclide in groundwater. We also confirm that there is a tritium plume in the shallow aquifer.

We saw a maximum concentration of about 3,500 picocuries per liter. And it is aligned with the direction of shallow groundwater flow, which is to the northwest towards the Deerfield River as it exits the Sherman reservoir. However, for the first time we identified a second tritium plume, which occurs in deeper sand lenses within the lodgement till.

Here the maximum concentration of tritium is 45,000 picocuries per liter. And the alignment of this plume is also toward the Deerfield River. We found tritium in one bedrock well of about 5,000 picocuries per liter.

That's the depiction of the tritium plume. Again, here's the vapor containment. The spent fuel pool is right off this corner. And so you can see that the most concentrated part of the plume occurs right in the vicinity of the IX pit and the trend is, again, to the northwest, off towards the Deerfield River.

DR. HORNBERGER: That's in the outwash?

MR. SCOTT: That's right. This is the shallow aquifer plume. This is a depiction. Well, it's contours of groundwater elevations in the shell or plume. And it simply confirms that groundwater flow is indeed towards the northwest. The vapor containment is right here. And so the plume follows this same alignment.

This is a different groundwater flow path in a sub-basin of the site that is really up gradient of the industrial area and has not been significantly impacted by radionuclides.

Here's a depiction of the tritium concentrations in the deeper sand units, 300 to 100 feet deep. Again, the most concentrated portion is right at the IX pit spent fuel pool vicinity. It appears to be trending, you know, contrary to the groundwater flow, which in the deeper zones is again basically towards the northwest, but we think that this may simply be the result of our distribution of wells, available wells, that didn't give us a full picture of the distribution.

So in '04 we went back and drilled some more wells, again using the rotosonic method. We chose locations that would bound the plumes and give us some confidence that we had fully defined the extent.

And we did some work to study the interconnectivity between the aquifers by monitoring groundwater levels with data-logging pressure transducers, which were installed in wells and monitored over several weeks to months.

Basically the groundwater flow characteristics are that flow in the shallow aquifer is relatively fast, to hydraulic conductivity of about five feet per day. The net flow rate in the deeper groundwater is much slower. And it's controlled by these discontinuous sand lenses that are within a lower permeability matrix of lodgement till.

This is the shallow plume as we mapped it after the '04 investigation, when the additional wells were installed, same basic shape of the plume. It elongated a bit towards the north. I think that was probably a function of just a slightly higher concentration that we measured in this cluster of wells during that quarterly monitoring period.

So what we know about the source of the tritium plumes is we believe the primary source is a spent fuel pool/IX pit complex. The maximum tritium concentration occurs close to these structures, both in the shallow and the deeper aquifers.

We know the IX pit leaked in '63 and was repaired early in '65. A second line of evidence is that the REMP monitoring detected tritium in Sherman Spring, which is about 550 feet down gradient of this structure, first detected back in 1965 at peak levels of about 7 million picocuries per liter. And this was in the period right after the IX pit was repaired.

And since then it's declined continuously and was less than 200 picocuries per liter since 1993 except recently we have seen some minor spikes related to demolition activities just last year.

The IX pit was emptied in '95 and demolished in '05. And, similarly, the spent fuel pool was emptied in 2003, right after the fuel was removed to dry cask storage, and also demolished in '05.

The contaminant transport mechanisms we believe the tritium and the deeper groundwater along deep foundations and piping adjacent to the spent fuel pool at IX pit, our nested wells have confirmed that there is a downward flow potential in the vicinity of these structures.

We think that the tritium became trapped or retarded in these deeper sands and slowly diffuses into the shallow aquifer. And it is this condition that may sustain the low concentration shallow plume or plume in the shallow aquifer, which otherwise may have attenuated by now.

This is a depiction of the ion exchange pit and spent fuel pool. The leak occurred in this area. And we think it travelled through the relatively permeable backfill around the structures and beneath them.

And this is the isolated sand lens that the well with the highest concentration of tritium is completed in. And you can see the vertical distance between the bottom of the lowest structure of the spent fuel pool and this sand is only a few feet.

You really can't see it, I guess, from the blurred scale, but this is a 30-foot interval. So it's about five feet between the top of this sand and the bottom of this fuel chute, fuel transfer chute in the spent fuel pool.

This map, plan view map, shows the orientation of several cross-sections across the site, the A, A_1 cross-section is aligned, basically parallel to the shallow groundwater flow. And this next slide is a cross-section, EAA cross-section along that orientation.

What this shows is here is the vapor containment. The ion exchange pit and spent fuel pool are right here. And, again, the data show us that the highest concentrations of tritium are directly beneath these structures and they trend towards the northwest. There is a fairly concentrated component that goes to a depth of 100 feet or more.

This outer contour line is a 500 picocuries per liter. And this does not imply that all the material within this boundary has that concentration of tritium. It simply outlines the outer bounds of where we see it. The tritium occurs in these sand stringers, but this intervening matrix of lodgement till is virtually dry.

Just this past winter, we instituted our latest drilling program, where we drilled an additional 17 wells. We installed three multi well clusters, one right at the IX pit leak location. This was really the first time we could get access to that area because of all of the ongoing demolition activities.

These clusters, well clusters, were sited to confirm the plume source and also the absence of any additional radionuclides in groundwater other than tritium. And we did some testing to better define the interconductivity of the aquifers. We also replaced a few wells that were abandoned earlier in the program to facilitate plant demolition.

This is simply a site map showing the current distribution of wells that are going to be monitored going forward as part of our long-term monitoring program. There are currently, I believe, 53 wells. Again, this is the central core area of the site where the vapor containment formerly sat.

So our preliminary results of the latest investigation show us that tritium is still the only plant-related radionuclide in groundwater. Drilling results also confirm that the sand lenses in the deep till are of limited extent.

We conducted pumping tests in several of these wells to determine the hydrogeologic parameters of hydraulic conductivity and sortivity for key sand lenses. And we did this with a 24-hour constant rate test in the well with the highest tritium concentration.

We also conducted several two-hour pressure transient tests in 12 selected wells to test the hydraulic connection between various sand lenses. And during these tests, we used pressure transducers to monitor water levels in several nearby wells.

A numerical fate and transport model of the system is currently under development. And this model will incorporate the stratigraphic model that has been developed from drilling results; the water level measurements that have been made with the pressure transducers; of course, the groundwater sample analytical results; and the results of pumping tests.

This numerical fate and transport model will be used to validate our site conceptual model and to predict tritium concentrations at the compliance point at various times in the future as well as to demonstrate compliance with the criteria for license termination.

The lessons we have learned from these

investigations is that, first, there are multiple aquifers at the site. The initial work had only concentrated on the shallow aquifer. And we showed that that was not showing us the whole picture.

Contamination migrates through multiple aquifers to depths greater than 100 feet. Hydrogeologic investigation must be an iterative process which builds upon things that you have learned in previous work. It's important to develop a hydrogeologic conceptual site model, which aids you in placement of wells and understanding contaminant transport mechanisms and allows you to estimate aquifer characteristics.

We think long-term data trends are important to track. They allow bias detection in the groundwater quality data. They allow you to identify seasonal fluctuations and ultimately to identify new contaminant releases should they occur.

Water level monitoring has been instructive to us. It can demonstrate connection or isolation of discrete aquifers. And it's certainly useful for calibration of numerical monitoring.

The early investigations at Yankee were not sufficiently rigorous. As I said, the monitoring wells were not deep enough. And there was little regulatory involvement.

We found that it was useful to engage all the stakeholders to get their input so that we could satisfy all the questions. We found that we needed to analyze for a wide suite of radionuclides more so than had been done early on and also to include non-radiological constituents for site closure because, in addition to requirements of the NRC for license termination, there are state and local requirements as well.

Now, specifically I thought I would try to respond to a couple of the questions that were posed for this workshop, the first one of which is why are groundwater compliance monitoring data not used to enhance confidence in numerical models after site characterization and licensing is complete?

At least regarding operating power stations, from what we have seen, groundwater characterization during plant design and construction, which, of course, was 40 years ago or more, was not sufficiently detailed to support contaminant fate and transport modeling. Groundwater monitoring methods were in their infancy when the last power station was built. And so we have come a long way since then.

We believe rigorous groundwater

investigation should occur during plant construction or license extension activities with wells drilled near a down gradient from key sources of primary water. And those would include, of course, the spent fuel pool, refueling water storage tanks, and condensate tanks.

And data from this detailed initial investigation could then be used to build a numerical model and also to respond to contaminant releases more expeditiously because the stratigraphy and the groundwater flow directions, contaminant flow paths would already be known. And several monitoring points would be in place.

Long-term groundwater monitoring data, then, that would result from insulation or completion of this initial detailed investigation would allow you to detect contaminant releases, to refine your numerical model by monitoring any changes in state variables that are measured over time. And these would include hydraulic head, water temperature, tidal influence, surface water stage, and contaminant concentration temporal trends. And these include tritium, which we found to be a very useful early detector, early indicator of releases.

Of course, there may be hydrocarbons and solvents and their degradation products and some inorganic constituents as well. Boron, of course, which is added to primary water, can be another indicator that could be useful to track.

Question 6, what new methods and analytical tools are available that should be pursued? Two things come to mind here. Groundwater age determination by measuring a ratio of tritium to helium-3 may improve calibration of some models of groundwater systems. It could aid in the definition of groundwater flow paths and identify contaminant transport zones.

We tried this investigatory tool at Rowe with limited success. And I think the reason is the complex stratigraphy of these isolated sand lenses created mixing of different groundwater ages. And we could not quantify the mixing ratios. And so, as a result, the ages that resulted from our analysis were not useful. But I think it could be useful in other sites.

And, finally, soil-gas surveys, which would look for helium-3 or tritium could be useful for delineating shallow tritium plumes and also as an early warning indicator of releases.

That concludes my remarks. Thank you for inviting me today. And I would be happy to respond to any questions.

MEMBER CLARKE: Thank you, David. We are going to hold the questions until after the panel is finished.

MR. SCOTT: Okay.

MEMBER CLARKE: Next speaker is Jim Shepherd, NRC. He will address the role of models in decision-making for the Commission.

6) THE STAFF'S PERSPECTIVES ON THE USE OF GROUNDWATER MONITORING AND MODELING FOR REGULATORY DECISION-MAKING

MR. SHEPHERD: Good morning. It is always a pleasure to be here to discuss one of my favorite subjects. In a half and hour or so, my good friend Mark will tell you why these complex models are not needed in all cases. That simple problem should remain simple. What I am here to talk about is the complex side.

Perhaps you will recall a couple of years ago, Gary Stairwalt and I gave you a demonstration of Earth Vision and some rather detailed models we developed of the Sequoyah fuel site. There are many other sites, perhaps not quite that complex, but in uranium recovery, other parts of the fuel cycle power reactors, as you have just heard, especially with the recent tritium releases, that are currently or will in the foreseeable future undergo decommissioning and have a significant amount of contamination, especially in the subsurface.

So, in the words of Albert Einstein, we like to keep everything as simple as possible but not simpler. So I will begin with a brief overview of 3-D models, talk about a couple of specific examples, some potential applications that we have in mind, and then a conclusion.

There are a lot of words here which I won't read. Experience has taught us that we have to account for variability in subsurface, stratigraphy, as well as the hydrology in order to identify the axillar potential migration of radionuclides during the time they're in the ground after being released from these facilities.

Often the data is presented to us in tabular format. And especially over several years, it's very difficult, at least for me, to identify potential migration or axillar migration paths shown in reams of paper of many tables of data.

I believe that a more detailed evaluation that can identify concentrations of volumes, rates and migration calculation of volumes of specific concentration, and so on, is very useful.

So why a 3-D model, instead of a 2-D model or tabular data? First, the type of model, rather than directly evaluating the data, provides a visual picture of what is going on.

Often survey data is reported by survey unit. Adjacent survey units may actually be sent to us at different periods of time, ranging from weeks to months apart. So it can become very difficult to try and maintain a mental picture of what is going on at a particular site.

Many of the decommissioning sites have more than one water-bearing unit beneath the site. A 2-D model can explore each of these individually. We can do physical or graphical overlays. But it becomes difficult to try and show both the overlays in the temporal changes in a 2-D format.

The 3-D models rise admirably to this challenge, I believe. They can be cut, sliced, diced, rotated, various pieces turned on and off, and even turned into time-lapse movies in some cases.

We use the results of these models in three distinct areas of decommissioning. The first is on receipt of the decommissioning plan. We need to determine whether the licensee's characterization of the current conditions of the site is, in fact, accurate and adequate.

That is, have they identified what the contamination is, the isotopes, the physical and chemical forms, and so on? Have they identified where the contamination is? Is it in tanks, in sumps, in cracks or joints in the floors, in the soil, or is it migrating through the groundwater?

And also we need to know how much contamination there is; that is, how much volume would need to be excavated in order to meet release conditions for the license.

The second thing we look at is whether the planned activities will, in fact, remediate all of the contamination that will allow the license to be released for the specific conditions, generally unrestricted use. And that has to take into account the projected land use and the pathways for whoever the appropriate land users will be. I find that maps help both me, the licensees, and the public have a better understanding of what is going on in this process.

After remediation has been completed, the licensee then must conduct the radiological surveys to demonstrate compliance. As with the characterization data, there are often very large volumes; in fact, more volume in general than the characterization because now they must prove that they meet the release limits.

And, in addition to the base numbers under Marson, there is also the statistical analysis and bounds and verifications. In some cases, where there are point values that exceed the derived concentration guideline limits for points, they need the supporting data to have the elevated measurement areas evaluated. So the volume of data becomes very difficult to deal with.

Then, of course, there are the conditions under which Marson does not apply, construction materials, subsurface soil, groundwater, which most of the sites that we deal with, in fact, have so that the data volume grows exponentially.

As with the characterization, I find it much simpler to look at a picture of the data and the concentrations. And that allows me to focus more on potential problem areas.

It's also, again, a very useful tool in explaining to the public what contamination is there, where it is, where it has moved, and where it might go in the future.

In the rare case that we would end up with a site that was unable to meet release criteria, we would have a restricted release condition. And, by definition, then, there would be some residual contamination remaining on site that would have the potential for migration. And that potential needs to be evaluated to determine whether the institutional controls will perform.

Are the right things being monitored? Are they being monitored in the right place? And are they being monitored at the right intervals? Again, these kinds of questions I feel can be answered usefully with the use of this kind of modeling.

Now to move to a couple of examples, which I will go through very briefly. We don't have time for all of the background. Kiski Valley was a non-licensee that came to possess licensable quantities of materials by concentrating effluents from a licensed site, legally released effluents; and the Big Rock Point reactor, which is undergoing decommissioning.

At the Kiski Valley site, contamination was uranium-contaminated sludge ash with an average concentration of 147 picocuries per gram, 4 percent enriched from a nearby fuel cycle facility.

The regulatory limits for the discharge were always met by that facility. The Kiski Valley Water Pollution Control Authority and its contractors did a great deal of characterization of the site through extensive sampling of the lagoons.

As I will show you in a couple of pictures, the staff formed a dose assessment based on this characterization in the models and concluded that it was not necessary for Kiski Valley to do any further remediation.

This is one picture of the site that shows what we call a chair cut through the facility. You can see the color coding. The lower concentrations are in the deeper purple, moving up to the higher concentrations in the red. There is actually a relatively small amount of the high concentration material. It's overlain by a large amount of the low concentration. And we feel that it's really very low likelihood that an individual would actually get into the high concentration material.

This is another view. What I would point out here in the lower right corner, there's a calculation of the volume of material that exceeds 30 picocuries per gram, which translates roughly to an unrestricted release limit of about 4,600 cubic feet, all of which would have to be excavated, in addition to the even lower concentration material that was physically on top of it.

In this case, I reduced the concentration displayed to only that above 800, the highest concentration measured. And you can see that the total volume is about 14 cubic feet.

So there would be a very large volume of material removed in order to get to a relatively small volume of high-risk material. And, again, we concluded that that was not a risk-informed decision and determined that the operator of the site need not perform any further remediation.

Next we will look quickly at Big Rock. This site is adjacent to Lake Michigan, which is a site north from the containment vessel. There are several geologic units underlying the site, which I will show you in a cross-section in a moment.

In 1984, the licensee identified a rupture of a condenser line. They estimate they released about a million curies of tritium in the vicinity of the underground of the turbine building.

During the early decommissioning activities, one of the wells that monitored a potential groundwater unit, unit 4 you'll see in the next slide was abandoned in order to pave over the area that would be used to remove the containment vessel or the reactor vessel from the containment.

That well had earlier shown an elevated concentration of tritium. And, as you will see in our slide, it potentially came from this release. And our concern was whether or not there was an unmonitored flow path for that contaminant.

The units are numbered from the bottom up: bedrock in green, a couple of clay units. Unit 4 is basically a sand unit. It would not qualify as a drinking water aquifer. The yield does not appear adequate. But it's in this unit that we are concerned with the migration.

This section is looking to the north. So to the left is west. And you can see if you adjust the scale mentally that there is about a one percent westerly tilt. And there is no longer a westerly well monitoring this unit.

This is another view. It identifies the thickness of the various units. The dark brown in the middle is unit 4. The boxes show the screen zone of various wells in that unit.

In this case, we're looking to the east

southeast. So the well is to the north of the containment that you can see in this vicinity here. And very little, if any, of the screen is actually in the unit as modeled.

Now, bear in mind that this is a model of the licensee's data, as opposed to a fact, but it raised enough questions that in our discussions with the licensee and their geologists, we determined that additional monitoring of that unit was warranted. And, in fact, they put in two additional wells to make us feel better and to ensure that they could demonstrate compliance with the release criteria.

Other potential applications for 3-D modeling. In complex systems, we feel that it is necessary. We can look at contaminant migration, both airborne, dispersion, surface water transport, groundwater transport, depending on the available data.

Final status surveys displayed in graphical form for me at least are much easier to understand than looking strictly at columns of numbers.

There are some additional uses of the data. One is to identify where compliance monitoring should be done. This concept is being coordinated with Research and their project, which I believe Tom is going to talk about later.

We can look at placement of wells for pump and treat, if you will, if that is an effective method of remediation in the particular media. And it's useful for calculating volumes that need to be excavated or pump and treat. And we can use that, in part, to both look at whether the licensee is physically performing the activity and what the associated costs would be.

Future uses. We can graphically display a land use in exposure-type scenarios. We can identify institutional control boundaries or physical or geopolitical features that could serve as potential control boundaries.

We can do things such as ground cover ingrowth as a time-lapse function. And we integrate both the subsurface modeling and the dose modeling analysis.

In conclusion, we are using 3-D graphics effectively and usefully. We look at time variants in the model. We are currently using it at existing sites and plan to use it for sites that we either currently have not completed or that we expect to receive.

We have completed about 20 complex sites. There are currently 35 more on the list. In addition to the uranium recovery sites, there are 130 sites. There are 103 operating power plants that will decommission in the foreseeable future, a number of fuel cycle facilities. All of these we believe will be classified as complex and would be very usefully addressed with this modeling.

Currently in the decommissioning directorate we have about 30 people working full-time on decommissioning with our own efforts and the support efforts of other offices, such as Research, even the General Counsel. We're extending some 90 FTEs per year on decommissioning. And this is a tool that we believe can help us.

MEMBER CLARKE: Jim, thank you very much.

We have one more presenter before the break: Mark Thaggard from the NRC.

MR. THAGGARD: Okay. Good morning. I supervise the staff here that's responsible for reviewing and evaluating dose analysis for decommissioning sites and also for reviewing performance assessment for non-high-level waste disposal facilities. We have kind of like a dual mission here.

I want to begin by saying that I think the genesis for this workshop actually started a couple of years ago, when one of my staff members, Dr. Esh, whom you are going to be hearing from shortly, presented our performance assessment approach for the West Valley site.

During his presentation, there were some questions that came about as to whether or not we were using existing groundwater contamination data at the site to calibrate performance assessment models.

I just wanted to say that, in general, if there is data available, we certainly use that data to try to help calibrate any analysis that we're performing.

In the context of decommissioning, there may be some limitations to our ability to do that. I think some of the sites that Jim talked about may be more the exception, rather than the rule. And I hope kind of that will come out through my presentation.

I want to begin by just briefly touching upon the regulations for decommissioning. This is important because it affects the type of analysis that needs to be done.

I'm not going to spend a lot of time on this because I think most of you are probably already familiar with these requirements, but basically there are two ways that a site can be decommissioned. One is for unrestricted release. And you have to meet a 25-millirem dose limit, a 1,000-year compliance period. The main thing I wanted to point out here is that the assessment here, we're looking at impacts on site, somebody coming on site using the site in the future.

So for the most part, there really isn't a need for doing sophisticated environmental transport modeling when you're looking at somebody coming on the site and their being exposed to the radiation that's remaining.

The second release criteria is for restricted release. In that case, you can impose some type of land use restrictions on the site to minimize the exposures. There is the higher dose limit in the event that the restrictions fail. You do have to meet the 25-millirem dose limit assuming that the restrictions are effective.

The main thing I want to point out with that particular requirement is that generally there are two analyses that need to be performed. One analysis looks at impacts off site in the event that the restrictions were effective in terms of keeping somebody from doing things on site. You still need to look at what would be the impacts off site.

The second analysis would look at the impacts assuming the restrictions failed. And that would be analogous to the unrestricted release case. But in the case of looking at the impacts off site, there may be a need in that case to do some more sophisticated environmental transport modeling because you are actually transporting, looking at the transport materials off site.

The NRC decommissions roughly 300 sites each year. Most of these are done through our regional offices. Most of them don't have environmental contamination. They're just building contamination. The more complicated sites, such as the ones that Jim talked about, are handled here at headquarters.

Of the more complicated sites that we handle here at headquarters, there is only a limited number that we know of right now that have existing groundwater contamination. There is also a very small number of sites where there is some consideration being given to releasing the site with land use restrictions. So just keep those two points in mind.

Most of the decommissioning is done, as I said, because it's done through our regional offices and it doesn't involve any type of environmental contamination. You are only looking at building contamination. Most of the decommissioning is actually accomplished through the use of screening tables that the NRC developed.

We have also developed screening tables for decommissioning sites that have soil contamination. One of the assumptions in order to apply those screening tables is that you have to demonstrate that there is no existing groundwater contamination. So you will probably need some monitoring information in that case to make that demonstration.

Most of the analysis because most of the sites that we're looking at for decommissioning, we're looking at unrestricted release. We're looking at impacts on site. Most of their analysis is done using a computer code called RESRAD, which was developed by the Department of Energy.

Some sites, more complicated analysis is needed if there is existing groundwater contamination at the site. Also, as I indicated, if the site is proposing to release the site with land use restrictions, then there may be a need for doing more sophisticated analysis in that case, but for the most part, those are somewhat limited. The number of sites that we're dealing with in those two categories is somewhat limited.

I just want to briefly touch upon the RESRAD code because, as I indicated, most of the analysis that is done in decommissioning is done using this code. It is a fairly simple code.

I would be the first to admit that my background is in groundwater hydrology. If there is an opportunity to do more complicated modeling, we would probably do it. But in most cases, there really isn't.

The RESRAD code assumes basically 1-D vertical transport. It assumes no dispersion in the unsaturated and the saturated zone. Basically what RESRAD code is it calculates the break-through curve of contaminants leaving the unsaturated zone and any contaminant that leaves the unsaturated zone is assumed to instantaneously reach the groundwater well, which is for the most part assumed to be immediately down gradient from the contamination source. There really isn't much in the way of contaminant transport modeling.

RESRAD does also calculate the amount of time it takes for the maximum concentration to get into the well. So there is a need to specify some hydrologic parameters within the code, including the dispersion coefficient because it does account for absorption in the contaminated zone, the unsaturated zone, and the saturated zone.

I want to talk a little bit about how we can integrate monitoring information with RESRAD. First of all, as I indicated, there is a limited number of hydrologic parameters that you do have to specify for the code, things such as hydraulic conductivity for the three different zones, porosity, bulk density, things like that. So if you have site-specific characterization data, you can certainly use that information to help define those parameters.

Another way that you can use monitoring information within the RESRAD code is -- and people have attempted to do this -- the code will try to calculate an effective Kd value if you have a site with existing groundwater contamination and you know when that contamination source originated.

If you put that information in the code, it will try to back-calculate an effective Kd value. And people have tried to do that with limited success, primarily because most people don't have a good handle on when the contamination source originated. So there is usually some uncertainty with that.

Another limitation is that RESRAD only calculates a single Kd value for the three different zones. So it's basically assuming that the Kd value for the contaminated zone, the unsaturated zone, and the saturated zone, that they're all equivalent. And in most cases, we're looking at different types of media. So that assumption is probably not valid.

And then the third limitation is that if you have got radioactive decay products, then you have to do some special consideration in order to try and handle those. So we found very limited success in being able to use existing groundwater data to help calibrate Kd values.

Existing groundwater data can be helpful in terms of giving us some broad indication of whether or not it's likely for contaminants to migrate down to the water table. For example, if you've got a site where you have got a source that's been exposed to the open environment for several years and you've got some existing groundwater data that shows that none of the contaminants have reached the groundwater, that gives you some broad indication as to likelihood of stuff migrating down in the future. So you can make some broad statements with the information.

As I indicated, for sites that do have existing groundwater contamination, there may be a need to do more complex modeling, some more sophisticated groundwater modeling, in terms of trying to figure out what is the appropriate remediation method, how much remediation is needed.

And if there is existing groundwater data, we can certainly use that information to try and help calibrate the model. If we know when the source originated, as I indicated, we can try to come up with some estimates on the velocity of the contaminant plume. And we have attempted to do that.

But, as I indicated, for the most part, there is usually a tremendous amount of uncertainty in terms of when the source originated. So you can't get a good fix on what the velocity is because of that.

Another problem that we tend to face with sites with existing contamination data is that a lot of the monitoring programs were set up for other purposes; like, for example, if you look at some of the nuclear power plants, they have the regional environmental monitoring program, which is a series of wells around the site boundary.

Most of those wells are a significant

difference away from the source areas. So you can't really rely on that information to give you much insights in terms of the contaminant migration. They're just too far away from the source.

Those are some of the problems that we found. Another limitation is that for a lot of the decommissioning sites, the monitoring data that they have covers a very short period of time because the primary content for decommissioning is to put in a few wells and monitor it for a short period of time to demonstrate that you don't have any contamination.

So for the most part, we don't have a lot of sites. We have longest records of data, I think. As I indicated before, those sites that Jim pointed out were some sites where we have more extensive amounts of data, especially for the Kiski Valley site and maybe the Sequoyah fuel site.

So I just want to summarize by saying that most of the decommissioning -- and I'm not just referring to the decommissioning that's done here at headquarters. I'm talking about broadly throughout the agency. Most decommissioning is accomplished through the use of screening tables because we're dealing mostly with just building contamination. So there's really not much in the way of environmental contamination.

If they don't use the screening tables, the other means that they primarily use is the RESRAD code. There are limited opportunities for integrating monitoring and modeling information with RESRAD. As I indicated, we certainly can use monitoring information to help define some of the hydrologic parameters, gain some insights in terms of the likelihood of contaminants reaching the water table.

In terms of sites with existing groundwater data, right now there's a small number of sites that we know of that have existing groundwater contamination. However, there's usually some uncertainty as to when the source originated. And in a lot of cases, the monitoring programs were set up for other purposes. So the wells may not be in optimum locations.

So, with that, I don't know if you want to take questions now or --

MEMBER CLARKE: Not yet, Mike, but we'll bring you back.

MR. THAGGARD: Okay.

MEMBER CLARKE: We're scheduled for a break. So let's take it and resume at 10:15.

(Whereupon, the foregoing matter went off the record at 10:02 a.m. and went back on the record at 10:17 a.m.)

MEMBER CLARKE: Okay, folks. Let's get started again. Our first speaker is Matt Kozak from Monitor Scientific.

7) THE ROLE OF MONITORING IN MODEL SUPPORT AND PERFORMANCE ASSESSMENT EVALUATIONS

DR. KOZAK: Thanks for inviting me to be here. In the interest of generating discussions later, I will try to be as controversial as possible.

MEMBER CLARKE: Unlike you, Matt.

DR. KOZAK: I would like to really talk about monitoring from a performance assessment perspective. And here we're talking about perhaps sites that are a little bit more complicated than some of the screening-level assessments that Mark has just presented.

So what I would like to do is just start with some definitions and get into this in a minute but find that sometimes people are talking about different things when they're talking about monitoring. I would like to make sure that that remains clear in the interest of clarity of thought, talk about some issues in using monitoring information in the context of performance assessment and looking at the value of the information in terms of what we can extract, what kind of information we can extract out of that for performance assessment and try to come to some conclusions. But I think I'm afraid today I'm only going to come to inconclusive conclusions.

So some definitions that I would like to point out, at least in the way that I am going to be talking about it in my presentation, are from my perspective, monitoring our observations, looking at the dependent variables from a performance assessment perspective, not looking at the independent variables. In other words, we're looking at concentrations. So we're looking at the outcomes of the models, as opposed to the input parameters.

Input for observations that would lead you to characterize the input parameters I would just call data collection. And so the performance assessment since it's prospective analysis needs all of these parameters in order to run the calculation, we typically don't have information on the output parameters.

So, really, in the context of data collection, the issues are associated with setting priorities on which data we need, which ones we should expend money on, and so forth. The confusion comes up because a lot of times we use the word "monitoring" to mean other things. So, for instance, water level monitoring programs that is a groundwater monitoring program but it's not monitoring on the sense that I'm talking about here that I would call a data collection activity.

So, looking at data collection just briefly first, it's worthwhile reminding ourselves that performance assessment is a very unusual activity in the sense that we're projecting doses over very long periods of time and we need the models to make decisions. We usually cannot observe the outcome of the model because the consequences will be happening so far in the future. And so what we have to do is come to decisions in the absence of those observations. And that imposes a lot of different kinds of ways of building confidence other than actually observing the outcomes of the models.

There is good NRC guidance on the integration of the modeling part of performance assessment and the data collection activities. There are some gaps in it in terms of how you establish priorities and things like that. But the NUREG-1573 and some of the NUREGs associated with the decommissioning activities describe this kind of process in detail, how to go through an iterative procedure to identify data collection.

Monitoring, on the other hand, again, in the interest of clarity of thought, we need to distinguish a couple of different situations. One is a proposed facility, where obviously we don't have anything we can monitor.

The other one would be an existing facility that may or may not have contaminant plume. So obviously the usefulness of monitoring is going to be very different from these kinds of things. And my argument would be that for a proposed modern facility, a monitoring system that you could propose in a license application for a new facility you would never expect to actually see it hit in our lifetimes given the kind of designs that we're looking at for any kind of waste disposal facilities.

So, really, what you have to do in that situation, monitoring it is nothing more or less than an approach to developing public confidence. And technically it's largely irrelevant. So it's more doing something because it feels good to do it, as opposed to that you technically would actually get some information out of this.

The one exception to that is that you may have some kind of ancillary data collection. So, for instance, you may put monitoring wells and you may learn something about your saturated zone by doing so. But that would be a data collection activity, as opposed to a monitoring activity, which is the reason for my distinction earlier.

So setting aside now, in addition, the proposed facilities that monitoring doesn't really apply to in a sense, what can we do with monitoring data from existing facilities from a performance assessment standpoint?

The first possibility is that we could have a negative monitoring result, we don't see anything. And this is an example of a disposal facility that I've worked on in Bulgaria, the Novi Han disposal facility.

If you went there today, it would look something like this lower picture, and it would look like a pretty clean, well-designed, well-maintained facility. Unfortunately, I had also been there ten years previously, and I saw what the facility really looked like before they remediated it.

The surface inspection suggests that there is some degradation of the engineered system. There probably is some leakage out of the facility. That's just a qualitative guess.

So in this circumstance, their monitoring system has not identified any leakage from the facility. There is no plume that has been observed. Gut reaction may tell you something different.

So one of the issues that this raises is that if you have a negative facility, it may or may not provide confidence that your facility is working well. And you don't necessarily know which the answer is because the monitoring programs tend to be fairly sparse.

There is a reasonable likelihood that a monitoring program may miss something, particularly in complex geological setting, which this is. This is a fractured rock kind of setting, which may be why they haven't found anything.

So here is a situation where we have a negative. We don't know whether it's a false negative or a correct negative. It doesn't really lend anything in my mind other than perhaps false confidence in the ability of the repository to retain the waste.

Okay. Looking at the other side of things, we could have a positive hit. This is an example out of the Idaho National Laboratory. This is their waste management facility out there, their radioactive waste management complex.

Here some years ago there was a positive hit for plutonium in the deep inner beds. Without going into the geology in great detail, they have sort of a fractured system. And then they have -- think of it as clay layers in which things could stick. And they observed some plutonium in a monitor when they were starting to put down some monitoring wells.

Those observations skewed this program enormously. There was a lot of information going into monitoring to try to confirm it. Their performance assessment was modified to try to calibrate the performance assessment to these observations.

A lot of work went into it. A lot of time and effort were spent. And ultimately the bottom line is now there is a lot of evidence from multiple lines of evidence that these were just a false positive.

The only question at this point is why that false positive occurred, not whether or not they are false. Even at this point it's very difficult to discard those observations. Even though there is an enormous amount of evidence that they are not considered to be credible anymore, if you try to discard them from the suite of observations, you're going to get into trouble politically and socially and so forth. So, again, it's the soft side of the performance assessment that comes in to make it difficult. So that's one of the issues if you actually get a hit, to make sure that it is real.

Then there are the true positives when you get a monitoring result and there actually is something there. This is a disposal site in the former Soviet Republic of Moldova at Chisenau. They observed some radium-226 migration outside of the vault. It was only about a meter outside of the vault in a disturbed zone.

Initial performance assessment showed that essentially it didn't matter, by the time it got to groundwater, that it would have decayed away because it was fairly low groundwater transport.

There were other issues that were more important. As you can see here, there trees growing out of the top of the vault and things like that.

Largely, when it came down to the decision-makers, those issues were largely ignored. And the decision process that went forward was focused very heavily on the fact that there was a little bit of radium that had gotten outside, a short distance outside, the vault.

So one of the problems with a true positive is that you get an observation. It may be radiologically inconsequential. And, yet, a lot of attention is focused on it. So, there again, the interpretation and the gut reaction that people have is that once there is some leakage outside of the repository, that there is a big problem and something needs to be done. And so, there again, it's not necessarily made on technical grounds. It's made on intuitive grounds, if you will.

So what does a monitoring observation mean from a performance assessor's standpoint? Let's say we have some type of initial baseline assessment. And so this is presumably a mean or a median curve or perhaps a conservative curve that represents our compliance assessment. And, really, what we care about in terms of concentration, which translates to dose, is the peak up there. Okay?

So we have gone through our license process. We have got our baseline assessment. This complies. The peak of this complies. And everybody is happy. And then we get a monitoring hit.

Now, there are a couple of things to notice about this. It's at a very early time. It's at a very low level, has very little to do with the peak. And, yet, as we have seen in these other facilities and in our own experiences, once you get the monitoring hit, a great deal of effort goes in to trying to understand that, perhaps rightly so.

From a performance assessor's standpoint, though, if I have to calibrate my performance assessment now to that monitoring hit, I'm going to do one of a few things.

If you look at the mathematics of a typical performance assessment model, there are a couple of things that I can do. First, I can cut down on the lag time; in other words, the delay time, that the performance assessment takes into account, whether from engineered barriers or groundwater velocity or what have you, and I can match that.

In terms of the confidence that I have in complying with the regulation, which comes back to the peak, given that most performance assessments are dominated by the long-lived activity, it's not going to make any difference in my confidence. It's going to do absolutely nothing for me in terms of information. So I may calibrate my assessment and not change ultimately the peak very much at all.

Alternatively, it could mean that I have more dispersion in my model. So if I put more dispersion in, I'm going to bring the peak down.

So now by calibrating it, perhaps I've gotten less conservative in my assessment. There are very few things that I can do to my performance assessment that are going to give me an earlier hit and a higher dose unless the hit is from very short-lived activity. The peak is almost invariably from a long-lived activity.

So what does it mean for a performance assessor if you get an early monitoring hit? Early arrival times from a performance assessment standpoint, I've tried to word it carefully here, but I'll be more blunt. They usually don't mean much in terms of the peak dose. But they are perceived to be a big problem. So the difference between the technical elements of the performance assessment and the perception of what that hit means is really the issue.

Early monitoring hit may be indicative of a greater dispersion or a fast path that's not critical to risk. I would suggest that it's probably unusual for a fast path like that to be a fast path or an early hit to really be indicative of a big problem related to the peak dose.

Calibration of the performance assessment to the observation may actually make it less conservative. If you're a regulator, that's probably not the direction that you want to push the assessment. From an operator's standpoint, it may allow them to relax some operational terms and limits. So it's not that there is no value to it. It's that we have to be careful what value we draw from that information.

So let me summarize that data collection, not monitoring, data collection, is an integral part of the performance assessment. There's guidance out there on how to do it. There's a lot of value in identifying the value of which data need to be collected, which are the most important in the performance assessment.

From a purely technical view, monitoring is largely irrelevant for new facilities. We will never expect to see a hit during our lifetimes, during our children's lifetimes, our children to the ^{n}th power lifetimes. However, we can use those monitoring networks to collect other kinds of data that are useful for data collection.

And so in that sense, we can satisfy the public relations objective of establishing a monitoring network and collecting data that we can actually use technically as well.

Monitoring is, I would say, of limited utility. We have to be very careful how we interpret the monitoring results that we get for operational facilities or for past practice facilities.

If we have a negative result, it doesn't necessarily provide confidence unless we're very careful in establishing a good monitoring program and spending a lot of time and money and effort establishing that monitoring program. The negatives don't necessarily provide confidence that there is not, indeed, a plume.

There are significant issues with false positive because of the public perception of the false positive. And true positives are of limited use in calibrating a performance assessment model because you're comparing something very early and low down on the initial part of the curve and what you really care about is the peak dose, which curves much later in time.

So we shouldn't despise any information. Any information that we can collect on waste management systems is good. So we need to have these kind of monitoring programs. However, we have to use them very cautiously because of the potential for misuse, either through the political process or social pressures that they can be very easily misinterpreted. And the tendency is that all of these cautions, that they don't really provide a great deal of information for performance assessment, will get overwhelmed by these social and political pressures.

So, again, my sort of inconclusive conclusions are that we want to have knowledge about the facility, but we have to be careful not to put too much emphasis on monitoring, as opposed to data collection. Monitoring programs should be designed for both monitoring and for data collection and that we have to be very careful how we interpret the information, not to give us too much confidence or lack of confidence, regardless of whether it's a positive or a negative hit.

And that's the end of my presentation. I'll turn it over to David Esh.

MEMBER CLARKE: Thank you, Matt.

Our next speaker is David Esh from the NRC, integrating monitoring with performance assessment.

DR. ESH: Thank you for having me. I'm David Esh of the Division of Waste Management and Environmental Protection. I'm going to apologize up front. I have a bit of a cold. So I'm going to be even less understandable and probably more unintelligible than usual, but you'll suffer through it.

(Laughter.)

DR. ESH: This was an interesting topic. I have to say up front that Matt and I didn't coordinate ahead of time, but you will see that the themes in both of our presentations are very similar. His is probably the commercial version, and now you have got the government version in terms of quality.

(Laughter.)

DR. ESH: There are three main areas I am going to talk about today: performance assessment, just at a high level to reiterate some things about what we are doing with performance assessment; then model support; and, finally, monitoring, and how they all fit together.

Performance assessments all of you probably understand are used to demonstrate compliance with the dose criteria. We do have two different types of problems. We have one in which we're looking at a proposed facility, and we have a situation where we are looking at existing contamination at an existing facility.

In terms of integrating monitoring information or data collection, it's substantially different for those two cases. The performance assessments, if you're looking at either an existing facility or a proposed facility, in many cases they adopt conservatism to manage uncertainty.

Knowledge is expensive. And there is a lot of uncertainty that goes into these calculations. One of the options to deal with that uncertainty is an attempt to be conservative or pessimistic on how you're treating parameters or inputs.

In theory, the actual risk and the performance assessment compliance risk estimate would be identical, but in practice, they aren't probably similar much at all because there are a number of conservatisms employed in the calculations or at least from a regulator's perspective, that's what we would hope.

I think through our regulatory process, our review process, we bias things in the conservative direction. There may be rarer circumstances where you have missed something, your conceptual model is incomplete, and your monitoring data was incomplete, and the data that you based your calculation on was incomplete, and you have made a mistake of some sort.

But I imagine if we could go forward in time and we could compare what we have predicted in the performance assessment calculations with what we actually observe, in most cases, predominant number of cases, the projection in the performance assessment would be higher than what we actually observe.

And that causes a problem when we're talking about monitoring data because we're doing this performance assessment calculation. We say, well, we want to use monitoring to corroborate our performance assessment. But if you get that number from your monitoring system, it's probably not going to compare well.

So then where does that lead you? It leads you into the situations that Matt talked about, where you're trying to adjust something to make some numbers fit that aren't going to fit by the process that you are using to generate them.

So the model support for the performance assessment is very, very essential to the whole process because these models are only as good, the results from the models are only as good, as the support that you have for the models.

These models, as we have talked about earlier this morning, can't be validated in the traditional sense because of the spatial and temporal scales involved, but that doesn't mean that you get to say, well, we can't do anything for model validation or confidence building. There's a lot of things that you can do for confidence building. And we advocate multiple lines of support or multiple lines of evidence to try to support these models.

And from our standpoint, model support is essential to our regulatory decision-making. We would much rather see a simple model with a higher degree of support than a very complicated, sophisticated model with little or no information to support the output from it. It's a lot easier for us to make a regulatory decision on the former case, instead of the latter case.

Traditional monitoring is used to observe the concentration of contaminants in the environmental media. These monitoring systems are rarely developed to corroborate the performance assessment conceptual models. The monitoring is used to demonstrate compliance with environmental concentrations; or, i.e., dose criteria. So you're looking at one of the radionuclide concentrations in soil, water, and air.

But the performance assessment calculations involve a lot more than what you are getting down on the endpoint. And for the more complicated problems, the ones that I work on that have a lot of engineering, there are a lot of things that go on upstream prior to producing that number on the bottom end that you can get a lot of information about and you can develop a lot of understanding.

Monitoring of engineered systems for waste problems has been very limited and sporadic, but when it has been done, in my opinion, it's yielded extremely valuable observations. And you're going to hear from a couple of individuals later in this workshop: Jody Waugh from Stoler Corporation for DOE and Craig Benson from University of Wisconsin as part of the Environmental Protection Agency's ACAP Program.

I have to commend both of those agencies, DOE and EPA, because they invested in those individuals or their groups learning more about some systems that they really didn't have to learn more about. Whenever somebody is trying to make a decision on a waste problem, if they get everybody to make a decision, why do they want to learn any more about it?

I mean, you're facing that problem in this work that we do. Unless there is a requirement for them to learn more about it, they aren't going to want to learn more about it because they made their decision. They get to move on. You don't want to know that you have made a bad decision, essentially.

(Laughter.)

DR. ESH: But in those situations in those groups, they did invest in them learning more about the problems. And they have both done extensive monitoring of engineered CAP systems and learning about how they function, learning about problems with them, et cetera. And at least some really good rules of thumb or guidelines I think could be drawn out of that information for different types of engineered systems.

For these waste problems, usually that degree of analysis or data collection doesn't occur for whatever reason, a variety of reasons. In my opinion, maybe it should.

This is a problem that we deal with. And I'm speaking primarily about this situation of a proposed facility right now. And this is a horsetail plot of performance assessment, arbitrary dose units. You get something that might look like this, an earlier peak here, where your peak risk may be, and then a longer-term peak.

And now I've shortened the time scale and made it a log scale on the *y*-axis. The point I want to make here is that this is a probablistic analysis of a proposed facility. And even for the probablistic analysis with uncertainty in a lot of the independent variables, you're still looking at over 300 years before you would expect to see anything in your monitoring system.

So if you're doing traditional environmental monitoring of the system, Dick Codell's great^{13} grandson would be sitting here at NRC looking at monitoring reports that have zeros in them.

And I imagine that after 50 or 70 years, people start saying, "Why are we collecting this information? What are we learning from this?" The only thing you would learn is if you see something early. And then it leads into the problems that Matt talked about.

I think the benefit could be you certainly want to monitor the system, but you want to develop your monitoring program in concert with how you expect it to work considering the uncertainties.

So that might mean that you put aside funds to monitor the system but you only expend a limited amount of resources early in the problem with the expectation that you're going to devote more later.

In this case if you're monitoring the system early, you may get a result. Probably the typical result is you would get a low result. You might get an early result somewhere in here, a small result, which causes all the things that Matt talked about: a public uproar and those sorts of things.

It would be very unlikely but possible that you could get an early result that's high up here because of the specific activity, some of the short-lived radionuclides. You had fast pathways that were transmitting a substantial fraction of your source. You could get a result like that.

If this model is in any way reasonable and it has gone through a rigorous review process, et cetera, I would judge it to be very unlikely that you are going to get this result. I acknowledge the complexity of the problems and systems we deal with. And it wouldn't surprise me at all to see something here, particularly for something like fast pathways, which we don't handle very well in performance assessments.

The problem with the fast pathways is you always have to ask yourself okay. I know that there are probably fast pathways. If you're talking about the near surface, you've got things like bioda, earthworms, rodents, other things, man, that punches holes in the surface and causes pathways. You know all of those things exist there and they can influence how things may be transported.

Then you get deeper and you get into the deep geologic-type fast pathways or even man-induced fast pathways down below. But those fast pathways may impact a fraction of your source term or a fraction of your contamination. And it's very important not to overreact to that information because you have to understand that just because you have observed something, it doesn't mean it's a catastrophe. But what it tells you is, well, I need to collect a little bit more and find out what exactly I am dealing with here. So I think it is very important for it to be an iterative approach.

In this monitoring process, I very much believe something our research group has talked about in the past. Performance indicators -- and this is falling along the line of data collection that was just talked about. Performance indicators should be used. And compliance monitoring should be supplemented with the monitoring of these performance indicators.

The indicators of the natural and

engineered system performance should be identified considering the performance assessment estimate. So, as I said, information or knowledge is expensive. So you want to make the best use of your resources that you have available to do that.

To me, one of the best ways to do that is to look at your performance assessment results and see, okay. What do I want to confirm? What am I most uncertain about? What is likely to lead, if anything is likely to lead, to an unacceptable result? Those are the things you want to monitor of your system.

These performance indicators are observables that are precursors to the eventual dose impact. So you may be looking at thousands of years of delay time for some contaminant to reach your boundary well or you may be able to observe the saturation state below your engineered tab or look at flux rates below your engineered facility, look at things earlier in the system that may be precursors to an eventual problem. And that's what these performance indicators are. They would confirm the conceptual representation of your system.

And in most cases, it's expected that these observed environmental concentrations will not compare well with the performance assessment estimates, as I have talked about earlier.

So here is an example. I just made a little picture of a simplified problem. We have a source and a waste cell. And it can release to the atmosphere, the unsaturated zone, saturated zone. You have a receptor and potential river.

And then I put some numbers on here. And then what I wanted to indicate is maybe some types of performance indicators you could use at these various points in the system.

So for all the points, 1 through 4, I think you could make use of conservative dyes and tracers that may go a long way to confirming how your environmental system is working.

If you are dealing with a very arid system now, even this isn't really going to work because the transport times of some conservative things may be very slow in an arid system. But in a humid system or semi-humid system, this type of approach might work well.

And then if you actually have a problem where you are putting in an engineered system or a type of engineered source term, you might think about introducing these materials into that part of the problem and not use the same tracers and dyes through it but use different ones in different parts so that then when you put in a well near your facility and you start monitoring, you can tell what is coming from where because the problem, one of the problems, with using environmental observations of radionuclide concentrations is you don't know what part of the facility that may have come from.

Some of these sites are complicated. There may be multiple sources. There may be multiple pathways. All you get is a positive hit, which doesn't allow you -- there are lots of interpretations that probably can cause you that positive result.

So if you are smart about how you design the facility, you might be able to design for these various alternatives that you could get that you could observe some output from your system.

An example that I used here is that something like moisture content may be a gross indicator of the saturation state of the system. But even that might not give you information about moisture flow rates. It just tells you the overall bulk saturation rate. If your flow system is dominated by discrete features, you're not going to learn an awful lot about the saturation.

And then for barriers, I would think that these indicators would be very specific to the barrier type and functionality that you have. An example I thought of is that maybe for these cementitious-type barriers, you can evaluate the alkalinity in the water near the barrier and the pores of the environmental media, also the N2C2 stress of the barrier. That might give you some information about the bulk properties of the barrier and its functioning.

Ideally, though, you would want to invest in some small representative samples that you could put in the same service environment and periodically remove them and see if they confirm your conceptual model that you had for that barrier.

Once again, this all depends on your specific problem, how important those things are to your results. So you would want to put your most emphasis on those aspects of the system that are going to be most determining the performance.

As we talked about, monitoring is very valuable, but it's also fraught with some problems. I emphasize Matt's point that caution is needed to ensure that in interpreting the results of the monitoring, which in many cases can be very complex and also uncertain, as a performance assessment guy or most engineers, you want to take a data point. And you assume that it's good.

If somebody put an error bar on it, well, then that gives you some uncertainty. Well, even an error bar might not mean that that sample is representative. The information could be incorrect.

So it can also be very complex. And the example I like to think of is water table fluctuations, which can vary daily or diurnally, seasonally on longer time scales. So if you only correct a few numbers of water level of an aquifer water level, you don't know which part of the uncertainty you are looking at. And you could interpret it very differently. So you have to have an adequate amount of information that you don't misinterpret the information that you get.

One other caution that I have here -- and it is a difficult one -- is that I think you have to ensure that your monitoring system doesn't introduce any pathways for water contaminants. We see that a lot of times at different sites, and it is a challenge. You want to learn about your system, but you don't want to cause a problem at the same time.

Confirmation in this process using monitoring information, it should be really biased towards verifying the conceptual representation of your system and not trying to get two numbers that are going to match because if you're trying to do that, you're probably going down the wrong path to begin with.

In conclusion, these monitoring plans usually have the objective of supplying confirmation of performance assessment conceptual models, in addition to satisfying the regulatory requirements of characterizing the environmental concentrations. They certainly need to recognize the spatial and temporal challenges.

Monitoring should be designed into the system. You need to do that up front in concert with your performance assessment. So what do I need to learn more about? And how am I going to do that?

Confirmation of the performance assessment conceptual models is different from matching the performance assessment output with environmental contamination measurements.

That's all I have.

MEMBER CLARKE: David, thank you.

At this point we're at the panel discussion. So everyone stay where you are. And let me turn it over to Professor Hornberger.

DR. HORNBERGER: Thanks, Jim.

8) SESSION I PANEL DISCUSSION

DR. HORNBERGER: I am George Hornberger. I am with the Nuclear Waste Technical Review Board. I am here on their nickel, but I will warn you that anything I say represents my own opinion and not the opinion of the board.

We have a little over a half an hour for the panel discussion because one of the most valuable things in these meetings is to give the Committee a chance to ask questions. And we are going to end promptly at 11:30 to make at least half an hour available to the Committee to ask questions.

Let me pose sort of a question that has arisen. We have heard a lot this morning ranging from how Yankee is using a lot of data and incorporating into models and some of the problems associated with the longer-term issues, as Dave just mentioned. Matt's example was a deterministic one. Dave showed a horse tail. There are some differences.

The question I would like to pose is, as I listen to this, you people are all right there on the firing line. And I am an academic. Okay? And I always think in terms of what the industry calls the valley of death, which is you develop some research and it just never gets over to application.

And so as an academic, I look at some of these problems, and I say, hey, there are things that people are doing. We're doing data assimilation, where we're taking data. Even if it's not monitoring information, we're taking data. And we are incorporating it into models in a very structured way, accounting for uncertainty.

The risk-oriented people would say, well, why don't we take a Bayessian approach? We don't have to say, "Oh, we'll recalibrate the model. And now this is truth." We can do Bayessian updating.

And the question I would like to pose for the panel I think in the discussion would be, what is your observation on impediments to translating some research ideas like this, not necessarily those specific ones, into practice that would be useful to regulators or the industry? And shall we just go around this way?

MR. DAROIS: Hi. My name is Eric Darois. I've got two hats on today and tomorrow. One is from EPRI, and the other one is from Radiation Safety and Control Services.

I have been involved with Connecticut Yankee, Yankee Rowe, groundwater issues. And EPRI work has taken me to several other plants to do some assessments and participating in some of their work.

So, with that said, to specifically address George's question, I look through what we have been through for putting together the license termination plans, the dose modeling behind it for Connecticut Yankee and Yankee Rowe. And I think we have got to look at the process that we're following, the road map that we're following.

The sites as they are operating today, the nuclear power plants at least, have little or no incentive to develop any site conceptual models, transport models, or the like. I think that may be changing in the next number of years, but in terms of where we are today, that is virtually nonexistent.

When they choose to decommission the sites, they go through all the regulatory processes and notifications. And usually the first thing out of the chute for developing in support of the LTP is let's pull out RESRAD and let's start identifying the input parameters we need. Let's run the code. Let's calculate our DCGLs, whether they be groundwater, soils, building surfaces. So we know what our targets are to take the rest of the plant down. That's exactly what happened at the decommissioning sites I have been involved with.

When Dave gave his presentation earlier about Yankee Rowe's modeling efforts, that is the tail. That is the end of the process. And that is being done to satisfy ourselves, the states, NRC that we have got the right number, that we have identified the worst of it, if you will. It's really not to drive the limits we're living with.

So I think the process could be a little bit backwards. And right now there's no incentive for anyone to look at fate and transport early. So hopefully that will give you insight into what we have lived anyways.

Thank you.

MR. SCOTT: Yes. I would just add --

DR. HORNBERGER: Speak your name before you start just for the record.

MR. SCOTT: Dave Scott from Radiation Safety and Control and EPRI.

You know, I would agree that the emphasis has not been on characterizing a site early and using that characterization data to develop a model to allow compliance assessment throughout the life of the plant.

It isn't until decommissioning that these issues seem to come to the floor. And I would argue, as Eric, that we have got to start the process earlier.

DR. ESH: It's an interesting question.

DR. HORNBERGER: Name?

DR. ESH: David Esh, NRC.

I like to think of the valley of death, I think, as you put it. It can be somewhat insurmountable at times. And maybe the agencies involved, like ours, play a role in helping bridge that, I think.

If there's no requirement to do something like we have been discussing, then it won't get done, especially if it costs money. And if it costs a lot of money, you've got to show a benefit to it. Otherwise, it won't happen.

So I think the bottom line is you would have to, number one, allow for people to do that; and, number two, show that it can give some benefit, both in terms of a higher level of protection of the people you are trying to protect and in some sort of economic benefit to the people that could use that process that are trying to solve the problem.

That's how you would make the information more, bridge the gap from the things that are available to what is actually done in practice.

DR. KOZAK: Matt Kozak, Monitor Scientific.

There's not a great deal more that I can add, I don't think. It's really a matter of incentive. I think the decommissioning world may be a particularly egregious example of when people want to just get out the RESRAD and run it and just tell me what the answer is and be done with it.

Waste management tends to be a little bit better than that but not much. And particularly in a lot of countries that I have worked in, budgets are not large. And so you are trying to do things as quickly as possible. And there's not a great deal of interest in trying to push forward some of these ideas.

MR. SHEPHERD: Jim Shepherd, NRC.

As you probably noticed in Mark's presentation and mine, there is something of a disconnect between the state of the art of groundwater monitoring and the state of the art of dose modeling. That gap I think has a need to be bridged. I think perhaps the academic side can assist us in doing that.

MR. THAGGARD: I'm Mark Thaggard, NRC. I've just got two points.

I kind of agree with everything that has been said. I just want to point out that there are some practical limitations from a regulatory standpoint in terms of the time and the amount of effort that we have in terms to reviewing either decommissioning projects or in terms of working on waste disposal facilities.

I mean, we don't have an indefinite amount of time to work on these things. There are time constraints. And so trying to integrate something that's new into the process becomes a little bit difficult from that standpoint. So that's just one observation I wanted to make.

The other point I wanted to make is that in terms of the Bayessian updating technique, which was the example that you gave, I think right now we are having difficulty getting people to use probablistic analysis. And so we've got to get people to that stage first before we can move forward into going into things like Bayessian updating techniques.

DR. ICHIMURA: I'm Vernon Ichimura. And I represent a company that operates a disposal site to address regarding updates of models and updates of processes and updates of techniques that we use.

From almost day one in the pre-licensing process of this particular facility, the Barnwell facility, there was a conceptual model. A conceptual model was used to initially describe what might happen to the facility with time. And the conceptual model has been updated, and I will talk a little more about that this afternoon by showing you some of the changes and some of the assumptions in the conceptual model.

A lot of these changes that were made in the updates of this model and the ensuing numerical model that follows with the conceptual model are based on observations. And I hope this information will kind of enlighten you about the process by which -- it may not have been a very formal process, but it was a process which led to the current model of the facility we have today.

DR. HORNBERGER: By the way, don't let my sort of questions to try to get things going deter you from saying some really bold insight that you want to share with us. I don't mean to focus things too much.

It strikes me that a lot of the discussion this morning also goes to the fact that there are the two kinds of cases: one where environmental contamination exists and you actually are measuring things. And the other is where you have a facility, whether you're decommissioning it or if you're building a new waste facility. You may expect to see all zeroes, at least as Dave said, for 300 years.

What Dave described has in another context been referred to as performance confirmation. And I think you used the word "confirming."

I'm just curious as to how this is viewed, both by regulators and the industry, as to how much time has gone into thinking about confirmatory monitoring and how this should both feed back into the modeling sphere and also how much we can afford because obviously it does come down to both time and expense, real dollar expense.

Does anyone have comments to share on those issues? Go ahead, Eric.

MR. DAROIS: Yes, just speaking from the nuclear power point of view, I don't think the models that are in place are used to do much predictive work per se. I mean, certainly we run them in the future.

There is often a very limited monitoring program that's negotiated with the stakeholders, sometimes as little as 18 months, sometimes as much as 5 years for a nuclear power plant. The objective there is to ensure that you don't exceed some pre-negotiated concentration value, rather than does the model predict what we're seeing holistically in a three-dimensional sense.

So I don't think there's much insight that's being applied.

DR. HORNBERGER: I presume that some of the confirmation wouldn't necessarily go to flow and transport modeling but, rather, to whether your value is remaining intact.

DR. KOZAK: Matt Kozak.

It is worth noting, I think, that Centre de L'aube in France and El Cabril in Spain both have monitoring systems that purport to capture all of the leachate that might be coming through their vault.

There again, I'm not entirely convinced that they might be getting false negatives. They've never seen any water come through their system. So I don't know if that means the system doesn't work or if they have no water in their system.

That is one comment that I want to make. The second one is that internationally the IAEA is spending a lot of time these days talking about what used to be called in the old 10 CFR 60 days subsystem requirements and if you are going to take credit for a particular function for a feature in a performance assessment, that you should be able to demonstrate that you can comply with that; so if you take credit for a particular leakage rate through a cover, for instance, that you should have some plan in place to demonstrate that you can meet that requirement.

Functionally I'm not sure how well they can do that, but they are pushing that idea pretty actively these days.

DR. HORNBERGER: Other comments?

(No response.)

DR. HORNBERGER: How about the other case? Do we have comments on the other case, where you actually have existing contamination? I mean, Mark's presentation is at all very limited concern. And, yet, he acknowledged that I think it was West Valley that stimulated at least this, in part. And I would argue that West Valley is not an unimportant consideration for the NRC.

(Laughter.)

DR. HORNBERGER: Dave says, Dave Esh says, it's a "No. Never mind." That's part of the record now.

(Laughter.)

DR. HORNBERGER: Would you like to comment on that, Dave, to get the record straight?

DR. ESH: I'll let the record stand.

MR. THAGGARD: I would like to correct the record. Mark Thaggard.

(Laughter.)

MR. THAGGARD: I didn't mean to imply that the sites with existing contamination were not important. What I was trying to point out is that there aren't a lot of those sites that we have existing contamination, at least in the sphere of decommissioning.

But clearly if you've got existing contamination, that's an area of concern. So I didn't want to give that message.

DR. HORNBERGER: No. I always overstate things, Mark, to make the point, but this is the other case. And, again, Yankee with the tritium plume is an example, right?

And, you know, perhaps to focus the question, -- maybe I can challenge Dave here -- if I look at some of the data that Dave showed on maps of the tritium plume, it strikes me that that plume is too fat. That is, there's way too much, in simple groundwater transport model terms, way too much model transverse dispersion. It can't be supported.

And I would argue that perhaps this should lead one to reconsider the whole basis for that groundwater transport modeling. And how would you use that information to get a better handle on what might be going on there? And you can disagree with me on my conclusion.

MR. SCOTT: Dave Scott, RSCS.

Dispersivity is one of those idyllic parameters that are input to numeric models. That is a very difficult parameter to quantify. And that has a direct bearing on the width of a plume that you depict. And so if we could develop better ways of estimating dispersivity, that would certainly help.

DR. HORNBERGER: Matt?

DR. KOZAK: Please correct me if I'm wrong. While I was watching your presentation, I was doing some quick calculations on the back of an envelope.

Dosimetrically those tritium concentrations are totally inconsequential. And so we're spending a great deal of money trying to understand the plume that radiologically doesn't matter. That's my issue from a performance assessor's standpoint.

MR. SCOTT: Yes. That's true.

MR. DAROIS: Let me just add to that just to give you a little history on that. When the LTP was first written -- and this begs a little bit to the process issues I spoke to earlier -- when the LTP was first drafted, what we had for groundwater information at Yankee Rowe was the initial study that was done in the '90s, which suggested merely a surfacial plume in the overburden.

That maximum concentration that was observed for tritium was at or about the EPA's MCL of 20,000 picocuries per liter. So we said, we, the collective "we," said, hey, let's just put this number in the LTP. And we'll commit to being less than this value. It's unlikely we'll find anything higher. So let's do that.

So as the investigation pursued, we had 48,000 picocuries per liter and still dosimetrically inconsequential but not politically inconsequential. And that really was then the driver for a lot of the work.

DR. ESH: This is Dave Esh with the NRC.

I think Mark and I both emphasized that when there is existing information, by all means, it should be used. We just have to use it cautiously.

At the West Valley site, there is existing information, which is very valuable. It's not valuable if you're a member of the public there. You don't like the fact that the site has been contaminated. But to try to assess long-term risk impacts, it's one of the most valuable pieces of information you can have.

I think it applies at sites like that. But, as Mark indicated, the run of the mill decommissioning site does not have information, doesn't have existing contamination. So there's not much you can do there.

MR. THAGGARD: Yes. The other point, too, is like, even the Sequoyah fuel site, which I did a lot of work on, you know, there is a lot of existing groundwater information at that site.

And when I was working on that site, we were trying to use the data to help calibrate the groundwater transport model that had been developed for the site. And we were having a really difficult time with it.

And so I am not trying to indicate that you can't use it, but there are just limitations because we were having problems trying to figure out when the source originated. And even looking at the data over different time periods, we were trying to come up with some estimates on velocity. And we were just having a real difficult time with it.

So the only thing I was trying to point out is that if there is data like that, to the extent we can, we try to use it. But I wouldn't by any means say that you should think that you're going to necessarily gain a whole lot from it, you know, because there's a lot of unknowns with it. And so you could spend a lot of time just trying to deal with the unknowns. So that was the point that I was trying to bring out.

DR. HORNBERGER: I think that the bottom line, then, here is that in most or at least very, very many of the cases, certainly in decommissioning, the risks are very low indeed. And if you have a very, very low-risk situation, a complicated modeling just isn't necessitated.

The question, then, of course, can come back to the very few sites. And I would argue West Valley would be one of those where a significant risk does exist for off-site contamination. And then this kind of linkage between relatively complex groundwater flow and transport modeling with data collection efforts would be warranted.

This is probably not the exact problem that is of most interest to the group of presenters this morning. Is that right?

DR. ESH: This is Dave Esh with the NRC.

At the really complicated sites, I think the value of the information, the reality of analysis for those sites, there is a lot of uncertainty in both the conceptual model, the structure of the model, the conceptual understanding, the data, other inputs.

And if you did a deterministic analysis where you were optimistic about a lot of your parameters and models, you may get a result that greatly flies under your limit that you are trying to achieve; whereas, if you go the other approach and you were very pessimistic for a number of those things, you're greatly over your limit.

The reality might be somewhere in between. It's those sites where collecting information on performance indicators or other designing some of this information into your system or trying to do some studies can be really valuable because it can help reduce that uncertainty and tell you whether you are in a situation where you have the high risk or whether you're in a situation where you have the lower risk.

MR. SHEPHERD: Jim Shepherd, NRC.

I think it depends, in part, on how you define risk. Certainly dose from the tritium that has been found at the reactor sites thus far is not dose-significant. In fact, it is usually several orders of magnitude below the appendix B, table 2 effluent limits that the NRC allows for normal discharge.

The risk I think we face is a collective loss of confidence in both the licensees and the NRC that up until probably February of this year, neither they nor we really acknowledged the fact that most reactors are leaking.

And it's not what they leaked or even how much they leaked. It is that they leaked and we didn't know about it. I think that's where the risk is. And that's an entirely different realm from the kind of modeling we're talking about here.

Having determined that there is a risk, we now have to come back and reestablish our credibility and be able to justify the conclusions that, in fact, there is no public health issue. And that's going to be a difficult hurdle to overcome at this point.

MR. DAROIS: This is Eric Darois.

I think it's important to recognize as well in the nuclear power industry. Albeit most of the issues have been tritium, it's not exclusive to tritium. So as soon as we enter strontium-90 into the picture, I don't have a clear understanding of when enough is enough in terms of modeling and site conceptual model. The source terms, you know, at their point of origination is significant. We do have a site that's a fractured bedrock site that can transport fairly high concentrations depending on how it's moving.

So how far do you study it before you say, "I'm done"? Dr. Ryan had a good analogy earlier this morning when we were discussing this. He said, you know, a geologist's work is done when he just wants one more hole in the ground, just one more.

So, I mean, you know, there's a point at which --

DR. HORNBERGER: In other words, it's never done.

MR. DAROIS: It's never done, right, just one more.

(Laughter.)

MEMBER HINZE: I take exception.

MR. DAROIS: So, I mean, there's a point of how do we define how big the problem is and how much do you study it and no good answers.

MR. SHEPHERD: Well, I think the politics dictate that we study it much more than if this initiative had begun two, three, five years ago and we had come out and said, you know, "Oh, by the way, here's what we're finding. We've already explained to you what the dose consequences are or are not."

And this is just a step in a continual process that had already been established. Consequently, we now have to do much more to go back and reestablish our collective credibility.

DR. HORNBERGER: Final comments from the panel before we --

(No response.)

DR. HORNBERGER: We will turn it over to questions.

MEMBER CLARKE: Thank you, George.

I think Professor Hinze wants to address the one more well issue. So let's start with him.

MEMBER HINZE: Well, if I might, might I respond to Professor Hornberger's question about the valley of death? It seems to me that we do have a lot of technology that is available to us. And if you want to, you can place that into the academic box. And we aren't seeing a great deal of that technology being used in the characterization or the monitoring of sites.

And it may come as a surprise to you, but I would include in that some geophysical methods. And we have criticisms of geophysical methods. They can be slow. They can be expensive, Mark. But they also have many advantages.

Included among those is the fact that you can get a much more representative sample than you can from these point observations. In addition, for example, you don't have to worry about the plugging of holes, which concerns me a great deal in terms of this whole monitoring. And Esh brought this up very clearly. We have to be concerned about that.

Yet, there has been a great deal of development in various research areas and academia of surface to surface, hole to surface, hole to hole to try to increase resolution, which is the major stumbling block I think of geophysical methods, in addition to time and money.

Those have really improved the resolution. And we have seen a great deal of this. Now, the problem is, how do we get that across the valley of death? It seems to me that there is a real need here for technology transfer and technology demonstration.

There are opportunities for this. And who is best to do this? Well, I don't know. National Science Foundation really doesn't support this, let me tell you, having attempted to obtain grants to do that sort of thing. You run into a dead end.

So I think it is left up to the more

technology-oriented, problem-oriented agencies of the government to consider this? Enough said about that, but I really think that you have hit on an extremely important point. And I think that there are solutions to it.

I saw in Dave's presentation where he was trying to push the envelope a little bit with using some of these age dating techniques. And that's another part of the geophysics. But we need to demonstrate those much more clearly. I, for one, would like to learn more about lessons learned regarding some of those technical things.

Then my dear friend, former friend, Dr. Clarke, --

(Laughter.)

MEMBER HINZE: -- said I could only have one question. Let me ask a --

MEMBER CLARKE: I didn't say anything about a lecture, Bill.

MEMBER HINZE: Well, George opened it up. So don't blame me. Let me ask a generic and a very naive question from these experts.

Incidentally, I think these presentations were just great. And it's a lot of chewy, chewy material, a lot of meat and potatoes there to grind on.

Let me ask a naive question. Many of our monitoring systems and data collection systems, if you will, are based upon models. We develop a conceptual model. And we set out, and we develop a monitoring scheme system and a data collection system which is based upon that model, whether that may be simply a conceptual model or it can be a numerical model.

And then what we do is we validate our model with the results from holes, drill holes and measurements, whose location, depth, and frequency of observation are based upon our models.

If you will, it seems to me that we are going in a cage here. We're going around and around. The question that I would ask is, how do you respond to concerns that this approach biases the results of the validation of the models, this approach, which is based upon using the models to design the experiment?

(No response.)

MEMBER HINZE: I guess that means no one understands the question. Is that? The question is, we develop a model. We design an experiment to test that model based upon that model. And then we remove ourselves from the situation. It's either validated or not validated.

MR. SHEPHERD: This is Jim Shepherd.

I think if we don't begin with a model, our alternative is to go out and just randomly poke holes in the ground. And I will go back and point to Sequoyah fuels, who pretty much did that. They put about 100 holes in 85 acres and connected two uncontaminated aquifers to a contaminated aquifer. And now we're sure we don't know what the extent of the problem is.

I think your last statement, if I can turn it around, once we get the results of the analysis if it does not validate the model that we begin with, we then go back and revise the model. And I think generally that is a more efficient approach than going out and randomly collecting data and then trying to develop the initial model from that random data. It could be done, but I think it's more efficient to go the other way.

MEMBER HINZE: Jim, what you're saying is that we have to do this in an iterative manner.

MR. SHEPHERD: Absolutely.

MEMBER HINZE: And I think that's a very important thing. It's one thing that we haven't heard here today, that we do need iteration on this. And we have to keep our minds open and our pocketbooks, our budget clear so that we have that opportunity.

MR. DAROIS: May I?

MEMBER CLARKE: Go ahead.

MR. DAROIS: To your first comment, I think this process is nothing more than a typical scientific investigation, where you start out with a hypothesis. And in this case, the hypothesis is a conceptual site model.

But one of the things we found in doing, to your second issue, really, these EPRI assessments is that normally the nuclear power plants underestimate the effort, don't recognize that it is iterative, and this is something we are certainly advertising quite a bit of in our involvement with the EPRI in nuclear plants.

So I think they are starting to recognize the iterative process. And at least they're hearing us say don't underestimate the resources it may take to get there. It's going to take a while to sink in, though.

MEMBER HINZE: If I could have just one more second, Jim? Then I'll get out of the way.

I have asked, why is that monitoring well placed there? And the question that I get back is that, well, that is for our model set that we should test to validate the model. Well, you know, if it doesn't validate the model, you know, we have to go through some iterative process here.

The characterization is in many cases insufficient to really -- it's really insufficient to really diagnose that model, to have something approaching the truth, even if we have to have one more data point.

(Laughter.)

MR. THAGGARD: Can I just make one point? Our current guidance actually does say that right now, that it should be iterative approach. And, Jim, I think Dr. Kozak alluded to NUREG-1573. In that document, we do indicate that it should be an iterative process.

MEMBER CLARKE: Thanks, Mark.

Allen?

VICE CHAIRMAN CROFF: Yes. I welcome an answer from anybody, but this question was stimulated by Vernon's. So it's probably best started with him.

Early in your presentation, you showed a partially filled trench. And I believe you said that you also did some modeling and, of course, you gathered data from that trench. Does modeling and getting data from a partially filled trench, whether there's maybe a cap over part of it, part of it is open -- what special challenges or issues arise from that situation and what success have you had?

DR. ICHIMURA: During the presentation, I showed a very large trench. It had numerous waste packages inside the trench. What I alluded to there would be one could imagine what the source term might be because each package is different, is unique.

It's one of the things that the modelers don't even take into account. Usually when you look at models, it's lumped into one single source term that's uniform. So the reality is source terms are not unique. It's spatially variable. Well, there are spatial variable and temporal variable considerations.

To answer your question regarding what information we collect from the trenches themselves, we have sumps that collect water from the disposal trenches. We know these sumps are only effective within a very, very small radius of its collection point because most of the water infiltrates and bypasses the sumps.

So, in other words, as we have developed and we understand the site, the sumps give us limited information. It gives us information about radionuclides that we might not see in a groundwater system. "Groundwater," by that, I mean transport beneath the water table. But it gives you some indicators like, for example, some of the radionuclides that you don't really see in groundwater, such as cobalt, cesium, and maybe some of the transuranics early on, like uranium. And this gives you an indicator of what might be in the source term in the trench outside the waste package.

VICE CHAIRMAN CROFF: How do you account for the heterogeneity of the source term?

DR. ICHIMURA: At the current time the way we approach the modeling is we look at the performance assessment from the standpoint of what we see in the groundwater system. And we use the concentration that is the higher value of what we see in the groundwater to project what we would see at the compliance location at some future point in time.

So, in other words, this is a compliance-type model. It's very different from what one would consider a reality-type model, which would give you what you might see in the groundwater system from point A to point B. We don't do that.

On the other hand, we would address the regulatory requirements. What do we see upstream in the transport zone? And what do we expect at the downstream location or compliance location? And that's how our models are set up.

MEMBER CLARKE: Mike?

CHAIRMAN RYAN: Thanks, Jim. Fascinating morning.

I am thinking back to yesterday, when Jim Shepherd was down and we finished a letter on the guidance, the draft rule that's in preparation for legacy sites. And, in part, I think what some of you have talked about, in part, or in whole are sites that have been out there for 30 or 40 years and something has developed over that time period.

My question turns into the other time direction. What are we going to do to mine all of these experiences to help folks design better facilities and to get ahead of the game, if you will, in monitoring and modeling? You know, I might even save a little extra money by doing that and give Professor Hinze one or two more wells down the line.

But I think there's an opportunity here. And I would ask. Jim, maybe you could lead us off or give us some insights as to how is all of this, this experience, which is pretty rich when you think about it -- and I've heard Commissioner Merrifield on several occasions talk about the knowledge management for decommissioning lessons learned and so forth. There's a lot of things we could learn to pass on.

For example, what would you do different at Yankee's design if you know this was going to happen? I'll bet you have got a list of things you could do. So how do we capture that to pass it on to the next generation of facilities that would be licensed for one purpose or another?

MR. SHEPHERD: This is Jim Shepherd.

I think, to begin, some of the lessons learned is being factored into the guidance I am writing to support the proposed rule, specifically the early characterization of the site; ideally, as in the case of the new reactors, before they are constructed so that they will have a better understanding of where things might go when they leak.

I firmly believe, no matter how good a designer and construction crew you have, if you build a facility with steel, concrete, and water, there will be releases at some point in time. How do you know where those will go when they occur?

There is considerable effort under several names. We are working with the NRR side trying to factor these lessons in to revisions for the standard review plan in order to identify construction design ideas, something as simple as making sure your sumps are large enough and in the right place to capture leaks that occur within the facility.

There are interesting trade-offs. Things like the spent fuel pool and some of the water storage tanks from a worker radiological safety point of view are well-placed below grade, from a monitoring and inspection point of view would be much better to be above grade.

There is some effort on identifying techniques that could be used to inspect areas that are not readily available for visual inspection. There are some construction things that can be done there.

We begin as part of the integrated decommissioning improvement program collecting lessons learned from our decommissioning sites. And that will be a report in and of itself, in addition to our support for NRR. And then a new initiative on knowledge management is also collecting lessons learned.

CHAIRMAN RYAN: The second question I guess really is one for Mark. You mentioned there are a number of decommissioning activities that go on at various licensed facilities that are relatively straightforward. They're at the surface. There's very little potential for, say, groundwater contamination or decontamination.

Is that really where the agreement states face most of their work? I mean, do the agreement states get too involved in complicated sites? I call for everybody's benefit that there are a lot more licensees in the agreement state arena than there are direct licensees of NRC. And I'm just curious what your insights are there.

MR. THAGGARD: Well, I don't think you can put it in one bucket versus the other. I think they probably have -- there are probably some complicated decommissioning sites in some of the agreement states. Some of them we handed off to them when they became agreement states.

I wouldn't say it's all here or all there. They're probably dealing with some of the same issues that we have to deal with for our complex sites.

CHAIRMAN RYAN: Well, that's a real challenge because, you know, as you know, their resources are probably much more limited than, say, the resources here at NRC and particularly at this table, the expertise that's here.

So how are they wrestling with these

decisions or do you have much feedback on that at this point?

MR. THAGGARD: I don't have a lot of feedback, but I think there are a lot of things that we can learn from us. I mean, one of the things that we picked up from the State of Ohio was this whole concept of the perpetual license. That was something that originated with the State of Ohio from a site that they inherited from us when they became an agreement state: the Sugarwood site.

So I think that there are probably things that we can learn from them, and there are certain things that they can learn from us. I think that some of that is occurring.

You know, we have interactions with agreement states through the CRCPD and the agreement state program. So I think that there is something that we can learn from them and they certainly can learn from us.

CHAIRMAN RYAN: Well, thanks.

The last question is I am taken by -- I think Matt Kozak said it clearly, that very often we're evaluating and dealing with concentrations of tritium or other radionuclides that dosimetrically are well below any bar in terms of performance assessment.

Is there any way any of you can see forward to stop dealing with them?

You know, the old question I used to like to ask is, when am I done? How do I get to when am I done or can I change, you know, the thought that I had 20 years ago that the 3,500 number was a good one but really doesn't need to be the number today?

MR. DAROIS: I have an opinion.

CHAIRMAN RYAN: Please.

MR. DAROIS: Just resolve the differences between NRC and EPA on what the MCL ought to be.

CHAIRMAN RYAN: Could you expand on that a little bit?

(Laughter.)

CHAIRMAN RYAN: How do we get there, Eric?

MR. DAROIS: Well, you didn't ask that.

I think that's the crux of the issue. You know, it's more of a political issue, and it's more the issue that the plants are leaking, if you will, -- that term was used earlier -- and that the material is getting off site. It's not an approved pathway for discharge and all of that.

In a related issue to that, I will just mention that I believe that there is a lack of understanding or data, cohesive data, on what background is, especially when you get to tritium, what rainfall does to the local site environs when you are releasing airborne tritium and how that affects the things you see.

So I think there are some issues that could help us all understand because when people are getting excited at two, three, four, five hundred picocuries per liter at the site boundary, there are a lot of things that could cause that. Some of this is anthropogenic. Some of it is not.

You know, there are lots of issues to play here. I just think it needs a little bit more understanding, that as well as where our minimum detectable concentrations ought to be.

I don't want to take the floor.

CHAIRMAN RYAN: Thanks.

MR. DAROIS: I would like to get back to your first question at some point, though.

CHAIRMAN RYAN: Okay.

MEMBER CLARKE: Thanks, Mike.

Ruth?

MEMBER WEINER: I wanted to add my congratulations to a really interesting session. I guess my first question is directed more to Dave and Matt.

There are models that we have that we know work; for example, radioactive decay. We can calculate radioactive decay if you know what the activity is at time X. Then you can carry that out to any infinite time that you want. The same thing is true for a number of chemical reactions. We know how they work. We know what the time dependence is.

If you could reduce the uncertainty in your data collection to a point -- and I might point out that initially, way back when I was in school, for example, we learned that the first model is made from observations. I mean, our model of radioactive decay was from observing radioactive decay.

So if you could reduce the uncertainty in your data collection to a point where it is really pretty minimal, would you do away with monitoring entirely and just simply -- because you would then have increased confidence.

Now, I don't want to get into the politics of that. That's another thing. People believe what they want to believe. Especially politically they believe what they want to believe. But as scientists, if you could reduce it to that point, could you then do away with monitoring?

DR. ESH: Do you want to answer that?

MEMBER WEINER: Is this the commercial view?

DR. KOZAK: No. For the record, I may work for a commercial company, but I don't necessarily represent commercial interests. I represent as many regulators as I do other government agencies and commercial entities.

As I said in my presentation, I think from a technical point of view, monitoring doesn't provide a great deal of information, even when you have a monitoring observation, even when you have a hit.

Would I completely get rid of it? Probably not, simply because of the ancillary information that it provides, that there is other soft information.

I agree with what -- by the way, we'll segue. I agree with what you said about models coming from observations. And earlier we were saying some things about monitoring and data collection, things like that.

People tend to get something in their mind when people say modeling. That's just our understanding is what the model is. It's not anything mathematical. It's not anything special. It's not a separate entity.

So I think that comes back to Bill's question about does the model itself bias. Of course, our knowledge biases what we do next. And I think that is the way to think about this.

DR. ESH: This is David Esh. I would agree with what Matt said.

I also think that you can understand it up front. You can understand it some up front and some at the back end or you can understand it all at the back end. If the risk is necessary, you're going to have to understand it at some point in time.

I think the approach we use now, we try to get more understanding on the front end. But there are a lot of barriers to that. People are wanting to make decisions and proceed, et cetera. So we recognize that. We try to always ensure we make good decisions on the front end.

But information is sparse and uncertain. So if you can get more information on the back end that helps ensure that you made a good decision, we think that is a good thing.

The reality is that information can be quite limited sometimes for some key things. And if you have more understanding, you can make better decisions.

MEMBER WEINER: Along that line -- and my next question is going to be very, very, politically incorrect -- given especially the presentations that the two of you, Matt and Dave, made on performance assessment, what is your opinion of even the 10,000-year regulatory period, let alone the million-year regulatory period that has been proposed for the high-level waste repository? I told you it was politically incorrect.

DR. KOZAK: I'll let David take that one.

(Laughter.)

MEMBER WEINER: And especially in the light that 40 CFR 191, which was the first regulation, said that performance assessment was the tool by which reasonable assurance would be provided to the public that the standards, that the EPA standards, would be met.

DR. ESH: Well, this is Dave Esh.

I think that in my presentation, I tried to reemphasize or at least highlight these time frames that we're talking about because we lose sight of it. And we talk 1,000 years, 10,000 years, longer than that. A few hundred years is a very long period of time.

I have trouble tracing my ancestry more

than 150 years, let alone 1,000. So I think it's necessary to consider long periods of time when you're trying to project the results of your action, but if you're talking about trying to monitor for long periods of time, in my opinion that's a foolish endeavor, the value of the problems that we talked about.

And if we think the natural systems and engineered systems that we deal with are complicated, I'm sure the temporal aspects of the societal system, the human system swamps it.

I imagine if we were trying to say that one of the reasons why we will have confidence in an action is because we can have some very extreme long-term monitoring system, that's foolish in my opinion.

I don't know if I answered your question, but --

MEMBER WEINER: It was a very good attempt. Matt, do you want to add anything to that?

(Laughter.)

DR. KOZAK: I agree that we need to consider the consequences of our actions over long periods of time. On the other hand, it's worth keeping in mind that even considering 10,000 years is unprecedented in any other human endeavor.

No one has ever tried to project the consequences of their actions over that long a period of time. And the judgment of where that cutoff is is above my pay grade.

(Laughter.)

MEMBER WEINER: Finally, if --

MR. THAGGARD: He stole my answer.

MEMBER WEINER: Yes.

MR. SHEPHERD: This is Jim Shepherd.

If I could sort of tie those two questions together, I think as we go out in time, we find that it becomes more and more difficult to bound the uncertainty.

Radiological decay is a well-understood phenomenon. And there are very few things that can actually perturb it; whereas, the basic movement of waste through the environment to some human receptor is not well-understood. And there are many, many things that can perturb it.

And I don't believe that we could ever reduce the uncertainty to the point that we would have so much confidence in the model that we would not need to take any more observations to justify it.

When we get into the 10,000 to

million-year time frame, we just don't know enough.

MEMBER WEINER: Finally, I would like to ask. A number of people on the panel said, well, these doses, these consequences are really insignificant, but politically they're significant. How do we get the politics out of it?

(No response.)

MEMBER CLARKE: Thank you, Ruth.

(Laughter.)

MEMBER WEINER: Anybody want to tackle that?

MR. SCOTT: Yes. This is Dave Scott.

I think a good starting point is to increase our characterization, improve our characterization, to the point where we are able to gain the confidence of more of the public that we know what we're doing. And, I mean, I think we're seeing a sea change within the industry.

From where I sit, the groundwater flow path has been neglected. And that's changing. I think that's one of the reasons that we're here now, because we recognize that we have to consider the groundwater implications of any releases from a site, be they dose-significant or not because many members of the public don't really consider dose. All they know is it's a release. And the dose is of secondary significance to them.

DR. ESH: Ruth, in regard to that -- this is Dave Esh -- whenever you talk about uncertainties and some uncertainties, some things are known and some things are not known very well.

The thing that I think of when I hear about the tritium information is, yes, it might not be significant from risk implications, but it also may be a very valuable source of information to constrain the uncertainty in your hydrology, your hydrology model, your hydrology understanding, which then just leaves you with uncertainty in the geochemical aspects of the other nuclides, the strontium-90s of the world or the transuranics or whatever the other things because most of the times when you have these problems, it's not just one isotope that was released. It's a mixture of isotopes that were released. You just see the tritium because it's the highest mobility.

MR. SHEPHERD: This is Jim Shepherd.

When I started managing the Sequoyah fuel site, we had a very similar problem where the public in the area in general did not trust what the licensee said and they did not trust what the NRC said. And it took us several years of rather regular meetings with them before they began to believe that we were actually telling them the truth.

Once they saw that, they could then take an answer and say, "I don't like that answer," but it wasn't a matter of "I don't believe you." It was a matter of "Here is something that I believe what you say is true. I don't like it. Can you change it?"

And I think it's a matter of time now that we need to rebuild confidence, both the agency and the operators, that the public can believe what they hear. Rather than the immediate starting out with "It's no problem," now I'll tell you what it was.

Their immediate reaction is "If it got loose, I think it's a problem." And we have got to rebuild that confidence. And I think that's going to take a very concerted effort, probably over some period of time.

MEMBER CLARKE: Thanks, Jim.

We have had a request from one member of the public to ask a question. We do have a few minutes. So, John, would you like to come to the microphone?

PARTICIPANT: Jim, thanks for taking my question.

Listening to speakers, what I sense is

there is a little bit of a gap in the discussion so far. Some people talked about compliance but didn't emphasize it. The first two speakers, being Vernon and Dave, talked about their great case histories.

And I would ask, what was the dialogue about the point of compliance? In fact, there are multiple points of compliance, especially at Barnwell. Who is actually at that point of compliance? And what are the time frames?

All the discussion this morning talks about monitoring, transport scenarios, et cetera, but it really comes together when you focus on point of compliance issues.

So the question is first to Vernon and Dave if there is time. Can you give us a little bit of experience? How was the point of compliance assessed? Actually, there are multiple points of compliance, for example, at Barnwell. And who is the recipient? And what time frames?

Focusing on those helps knit a lot of what you talked about this morning together. Without it, it doesn't make a lot of sense to me. So I'll just pose that question. Maybe over the next two days people can hit on that also.

DR. ICHIMURA: I would like to say a

little bit about the point of compliance. Before I start that effort, I want to emphasize that from a licensee's standpoint, we're looking at how do we meet regulatory requirements. And regulatory requirements are measured or projected at a place we call point of compliance or compliance surface or compliance point.

The compliance point may change with time. And it may be a function of the type of operations you are doing at the current time, as an example.

During the operational phase of the facility at the burial site, one point of compliance would be direct gamma radiation. And nuclear plants are the same thing. Point of compliance in this particular case during the operation would be the fence around the facility.

And it is a negotiated line, a line in the sand, that is negotiated with the regulatory agency. That is where the point of compliance occurs. So we do one of several things, like I mentioned before. We can model gamma radioactivity from the source, the trench to the fence. We also follow up at the point of compliance measurements on direct gamma using TLDs as an example. So that's during operations.

Taking the extreme case, in the case of closure, we have a point of compliance, say, for projection purposes for the groundwater pathway, which is quite different. It is a point that we negotiated where groundwater eventually becomes surface water and leaves the facility.

When it leaves a facility or leaves properties controlled by Chem Nuclear, it is no longer controlled by Chem Nuclear. And it becomes available, at least in the hypothetical scenario, to a general member of the public. And that point of compliance is difference from that of the fence. And the time frame that we have done the analysis for in the performance assessment is 2,000 years.

So these are two extreme examples of point of compliance with respect to that applies to our facility.

MEMBER CLARKE: Thanks, Vernon.

It is 12:00 o'clock. Let's break for lunch. And we'll be back at 1:00. Thank you all.

(Whereupon, a luncheon recess was taken at 12:01 p.m. until 1:03 p.m.)

CHAIRMAN RYAN: If we could come to order, please.

I want to thank our morning participants for keeping us on schedule this morning, and I'll turn the meeting promptly back to Jim Clarke.

Jim.

DR. CLARKE: Okay, thank you, Mike.

Our first presenter this afternoon is Make Fayer from PNNL.

Welcome, Mike. Thank you.

EVALUATING RADIONUCLIDE RELEASES AND GROUND WATER CONTAMINATION (CASE STUDIES)

HANFORD

MR. FAYER: Just a quick little bio. I grew up in New Jersey, born and raised there. And it doesn't mean I'm a fan of landfill solutions for everything.

But the point is, I spent the first part of my life there, in a wet environment with thunder showers and nor'easters and hurricanes.

And then when we finished school, my wife and I moved to Richard, which is in the West. And we don't have the thunder showers you have here. We don't have the nor'easters or the hurricanes, and we don't have the humidity.

And that was one of the reasons we ended up staying out there. We just got to really like the place. Originally it was just going to be a little sojourn, and then come back to the East Coast.

But there is a tie-in to contaminant

transport, and that is the recognition that obviously conditions out here are different than they are out West, so whenever you evaluate contaminant transport, you have to consider those site-specific conditions.

When I pulled this together, this presentation, I borrowed a lot from the published monitoring ports for the site. Annually there is a report. I have a copy of this year's groundwater monitoring report. It's quite extensive.

This actually is the summary. The actual report is several inches thick. So there's quite a lot of information that is published every year.

If anyone is interested in more details of anything I cover, see me afterwards and I can show you how to get a copy of this, or to contact people at the site for more details.

The talk is only about 14 slides, so it's fairly short. But I'm going to cover the recommendations up front so they're fresh in your minds as to I go through the rest of the slides.

I do have one slide on generic transport considerations, just to set the tone before we get to the site specific examples.

I have pulled up to the front the summary for the talk, to drive home the point about contaminant transport being governed by a complex relationship of site specific and contaminant specific features, events and processes.

And so every time I might look at a new site, I always look at the whole suite of things that could happen, and then decide how to approach it.

I think you need to address those in order to gain understanding, in order to know how to monitor, and in order to know how to predict contaminant transport in any of these sites.

So think of that as we go through this, that's my perspective.

Okay, I've got four recommendations. These are things that I think are probably common knowledge or commonly accepted, but maybe not stated in the same way that I've stated them here.

The first has to do with compliance monitoring. I've heard that a lot this morning. And my experience out at the site is that compliance monitoring is what is required to do.

And it may not be related to anything in particular, other than the regulation says, you must do this, this and this, and they do that. And then they meet whatever the terms are for the agreement.

But if we expand compliance monitoring to be what I call compliance assessment, not only do you meet or understand what's being measured at specific locations, but you understand why you're seeing those values at those locations. So it's the understanding part you want to get at. And that's why I would call it compliance assessment.

So that would include whatever is regulatorily driven, whatever monitoring is done for ES&H, environmental safety and health considerations, or perhaps stakeholder requirements.

And then for performance, you would have sites where remediation is ongoing. You want to evaluate how well it's doing, so there might be some localized monitoring going on for that activity.

Second, I would assign, I would recommend assigning a compliance assessment phoner, someone who is responsible for understanding the site. So they can explain why they see a plume, and it's moving a certain way.

That may not be the intent of current compliance requirements, but the understanding part is more important, I think, to the public, and certainly should be important to us to be able to have a monitoring model at the site.

I think of monitoring and modeling as

linked pieces of the puzzle. I don't think you can have one without the other. My bias is both.

Modeling in my mind encompasses our understanding of the site. Monitoring confirms that we're correct.

Third point is, conduct regular external peer reviews. Again, I think everyone would agree with that. I just would reinforce it because peer reviews can be expensive. They can be time consuming. So they can be drivers sometime to lengthen the interval. Perhaps do away with it. Perhaps people think we already know enough.

And I would argue against that. I think you need these regular reviews by outsiders to confirm that you are doing things correctly; that you are not missing anything. And if there is new knowledge that you are not using, this is a venue to bring that new knowledge into the assessment.

The final recommendation is to include what I've called entry portals for new data, science and legal interpretations, public interest. And the reason I did this is because many of these assessment activities go on for many, many years. And science doesn't stop. Data collection doesn't stop. So you have to have a way to bring that new information and understanding into the process.

I understand that if you are responsible for the contract for a site, you don't want to have anything interfere with decisions that have already been made. But I think that is maybe a shortsighted approach. So there has to be some way of doing this that doesn't penalize the contractor.

If there are no questions, I'll move on.

This slide is just meant to prime you for the examples I'm going to show, some transport issues that have occurred out of Hanford, things we might ask as we go to a new site, what do we do.

It's not an all-inclusive list. It's to get you thinking about the variety of things you need to consider.

Is the waste of gas, a liquid, is it an aqueous solution, is it solid such as a colloid. Each of those determine what type of pathways may be taken, and what kind of mechanisms would cause them to be moved to the environment.

Is it dilute or concentrated? Many of the contaminant sediment interaction lab tests really focus on dilute solutions. And for many of them it may be reasonable to assume a very linear relationship with concentration.

But when you start to get up to very high concentrations, that doesn't hold. You are outside the realm of where you measured your interactions, so you have to be aware of what type of waste you're dealing with from a concentration standpoint.

Same thing for pure or mixed. Some times - well, many times - out at the site, contaminants have been mixed. And meaning that you have multiple radionuclides, multiple chemicals. They can affect each other as far as their absorption into the sediments. So you have to understand what's in that mix to understand what gets absorbs first, what gets absorbed next, as it moves through the system. Is it diffusion or advection dominated? That's pretty straightforward.

Is the media uniform or heterogeneous - or excuse me, homogeneous, isotropic? Obviously, we would all recognize that really the best place to find that kind of medium is in the laboratory. But even in the lab, it's actually difficult to make a uniform homogeneous isotropic medium; it takes a lot of skill. So if it's that difficult to create in the lab, you have to realize, in the field there is nothing like this.

Now that shouldn't stop us from making or trying to make predictions of what happens. We have to make assumptions about a lot of things. And so we could simplify, and we do that. But then we test. We confirm that that simplification is sufficient for that particular site.

Constant or variable flow conditions: I think a lot of analyses sometimes are done with steady state solutions, and that may be appropriate for some sites, but you have to confirm that that is the case. I have an example where it is not.

Same thing for transport conditions. Some of our disposal sites had some very concentrated solutions, very very high pH. As it first enters the ground, it behaves one way. As it moves through the ground it gets diluted, things absorb out and it starts to behave differently.

And so you have to understand the progression of the geochemistry that is going on.

And then finally, future conditions: some of you might think of this as scenario evaluation or scenario uncertainty. I kind of look at it relative to the baseline. And by baseline I mean your monitoring period, your evaluation period.

Are future conditions within that? Then you might feel comfortable and confident in how you project performance. If you are outside your baseline conditions, well, then you are starting to introduce some uncertainty, because you don't know for sure how that future condition is going to affect your site. You don't have experience, so you are making assumptions right there.

Okay, the list is not all inclusive, but it does get you thinking about how to look at a site.

Okay, I've got seven or eight examples, but before I get to them, I'll go through the site real quickly here.

It's out in South Central Washington state. It's on the dry side of the mountain, so we're only looking at like six inches of rain a year, mostly in the wintertime.

The Columbia River comes from the north, and loops right through the site. It's like the third major river in the United States. And it's one of the reasons the site was selected for a defense production mission: access to water; it's a remote location; dry. So there were up to nine reactors located on the northern site of the Hanford site, radiating fuel.

That was all brought up onto the plateau for processing into production facilities. And so the reactors are up along in here. The production facilities are right in the center, in here.

There have been contamination problems everywhere, around the reactors, and in the production facilities, and in some of the burial grounds all over the site.

There is also a test facility down in here called the 300 area, and again, there were some disposal pits there.

So we've got many sites. There's over 1,400 waste sites identified, some are quite small, just spills. But there are a significant number that are large and need attention.

The picture there is from the late `40s, early `50s, when there was initial construction. In the very distant part of that area you can see the T plant is already up and running.

In the foreground is the U plant under construction.

This all happened extremely quickly given the conditions at the time. It was war, or post-war, there was a lot of concern about security, Cold War; and the emphasis was on production.

There was some knowledge that there was a problem with radioactivity in the environment. They did take some measures to address it.

But given our viewpoint from 50 years later, it was inadequate what was done back then. But it's understandable how it happened.

Okay, first example. I called this insufficient early characterization, but there are a lot of things that might have been done better back then.

These are underground storage tanks for liquid waste. Typically 45 foot tall, 75 foot in diameter, and for processing the liquid waste would be streamed in here. The temperatures would be above boiling in a lot of these; pH is up to 14; concentrations are in the molar range.

These are very unusual and certainly not things you typically see in a vadose zone.

Properties were different than water. There were concerns - there is now concerns about any dissolution and precipitation reactions that occur when the stuff is leaked.

It was constructed with reinforced concrete, and a carbon steel liner on the sides and the bottom. I think the expectation was, they were going to be secure for the lifetime of this facility. But because of the high temperatures, there was an unexpected buckling of the plate. There were other mechanisms suggested for why these things leaked, bu9t a number of them did leak.

Sometimes the leak was difficult to discern by a drop in liquid level. If you can try and imagine the liquid level in a huge tank 75 foot across, it's hard to detect a small change.

Some of the tanks had what are called lateral bore holes underneath where you could run a gamma system. Those are difficult to maintain, because you had to go down 50 feet and run these things laterally.

Once the stuff leaked, typically the cesium would absorb very close by, and would tend to swamp the gamma system, and you really couldn't make much more headway out of that information. Once you knew it leaked, that's all you knew. There is no backup plan. You can't go back, and retrieve it. When they first built them, they didn't really put a lot of effort into characterizing beneath the tanks.

I mean 50 years later, we'd love to get there, but you just can't get under there any more, because it's all contaminated.

The site is riddled with waste transfer lines, water lines, so it's a challenge; there is no question about it.

More recently they've approached it with things like slant bore hole, resistance technology for looking at subsurface contamination, which explores the volumetric part of the vadose zone. So there are ways that they can start to get around this.

But still, it's hard working around it, rather than to have done it up front.

Example two is a basin for fuel, spent fuel storage basin, in a K reactor area. And they built a liner system under this actually, but it turns out it was built with what's called a spray-on asphalt. They essentially formed some sort of collection pad; sprayed on asphalt; and that was their system for collecting data.

Groundwater system indicated a leak, or indicated possible leak, because they couldn't be sure. There were other disposal sites located nearby, so they weren't really sure where this leak was coming from. But they didn't find anything in this monitoring pad.

But it turns out they never tested the monitoring pad. They have no idea if it actually did work. They also found out that the monitoring pad didn't extend under some of the extensions to the basin where they would bring fuel in and out.

So the final speculation is that it leaked at the scene between those two pool entities.

By the way the fuel has already been removed, and this will be decommissioned shortly.

Changing flow conditions: the early years at the site a lot of liquid, millions of gallons were disposed in various ponds, trenches, ditches, and it raised the water table significantly, 30 feet or more, particularly on the western side of the site. Up through about 1979 it was probably at the peak.

A lot of wells were put in, usually screening the top five meters. So as we stopped disposing of liquid, the water table dropped, and all of a sudden we have bore holes that are no longer in the water table, so we're out of compliance for those particular sites.

Another issue there is that as the water table is dropped, we're all of a sudden discovering that the underlying basalt is now above the water table. And so it's now become an impediment, and it's causing flow directions to change.

Well, when you do that, the wells that were down gradient from the early site are now not anywhere near down gradient because the gradient has changed.

And so you have to be aware of how your flow system is changing and rearrange your monitoring scheme accordingly.

This is another example of changing flow conditions. The Columbia is controlled by a series of dams. And so water levels can rise and fall daily two, three, four, five feet easily, sometimes more. So you have these pressure pulses that flow back and forth across some of the near river waste sites.

It's very complicated trying to describe that. It doesn't lend itself well to a steady state solution. Steven is going to talk a lot more about this site, and I don't want to take away his thunder. But just so you know, that's an issue.

Inventory uncertainty: there are a lot of burial grounds out there. And of course many were put in in the `50, `60, `70 time frame, so documentation is not what you would expect, at least from today.

There is one in particular where there was no indication of tritium being in that burial ground, but by chance, one of the sitewide groundwater monitoring folks decided they'd like to sample that well for tritium, not because he suspected anything there, but he was trying to fine tune his regional map of tritium. And the first reading came back over a

100 million picocuries per liter, when he was expect 2,000 to 20,000 picocuries per liter.

And actually that didn't get captured right away. People weren't paying attention at the moment. It wasn't really on their radar screen.

The next sample came back at 8 million picocuries per liter. They realized they had a problem. This is a tiny little speck way out in the middle of a very very diffuse plume, and all of a sudden you've got this huge pulse.

It ties nicely to the burial ground. They went back through the records, combed through and decided, yep, they disposed tritium to this site.

They've now gone back in with the helium three gas technique, where you sample soil gas for helium three, which is a decay product from tritium. And they can isolate the portion of the burial ground where this tritium is concentrated. So that's very helpful when they want to go back in and excavate; they know where that's located.

This is a plume up here that is about four years afterwards. They finally can quantify where this thing is located. You can see how localized it is.

This is kind of related to Brian

Andraski's talk on tritium two, so a little tie in.

Contaminant source location: this is a carbon disposal problem. There is about three or four locations where carbon tet was used as a decreaser, disposed to trenches, essentially just to leach into the ground. The groundwater is about 80 to 100 meters below the surface here. It was just the practice back then.

Now we've got to deal with that. And the quantities are on the order of 5-700,000 liters of carbon tetrachloride, which is a huge amount.

They've done some mass balance calculations, and this was back in `93, and they at best could account for about 35 percent of the mass of carbon tet, so they couldn't really tell where the rest of it was. Speculation was about, because of Steen Appel maybe it actually went down into the ground water and is now at the base of the aquifer. If that's true, how do you actually go and sample for it and locate it? It's like a needle in the haystack.

Much of it could have been dispersed in the vadose zone. We just haven't captured it yet in our sampling.

They have had some vapor extraction and ground water extraction remediation techniques, or technologies. And they've probably removed about 20 percent of the carbon tet. So there is still an incredible amount that is still out there yet to be determined. How do you monitor something like this? How do you quantify the source term?

I threw this up here to drive home the point about the complexity of the subsurface. And it's true, I did cherry pick some of these photos to highlight some of the layering units out there. Many times these layers will cause things to spread far greater distances than you would normally expect.

Sometimes the layers terminate, and so you can't always assume that the layers are continuous. You have to be careful that they are not just going to pinch off, and you are going to be left with fluid moving downward at the edge.

We do have some features that are vertical. These are natural. They are called clastic dikes, and on the right side of the image is an example from many years ago where someone put water on the surface, at the top of the dike. You can see how it went down through the dike fairly intact, and then all of a sudden hit a layer down below and started to spread out. How do you represent that kind of behavior?

Now if we change the conditions and made that unsaturated flow, we may not even see that effect. The dike may become more of an impediment than a conduit.

The last example is unintended consequences, and I may be stealing Glenn's thunder. But I wanted to drive home the point that sometimes we design things that we think are perfect. But we have to have some humbleness about this and realize that if we think we're perfect, we've got to check. That's why we collect data.

In this case we built a barrier, surface barrier, that was actually quite effective. All the modeling and all the lysimeter work indicated it was effective.

We built it, and indeed it was effective. The problem was, it was built on the side of a hill, and so in order to keep the cover stable, we had to put side slips on it. And these have to be graveled, or sandy graveled, in order to be stable.

And they were stable. The cover stayed intact. But unfortunately they also promoted infiltration. So we had this perfect cover in the middle, and then we had this source of water on the sides, almost defeating the purpose of the cover itself.

And so that's why I called it unintended consequences.

This is all something that can be captured and thought of by a compliance assessment activity.

That's the end. I'll just leave you with that summary again about the uniqueness and complexity of the subsurface.

And then it's incumbent upon us to reflect that in our decisions, both monitoring and modeling.

DR. CLARKE: Thank you, Mike.

I failed to mention in the beginning that we are going to hold the questions until we complete the panel discussion. And we'll go from there.

So our next presenter is Brian Looney from Savannah River National Lab.

SAVANNAH RIVER NATIONAL LABORATORY

MR. LOONEY: While he is getting my slides up, I will talk a little bit about my dilemma.

I've tended to work at sites where there were plumes that exist. And I knew that we had these two objectives here of plumes that exist, and then monitoring sites where you want to have a sensitive system to tell you whether you in fact have monitoring.

So what I'll do is, I'll talk about it from my perspective of experience. But I think that some of the issues of the shape and structure of existing plumes might be informative, might inform us about thinking about plumes from newly designed and newly installed facilities.

So with that as a little bit of background, this is a picture of work we did in Russia where we're installing multilevel sampling and pump testing equipment in Russia. And just for scale, that guy's head is about this big in the picture.

Let me start off with a very simple idea. I think the most important thing with monitoring, which plays into also clean up, is that plumes have an anatomy. They have different characteristics in different parts of the plume.

So just for simplicity what I've done is, I've drawn these ovals where the red oval is the source zone that tends to be highly perturbed in an area of real release. The green zone is the primary plume. There is still a lot of contaminant in that zone, but the geochemistry is much more similar to regional background.

And then you have a dilute plume or a fringe where you have large volumes of water, and fairly small amounts of contaminant.

And one of our philosophies in the research group I worked in is that it's really important to match the personality of the remediation you use to the personality of the problem.

So you tend to use aggressive technologies in the center, and then you tend to use more standard technologies in the middle. And then you have to get creative again back out on the end.

Now that has financial ramifications, because the aggressive technologies tend to inject reagents. You are treating a certain fixed volume of earth, and so the volume you need is the kind of knowledge that tells you exactly where the contaminant is, because that's how you optimize the treatment.

If I know that I cost a certain amount per cubic meter to treat, and I know exactly where my stuff is, I'm treating the least number of cubic meters of earth.

Similarly in the green zone here, the primary plume, the traditional engineering treatment calls for dollars per volume of water, so dollars per thousand gallons would be an engineering unit.

And so the goal there is to figure out where the plume is so that you treat the least number of thousands of gallons.

And then when you get out into the dilute plume, you really have so much water to deal with, you have to be in units of dollars per time, or else you're basically in an untenable situation.

So it's these kinds of matching things that we try to do. And what I'll do is, I'm not going to belabor this, because this is really more of a remediation thing. But it has to do with the kind of characterization and monitoring technologies you use within each of these zones as well.

And of course in the real world a plume is not beautiful ovals. It looks more like this.

So this happens to be an example of a tritium plume at our Savannah River site from the old burial ground, and the source zone is up on the left. And essentially the plume moves in a curvilinear fashion through the aquifer and then crops out at the bottom fo the hill.

The plume is about between five and 20 feet thick. And one of the things that is important to note, and we'll come back to this, is that this structure of the plume has a fairly substantial impact on monitoring data.

There is a plume very near here that had a similar structure, and I was referring a journal article, and the monitoring wells that were put in were put in right at the source, about this far down, and they drew the plume as three ovals: a high concentration oval; a medium concentration oval; and essentially a zero oval.

And what they were really contouring was not the contamination; they were contouring the percent of the stream that was in the plume.

So to me this is kind of an important issue where the geometry of the contaminant moving through the subsurface is going to be an important issue, and one in which we can be both creative and thoughtful in our monitoring suggestions.

So I'm going to go through just a few examples. The first will really set the stage for the next talk.

I'm going to talk briefly about the Brookhaven High Flux Beam Reactor. This is just an interior shot showing the beam lines. This is an important national facility where people could lease or get access to beam time and do lots of scientific experiments.

And as part of running that reactor and getting the high flux beams, essentially there was a fuel canal which was shown on the right, and I'll give you the answer up front. It was shown to be leaking at a fairly low rate, something like six gallons per day. So a fairly low rate.

Now let's talk about how you would convert that reactor into a conceptual model. The reactor is essentially a large cap which keeps infiltration from moving in there. And then you have a fuel canal which is leaking into a canal, a very dry vadose zone, six gallons per day. And so that material is going to go into the vadose zone, and by capillarity is going to spread over a relatively large area.

That is exacerbated by the fact that there are coarse materials part way down through the vadose zone which in fact are going to serve in a vadose zone to further spread the contamination.

So now you have a very low volume source coming down to the water table over a very large area into a fast flowing aquifer. And the next talk will talk more about what happens in the ground water.

But the ramifications of that are, you get a very thin plume that occurs right at the top of the water table surface.

So now what they did at Brookhaven, and this is the reason we were called to come up there, is, they installed two horizontal wells thinking that would be a very robust way to figure out what was going on. One was five meters up gradient from the fuel canal, and the other was three meters down gradient of the fuel canal.

So now we have this beautiful idea. We have horizontal wells, immediately up gradient and down gradient of the fuel canal, properly installed, a good job. And the numbers just went all over the map. They went from almost zero to 100,000 picocuries per liter. And they couldn't figure out what was going on.

We went up to the conference room, and I drew this little sketch, and I said, well, the water levels are going up and down, and sometimes you're sampling nothing, and sometimes you're sampling a very high concentration that is right at the water table surface.

That was confirmed also by the vertical well that was put in down gradient, because the concentration in the vertical well would vary strongly as the water table went up and down.

If you do the calculation on this, the important thing about this is that it shows us that we can optimize our thinking and be very creative and actually get a very robust monitoring system.

If they had monitored tritium in the vadose zone here up front, it would have been fairly robust, because you would have had an early warning system that was insensitive to the expected variability of the environment.

To use a standard model, what normally happens is you assume you have some kind of infiltration rate. It mixes with the ground water flow, and you get this kind of expected thickness of plume. Most of the radionuclide risk assessment codes do something like this.

And essentially if you do that little ratio-ing, what you calculate at this particular site is that the plume expected under the Brookhaven High Flux Beam Reactor would be just a few inches thick.

So essentially you had a cordon well that was a meter below the water table, and a plume that was a few inches thick that was smearing up and down and becoming kind of interesting over time.

And then it gets one level more complicated, because at that point, Brookhaven did what I consider one of the best plume characterizations probably that's been done in the country for a fairly mobile contaminant, and essentially they characterized this area down here.

But what you see is that you have this area under the reactor where no water is coming in, and so the plume essentially hooks the water table surface. And as soon as it gets out from the footprint of the reactor, you have new infiltration coming in. So essentially you get the classical migration path. of the contaminant.

And sure enough, when lots of samples were taken, you essentially get exactly the expected path. You get hugging the water table, and then moving downward through the aquifer. And that angle on that is exactly what you would calculate from the earlier equation when you do the ratio-ing of the infiltration to the lateral water table.

In terms of what was seen in the down gradient vertical well, it did exactly what was expected as well. You have essentially a thin few-inch-thick layer that is moving up and down. It's being diluted by a variable zone of relatively clean water.

Now this is not a perfect model, but it's a conceptual model. And what happens is, over time this gets smeared around a little bit, so this really isn't zero, and there is some contamination up here.

But in essence what was happening is, the concentrations in the vertical well, immediately down gradient of the reactor, were simply varying as a function of the ratio of the thickness of the contaminated zone to the amount of clean water that was being sampled.

So that's kind of the Brookhaven High Flux Beam Reactor example. Let me just show a couple of other examples of conceptual, building on the talk we just had.

This is Hanford, and you can do a conceptual model at this kind of sitewide basis. So what you do is, you just draw everything at the site, and you kind of put it in perspective. And it's a bit of a cartoon, but very useful kind of cartoon.

And then what you can do is, you can zoom in on certain parts. So if you take this previous slide here, and you zoom in on the central plateau, that part that is on top of the hill, then you can draw the facilities in a little more detail, and you can kind of depict what kind of waste disposal goes on, you can describe it in more detail, and you get a little more kind of knowledge.

But when things really become useful is when you start noticing that there are some local things that actually control how contaminants are moving right in the vicinity of the waste facilities themselves.

And it's by drawing a sketch like this that I think you can get pretty creative in understanding and matching the geometry of your contaminant.

Or in the case of a new facility, putting your monitoring in in a way that is cost effective so that you're monitoring the place so that it's going to be robust and sensitive to the contaminant.

I think it came up earlier today, and the issue was, if you put in one of these new facilities, you expect to see zeroes for 300 years. The reason that we put monitoring in, is because we want to do our very, very best to figure out if it fails. And the way you do your very best is, you really think hard about the conceptual model associated with the facility itself.

So here's the conceptual model factors to remember. The first is that I think we can really take advantage of and understand plume trajectory and incorporate the controlling boundary conditions in hydrology into our models. And we need to collect depth discrete data during the characterization phase of work.

The reason I put this first bullet in here was because the first tritium plume I showed that kind of curved through the subsurface, that was not being controlled by the geology, that was just being controlled by where water entered and exited the system. So that kind of curve happens even if there is not lithological control. And I think that is an important issue.

People often think that if the plume is doing something like that, there has to be some kind of heterogeneity that is causing that. That happens just because water is pushing it around where it wants to push it around.

And then you have the layer on top of that hydrology, the layering in the heterogeneity in the lithology.

In terms of subsurface heterogeneity, I think it's important to optimize models based on all the characterizations collected at the different scales.

I think an important point here is, beware of sampling on arbitrary grids if a contaminant is going to be strongly controlled by lithology or geochemistry.

One quick example there is, I went to a site, and they were really proud. They took me into the conference room, and they showed me that there was a sticker on all of their meter sticks that was from NIST. They had mailed all their meter sticks to NIST to show that they had been calibrated, so that they could collect samples on an exact frequency in the subsurface.

And what happened was, there was a clear layer that was kind of undulating through the site, and they got a bunch of really high concentrations, and they got a bunch of really low concentrations. And they weren't contouring their contaminant. They were contouring the distance from the clay layer that they were taking their samples with their NIST-calibrated meter stick.

And then finally, and of course I have no solution to this, but I put it on the slide for Steve and others - I'm sorry for the insensitivity. And I think the case here is where characterization and monitoring might be able to help us bound what some of those things are.

Let me just show a couple of photographic examples. This is a dime right here. And the scale that we have on that system. So that's on a small scale. What we have is lots of little clay interpolated with sand on the scale of a dime at Savannah River.

And then this, just a few miles away, is a large plume that we have that is moving through the subsurface over the scale of about a square mile. That happens to be a solvent plume, but basically just to show the idea of heterogeneity.

The way we've dealt with that is, we tried to characterize on different scales with different tools, so we use a lot of direct push sampling. We try to use various sensors, optical, electrical, radiation sensors.

We use sorbents that specifically sorb contaminants. In some cases we can even get them to change colors in the field.

And then looking at the geometry of the actual access itself. So to kind of summarize, geometry considerations, I think it's important, the same as matching your remediation technology to the personality of the zone you're after, I think you have to match your access to your conceptual model geometry, through your selection of drilling and access methods, and your well construction decisions, where and how you put your screen in.

So as scientists we want short screens, because it gives us the most knowledge about the nature of the plume. But when it comes to making informed risk decisions, you actually, by putting in short screens, you give your biggest chance of missing the plume. But you give your chance of getting the highest concentrations.

By putting in long screens, you give yourself the least chance of missing the plume, but you have all the dilution of the clean water that goes in there.

So this is the tension. In every case in monitoring, I think one of the messages that I take home just from this morning is that there is a tension in making all these monitoring decisions where you want to be accurate, and yet have something that is relevant to informing your risk decision.

CHAIRMAN RYAN: Mike, excuse me, is someone on the bridge line?

VOICE: Hanford site.

CHAIRMAN RYAN: Okay, great. Would you mind putting your phone on mute, because when you make noise, we're hearing it.

Hello? Okay, thanks.

(Laughter)

MR. KOZAK: I think whenever you have access, you should maximize your value from it. So we do a lot of data collection during access, and use a lot of bore hole logging, so we do a lot of lithology, either with core examination or various sensors, electrical hydrologic thermal properties, samples of either solid, liquid or gas, various down hole spectroscopy.

I think there is a lot of innovative field-based methods that are out there. In the Office of Science they funded a lot of environmental push-pull tests. I think those are very promising and have some potential in application.

Once again, this is just an example. This is foot by foot core examination, was used to generation this lithological sequence. That lithological sequence was correlated with a lot of effort and work into that hydraulic connectivity distribution.

That was a various useful particular thing at this site. This is some of the reactor areas at Savannah River. And this lithology and hydraulic connectivity distribution explained why a particular plume in a certain area had a tritium plume that bifurcated into two layers.

So here's kind of the summary thoughts for my talk. Consider early warning systems. I think the idea of waiting for a contaminant to get into the water table before we even begin to think about monitoring it is a weak kind of monitoring paradigm if there is an alternative.

I think the idea that was mentioned earlier I think is a very powerful one, to think about incorporating tracers and indicators, either explicitly into your materials, or looking for opportunities in terms of the geochemistry or chemistry of your processed waters.

Consider plume geometry: I think we can exploit opportunities with plume geometry, and we can avoid pitfalls with plume geometry.

I think we should consider nonstandard approaches. The three examples I'll just highlight here are geophysics, looking at the different phases that you could sample; push-pull testing; and I think we can consider the geochemistry of the site especially as it has to do with the mobility of contaminants.

So just a couple fo quick photos. This of course is a pretty easy one. This happens to be cesium, but this is logging that was done at Hanford again. It was done near the tank farms. And essentially what was done at Hanford was, the cesium plume was monitoring with dry bore holes, and they essentially looked at the gamma distribution.

With some of the things we've been talking about this morning, tritium and strontium, it's going to be a much more difficult and challenging kind of activity.

So for geophysics, surface methods are good for trends, interfaces and changes. But you have some resolution issues, especially at depth. I think if you can come up with creative ways to use existing bore holes that geophysicists can often provide useful and interesting information.

And I think if geophysics has the potential to be interesting, that that site should even consider adding access at key locations.

I'm going to do just a little thought experiment for a few minutes, because one of my goals was to be controversial and give you guys something to talk about.

And what I'm going to talk about is, we had a series of talks that Miles Denim and I had put together. One of them is called gas, the forgotten phase in metals and radionuclide remediation. And I'm going to give a very short variant of gas, the forgotten phase in metals and radionuclide monitoring.

And what I want to talk a little bit about is, the ways that you can maybe be creative and get away from standard monitoring wells and get interesting and useful information.

So the general conceptual basis for this is things like tritium, mercury and even uranium and thorium may have the potential to be monitored through the gas phase through collection of gas.

Soil gas monitoring of metals has its roots in efflorescent geochemistry, so there is a large body of supporting scientific literature there.

And I think the key thing for site owners is gas sampling is easy, it's inexpensive. Many analytes are easy to analyze in the gas phase, often with equipment that can be used right on site.

As soon as you say, well, what about the gas phase, you can start breaking it down further. So this is kind of building this thought experiment.

Well, what if I could monitor the contaminant directly as a gas? What if I could monitor the contaminant using diagenetic gases that are formed, or indicator gases? Examples would be decay products.

And then finally, what if I could just monitor the conditions for contaminant mineral stability? Those would be using diagnositc gases. That would be the more traditional way that it was done in exploration geochemistry.

Tritium is the most obvious contaminant for direct monitoring. At most sites it's in the form of tritium substituted into water molecules.

This approach has been used at many sites. It's been used at Laurence Livermore, Savannah River, at Hanford.

One example here, this was a site where a tritium plume was cropping out at the bottom of a hill. A dam was built, and the water pumped up to the top. Some fraction of the tritium is evapotranspired, and some of it goes back into the subsurface and has a longer decay time. So this essentially becomes a phytoevapotranspiration system.

What we did at this site was, we installed multi-level monitors here, and simply went out once a month for 2-1/2 years and collected gas samples, pulled gas for 24 hours, put it through an ice chest that had some ice in it. And the data that was used with our regulators to allow us to run that system based entirely on a model that Cornell University did.

So in this case here's the shallow, and then increasing depths. And what you see is the tritium concentrations that were measured are the red squares here. And then the tritium concentrations that are predicted by the model are the blue. And it was this 2-1/2 years of data that our regulators said, you can now run the model and use that to run your phytoevapotranspiration system.

So that represents about 5,000 samples in the course of 2-1/2 years. And 5,000 samples, there were like 10 samples that we weren't successful in getting. Which is different than the section lysimeters which had about a 60 percent success rate.

Several contaminants are candidates for direct monitoring. In addition to tritium you have mercury, antimony, arsenic, tin, and others.

Just as a synopsis, direct measurement of gases is applicable to characterization in monitoring, the limitations are that relatively few contaminants express themselves in the gas phase, and that solid, solution equilibria are complex in gas-based concentrations and are controlled by biological reactions.

What I want to do is, this is a thought experiment - I'm not advocating we go out and do this, except possibly for tritium - but what I'm doing is, I'm simply trying to go through this process very quickly.

Another example is radon to monitor uranium or thorium. This is a case study where we had an area of gamma anomaly for bismuth-214. So we flew over the site, and we said, oh my god, there is a bunch of bismuth-214 here, and someone said, there's access bismuth-214. There must have been anthropogenic uranium that was put up in that area.

And we went back to the site, and just tried to figure out what was going on. And it became clear when we started looking at the decay chains that what happened is, you have your uranium that goes down here, and you get the radium - radon-222, and it's a gas. You come down here, and you get the radon-220, and it's a gas.

And so the hypothesis that we came up with was that what we had was, uranium and thorium that were at some depth, and the half life of radon-222 is five days, and the half life of radon-220 is 50 seconds. And so basically what we had was, radon-222 migrated to the surface and ended up showing up as bismuth -214, whereas the radon from thorium was not making it to the surface because of its transport time.

So how can we use that in monitoring? So if we have a site that has mixed radioactive materials, not purified uranium, you essentially have a cap. You have the radioactive spoils here.

If I put in a vadose zone causometer, and then I show a cross section, A-A prime here, and I sample from down here, I sample throughout, I basically am going to have a radon curve that looks something like this - not particularly useful, because what you have is the large body of radioactive material that is emanating the radon. You have it varying as a function of moisture content, and all kinds fo other things, and it gets a little bit messy.

So let's try to be creative. So what we said is, we've developed - we've looked at and other people have, barometric check valves. So that when barometric pressure goes down, you are under this large cap, you essentially slowly suck gas through these radioactive spoils, and so now what you have is a general trend of gas moving toward this over time.

And what this does is, that's going to sharpen up that radon right beneath the spoils. And then if the radium and other source material moves down into the screen zone, you are going to get the appearance or radon in the screen zone.

Once again just a thought experiment, but we are simply trying to encourage creativity and flexibility within the tension of having to have rigor and ability to document.

And then finally diagnostic gases, and this is the most classic example. What you have is, down at the ground surface you have oxygen that comes down and then slowly used through a isotropic homogeneous biologically uniform media. And then you have carbon dioxide coming up, across the site, a cross section is going to have nothing going on.

This is really for potentially monitoring stabilized nucleides, where reductants are used. What you would have then is an area of high electrons here in the center. And then you have rings of different gases, reduced gases here, methane, hydrogen sulfide, intermediate gases, carbon dioxide, carbon monoxide, and then oxidized gases on the outside.

And then if you plugged profiles of all of these gases which most of which can be analyzed on site for almost no money, you essentially can document that your contaminants should be stabilized without having to do lots of wells and lots of contaminants.

So the conclusions for the gas phase are as follows. We think that innovative monitoring for radionuclides might benefit by an expanded view, and by considering alternative phases for sampling.

Gas samples provide for early warning in terms of vadose monitoring. It may be more reliable than suction lysimeters for appropriate contaminants, and that was only a few perfect contaminants - but tritium happens to be one of them.

Tritium is probably easier to measure that helium-3 or helium-3 helium-4 ratios. That's why we selected to do that, but any of those things are fine.

And the three different approaches to gas monitoring - the direct and the indicators - can be combined with each other and traditional monitoring and with sensors to address the inherent limitations of each of the various approaches.

So there's my summary thoughts again. And what I'm going to do is very briefly do the geochemistry. And this is really - I'm going to show two slides that I developed for state regulators when they had a list of questions one time, and they were having a workshop.

They wanted to know about bioremediation of metals and radionuclides. And basically for metals and radionuclides I split what can be done into two categories. You can either stabilize them and keep them there, or you can extract them. Except for radioactive decay there is no degradation.

So stabilization includes redox processes, directed precipitation reactions, indirect manipulations, and thermal stabilization can be deployed by additional permeable reactive barriers, et cetera, and extraction.

So what I did is, I defined these things for them, and then they gave me a list of contaminants. And what I did is, I made them a consumer reports table that looks something like this, and I basically worked through a thought process for each element and did its geochemistry.

And I said, for tritium there is really not much that can be done except extraction by either plants or as a gas phase. But then as you get into some of the other things, you have more potential. And then I put in italics, because they were interested in the biological things, I simply put this in to show that what the National Academy has suggested to DOE is, they consider defense in depth as an important part of their work.

And defense in depth means that you need to design your facilities that they are going to be robust, and have something that picks up if something else fails. And I think monitoring can be built into that as well.

So for example it may be that you put an electron scavenger within a facility as part of its original design, and then monitoring can simply be to monitor the presence of that. That gives you a safety factor if your original line of defense leaks.

So then I added one to my slide, and I basically said, you need sensitive and leading indicators and trigger technically based operational decisions or contingencies, and I think that that is really important.

So in terms of the focus questions, I would say that the take-home message is that plumes tend to form very specific geometries based on the driving forces near the site. That is something that has probably been underrecognized and underutilized in interpreting data.

The location of screen zones, I think the opportunity for vadose monitoring has been underutilized.

And I think that basically by incorporating some of those ideas you can not only characterize existing plumes, but possibly also come up with fairly robust systems for new facilities as well.

DR. CLARKE: Thank you. We'll keep moving.

The next presentation is modeling and monitoring basis for tritium plume management.

We have two presenters, Tom Burke and Mike Hauptman from Brookhaven.

And Tom will start the presentation.

BROOKHAVEN NATIONAL LABORATORY

MR. BURKE: Good afternoon, how are you doing everyone. My name is Tom Burke. I'm with Brookhaven National Laboratory.

What we are going to talk about today, me and Mike, my partner, we're going to be talking about what we did with the HFBR tritium plume.

I am going to talk about the investigation and modeling, and Mike is going to focus on the remediation aspects.

I want to give you some background about the laboratory and the lab, and the context within which we did this.

First off, I've been a superfund project manager at the lab for the last 15 years, so this investigation and this problem and this remediation occurs in a substantially different context from I think the NRC, where you have siting licensing issues.

We had contamination issues before the tritium plume happens. To give you an idea, it's a fairly large facility, we currently have 17 ground water treatment systems. We have over 50 extraction wells. We're pumping 4,500 to 4,700 gallons per minute through those systems.

Most of them are for chlorinated solvents and BOCs. We have two strontium-90 treatment systems, handling the strontium-90 plumes.

And into that mix, we have the tritium.

Which button is it? Okay.

Picture of the high flux beam reactor in quiet days.

Where are we? We're in New York. We're on Long Island. We're on the eastern part of Long Island, in Suffolk County. Sole source aquifer, drinking water aquifers.

The laboratory was established in 1947. Prior to that it was an army base in World War I and World War II. We have approximately 2,700 employees. We're about 5,300 acres in size. That makes us about eight or nine square miles in size.

And the aerial photograph of the center of the laboratory, the industrialized center, this is the high flux beam reactor. It's located approximately 1.3 or 1.35 miles from the site boundary.

Drawing of the laboratory: here we are, high flux beam reactor about 1.3 miles from the boundary. The boundary along the southern edge is the Long Island Expressway, and there is a residential community south of the property.

This map is lined up north to south. The general ground water flow through this area is to the south.

An aerial view of the high flux beam reactor. That's the high flux beam reactor. This is another reactor, the graphite reactor, Brookhaven graphite research reactor, 1950-vintage.

Another map showing you the high flux beam reactor, ground water flow to the south. Of interest here, this is where the location of the spent fuel was. In our investigation we determined that the spent fuel pool was the primary source of contamination, even though after exhaustive investigation by us and others, there were other contributors to tritium at this facility. But the real primary one, they were smaller, the primary one was the leaking of the spent fuel pool at a rate of about six to nine gallons a day.

A cutaway of the reactor. Here we have the fuel canal, the spent fuel pool. The ground elevation here is approximately 70 feet to the water table. The bottom of the spent fuel pool is about 20, 23 feet to the water table. So we have about 20 - 23 feet of vadose zone that Brian had spoken about before.

To give you an idea of size, the inside diameter, the foundation. During the initial investigation, we did not drill through the containment zone. We only drilled outside the building. We did drill through the containment zone subsequently many years later, but during the initial investigation phase, we did not. It was only outside work, because at that time the reactor was still going to continue. It did not.

A little history on the reactor. It basically operated for about 30 megawatts, even though it was designed at 40 megawatts. It started in 1965. It basically operated as a research reactor, much different from your power reactors in size and power at 30 megawatts.

It was shut down in December, 1995, for routine maintenance and refueling. In December, 1996 we discovered tritium in the ground water outside the reactor. The source was ultimately tied to the spent fuel pool.

We began the investigation and remediation of the tritium leak under CERCLA. The Brookhaven National Laboratory was already an existing superfund site, and NPL site, and a CERCLA site.

Mike and I were both project managers in the superfund CERCLA office at the laboratory.

It was decided ultimately by the secretary of Energy to close the reactor based on program budget concerns in November of 1999.

The regulatory framework that we found ourselves in, at the laboratory at BNL we were a CERCLA superfund site, and we were at NPL in 1989.

In 1992 we had an interagency agreement, since there were issues of sovereign immunity. We had an agreement with the EPA, the state DEC, and another player, important player, was our local regulatory agency, the Suffolk County Department of Health Services.

In our site we had 30 problem areas, 30 contamination areas, of which one of them was the high flux beam reactor.

To give you a little geological, hydrogeological background, as I mentioned before, it was a sole source aquifer. The deposits were basically 1,500 feet of unconsolidated deposits above the bedrock, Pleistocene glacial tells, outwash deposits. Our hydraulic connectivity was in the range of 175 feet per day. Our ratio of horizontal to vertical gradient was about 10 to one. Our annual precipitation was about four feet of water, of which about half of that made it to recharge.

The depth to ground water from the reactor was a little bit over 70 feet. The bottom of the fuel pool was about 20 - 25 feet away.

At the laboratory we had a mix of contaminants. We had volatile organic chemicals, chlorinated solvents, up to about 7,000 parts per billion; the highest tritium we ultimately discovered was a little bit over 5 million picocuries per liter, and we also have strontium-90 up in the range of 3,200 picocuries per liter, not in the tritium plume but elsewhere. But all this is occurring on site.

The reason I put this map up, here is a map of the laboratory. Every little yellow dot is a problem area that was part of the CERCLA superfund operation that was going on since the early 1990s.

Here's a picture of the spent fuel pool that was ultimately emptied and drained to stop the source term, to prevent any additional material from leaking out to the environment.

The contamination was basically tritium, 40 to 140 million picocuries per liter. There were some trace amounts of heavy metal. There were no other significant radionuclides.

It was ultimately determined that our leak rate was about six to nine gallons per day over a period of about 12 years, releasing approximately five to six curies into the ground water.

Here's a picture of the spent fuel pool. It was approximately 65,000 gallons. After it was emptied, a liner was put in in anticipation that we were going to run the reactor again. We put the line in; we didn't run the reactor again; but we still put it in. If we were going to operate it, this would have been in place, and there would have been interstitial monitoring going on to warn us if there were any other future problems.

The initial characterization of the high flux beam reactor tritium discovery was significant. It actually occurred on a very accelerated aggressive schedule. There were a number of issues occurring at that time.

Normally we would not proceed in such an aggressive fashion. If I had to do it again, we'd hopefully be able to do it a little slower.

But what we did is, the initial characterization, everything we're going to talk about, happened in a period, from beginning to end, in a period of about four to five months.

We did a lot of subsurface investigation, well drilling, piezometers, geoprobes, vertical profiles, installation of permanent monitoring wells.

The geoprobes and the vertical profiles in this terminology I'm using, these are temporary wells, and they are multilevel temporary wells, where we're taking samples at different locations throughout the depth of the aquifer to help us in delineating the magnitude and extent of the contamination.

What we sampled for, we sampled for tritium, of course. We samples for gross alpha and beta; some strontium-90; and VOCs. The reason we had to sample the VOCs was, there was a colocated plume, unrelated sources. But there was still a VOC chlorinated solvent plume in the same place as the tritium was.

Modeling: we did a lot of modeling. The model we used was MODFLOW.MT3D. What was useful for us, before this problem happened, I had spent a year developing the detailed conceptual site model with our consultants to put together a fairly robust complicated model that was the size, it covered about 200 square miles, and it was a large sort of regional model from which we were going to use telescope mesh refinement to come in and do more detailed modeling for more site specific local areas.

This is a significant effort, and it's important, because we knew we had a lot of problems at the site. We were already doing this, and this was basically completed for the most part when the tritium happened, so we were able to come in and model the tritium. So this is not the only modeling we did.

We did a range of modeling, because some of this is simple, some of it is complicated. Some of it only takes a short amount of time; some of it takes a long time.

We did simple mass balance calculations, what leaked out, what do we think leaked out, what can we find in the aquifer down gradient of the reactor?

We did analytical 2-D/3-D modeling, and we our more complex numerical MODFLOW modeling. This is a flow transport.

Interestingly enough, even though we were doing different types of modeling, the range of the modeling provided similar results to each other, even given the fact that there were slightly different assumptions and strengths and weaknesses to the model.

As I mentioned before, we had the MODFLOW, and from that we were going to come in and do local finite difference models, which was the MT3D.

The interesting thing that happened when we modeled it in MODFLOW.MT3D that surprised us at the time was, it showed that the plume was in equilibrium - or not in equilibrium, but close to being in equilibrium, which surprised us. And we didn't believe it at first, but we went back and we remodeled it again. We had somebody else model it differently. And it kept on telling us - giving us the same results.

And it convinced us that the plume, the tritium plume, which I'll show you pictures of shortly, was moving down gradient, but it was at a point that it was diluting, dispersing, decaying at the same rate that the source term was releasing it to the environment. It wasn't quite at equilibrium, but it was close to it. And that we found to be surprising, because it wasn't like our classical chemical plumes that smear a lot, and obviously this has decay in it so it goes away much quicker than we had anticipated or expected. And that was a big surprise.

And in our regulatory meetings and contentions, it actually took us a long time to get them on board, and have the regulators, EPA and the state, to agree that what was occurring in the subsurface and the aquifer formation was as it was represented in our models.

The MODFLOW.MT3 plume, it matched very very well to what we had characterized on the ground. So when we showed the modeling results, we showed this, and when we showed the characterization results, we showed this. And they weren't exact, but they were close enough. And for those of us in the modeling and groundwater investigation business, we were very happy that they were so close.

The tritium transport process: some of these are significant, some of them aren't. But you always have to anticipate them, or at least account for them in your modeling exercises.

Certainly you have your advection primarily. You have your dispersion. That includes molecular diffusion, which is negligible. You have obviously your radioactive decay. Retardation is always an issue, but for tritium retardation is nothing.

Also for this system that we had chemical and biological reactions are basically considered nothing for the model.

What is driving this is the groundwater system, and our groundwater heads and groundwater flows.

The initial characterization that we did, we had three geoprobes operating, we had nine drill rigs operating simultaneously. We were installing profiles, vertical profiles, with F-10s, 18 hours a day, at 100-foot spacing, at 180 down to almost 200 feet deep, taking samples every five and 10 feet into the aquifer.

We were using five analytical labs simultaneously with quick 48 hour turnaround times.

Initially we installed 30 piezometers; 51 monitoring wells; 45 geoprobes; 77 temporary vertical profiles. We collected over 1,900 samples.

And I apologize, this may differ from what's in your handout. That was a subcost. The plume characterization, and the remediation that Mike is going to talk about, cost on the order of $6.3 million. And we're talking the bulk of that cost occurred in a four, five, six month period, which is very aggressive.

Currently what we have is, we have a permanent monitoring well network of 159 wells. This is augmented by annual temporary wells, combination of vertical profiles and geoprobes, where we drill and we install, we take samples. This costs us about $180,000 a year. Eighty thousand is for the monitoring well network, quarterly sampling; and we have maybe another 100,000 that we're using for installation of temporary wells.

What we found is that even though our transport understanding of the plume was very good - we know what it will be as it goes down gradient - there are things we can't control that shifts the plume a little bit to the left and a little bit to the right that makes the monitoring wells that we put in that were once good to be no longer in the proper location. And hence our monitoring well network becomes inadequate.

So we augment it with permanent monitoring wells. But we also go in and put temporary vertical profiles and geoprobes to help us continually characterize the plume. Because the modeling allowed us to match up the source term and the characterization to the predictive path of the plume.

And just remember, the MODFLOW is the flow model. It tells you where it's going. The MT3 transport tells you what it's going to be when it gets there.

Our flow model was pretty good. We had close to 200 calibrated head targets with very good residuals in it that were very, very helpful for the flow model that helped us gain confidence that the model we were using was the appropriate model to use to model the transport of the tritium.

A picture of the plume. This is the high flux beam reactor, lined up north to south the plume is. Obviously you have higher concentrations in the center of the plume, and lesser concentrations at the leading edge.

The distance here is about 12 years of travel time. The distance here is about 3,600 feet, which makes it about 3,200 - 3,400 feet to the site boundary.

Another picture of the plume. Once again there is the high flux beam reactor. Higher concentrations obviously out front.

Here you will notice there are multiple transects of wells that were placed in here, here, here, here, here, here and at the site boundary. The purpose of these wells was not only to prove to ourselves, but to convince others - we had to, the regulators and the public - that the tritium plume that we had discovered was not leaving the site proper.

Based on all those samples, we had and have very detailed cross sections of the plume, which enabled us to put it in the model, to give us greater confidence that we could predict where it would go, and at what concentrations it would be when it got there.

This is just one of the typical cross sections. It may match up slightly to the one Brian had shown you. The high flux beam reactor coming down.

The first 200 feet or so on the property is what we call the upper glacial aquifer. Even though we call it homogeneous, and we think it's homogeneous, and on some level it does act homogeneous, things are not as homoegeneous as you think it is.

If I had to go back and do this again, I would probably collect more data for variations on hydraulic connectivity, with CP, comopetromity of the bore hole physics, than we initially had done.

If I had to do this again, I'd revisit the use of West Bay multilevel systems again. We looked at at the time, but there were a number of reasons we didn't pick it, even though the West Bay multilevel systems offer you very, very good information.

With our formation we can do 100 - 120 feet with a geoprobe at fairly cheap costs, so it still makes sense for us.

Our clean up decision, in our record of decision: all the work that I mentioned that was done in a relatively short period of time was done under a removal action which was one of the terms, or one of the actions you can take under the superfund CERCLA program. Ultimately, it's incorporated into a record of decision.

Our record of decision said we would clean up the tritium plume to MCLs in 30 years or less. Even though there's been a lot of talk about dose rates, and that's very important for the NRC, what drives us, or what has always driven us, is the drinking water standards of the MCLs for our contaminants. For this it's 20,000 picocuries per liter.

Another aspect of our clean up decision that we had to guarantee that we could prevent or minimize further migration of tritium in the groundwater; the plume growth. The plume as we characterized it wasn't going to get any bigger, or significantly bigger than it already was, and we were going to monitor to confirm that. And if that didn't happen we would have to take additional actions, contingencies and trigger values that Michael will talk about.

MR. HAUPTMAN: Hi, everybody, switching in midstream.

I'm Mike Hauptman, and as Tom said, I've worked with him much more on the mediation end rather than characterization.

I just wanted to go back to this slide for a second. Tom mentioned the plume was in equilibrium. And that was something that we had to demonstrate to regulators and all our stakeholders, and that was the key to this record of decision statement, prevent or minimize plume growth.

We believed it. Our modeling showed it. And then we needed to demonstrate through monitoring, iteratively, that this was the truth. That's the crux of what I'm going to be talking about.

What happened, I'm going to go through details now, in order to maintain this equilibrium and generate credibility with the regulators and with the stakeholders, through many, many meetings the hydrogeological excavation based on the iterative modeling and monitoring that Tom was talking about, and then the monitoring that we did previous to this actual record of decision led to a threefold approach with two active and one passive measure.

The first active was a pump and recharge system at the head of the plume. The second was a low flow pumping near the source to remove high concentrations of groundwater. And then monitor natural attenuation which is the EPA's term, but which is really managing the plume so that it stays within that record of decision defined envelope; no further plume growth.

So yes, the plume was in equilibrium, but at one point we had to do this, and at another point we had to do this, to make sure it stayed in equilibrium.

How did we find out when and how to do that? Through modeling and monitoring, and I'm going to go through details of how that was achieved.

So the first was what we call the pump-and-recharge system. And the modeling here provided the groundwater flow direction of where the plume was heading. This was a flow-based remediation in which we pumped the groundwater at the head of the plume back to the top to give more time for dilution, dispersion and decay.

So the model provided the flow directions, the capture zone estimate at the leading edge of the plume; the time to clean up, how long would that plume continue to travel toward the pumping system; the pumping well locations, and the appropriate rate in order to capture the plume. That was provided by the model.

But to verify that we had to do monitoring. So once the system was established, there would be a well downgrading of the system to look for breakthrough, and there were permanent wells and temporary wells used throughout the plume to make sure that it was behaving as anticipated.

It was done in 1997, and we did include carbon treatment. As Tom said, there was a colocated VOC plume.

So here is a schematic of what happened. This is the plume, HFPR. You will notice also that there is a bifurcation here, and it looks like the center line of the plume is headed more to the southwest than this bifurcation which is to the southeast.

Notice that we put our pumping wells at the southeast leading edge, because the modeling, the flow modeling, had demonstrated that the natural gradient would take the plume in this curved direction.

From here the wells would recharge it up inside to allow more time for continuing decay.

But this as you can imagine was a large issue for the regulators. Because here again, there was a model saying one thing, but the data collected up to this time was saying another. So what do you do?

Well, we talked with our regulators. We had them involved early, and our other stakeholders. And we said, well, we believe this is due to former pumping of the supply well over here on the western side, and that time will show that this is where the plume goes.

And that was at that point in time where - we didn't know that yet - but our modeling indicated it.

That's just another picture of it.

Now I'm going to talk about the operation of this. One way that we helped the stakeholders to buy into our concept, it's not up here, but we had trigger levels at the leading edge of the plume.

So for example these pumping wells would pump as long as there was a level of 20,000 picocuries per liter here. So we built in a credibility if you will, safety, into our conceptual and numerical models, so it would help bring people on board with our concept.

So again, there is a trigger - which is still in place today, even though the wells aren't pumping. If this level here exceeds 20,000 picocuries per liter, the pumps will be turned back on, and then the recharge system will continue to operate.

So again as far as the operation, the modeling provided the groundwater flow direction, time to clean up, and pumping rates, and quarterly monitoring verified that.

We had three extraction wells, a total of 120 gallons per minute, and after three years of pumping it was shut down because the trigger level was no longer exceeded.

But we had to enter a standby phase, which we're in now, for 10 years, until 2014 or 2017, in which case, as I said, we can restart those pumps if necessary.

Just the VOC treatment system.

Now the second aspect of our plume management, this was the second active aspect, was the low flow extraction. And I'd like to talk here about the design, and how monitoring and monitoring helped us with that.

First of all, what is it? This is the HFDR. Here is an upper portion of the plume, I would say the highest concentrations back in 1997.

The idea was that, well, there are some high concentrations right here in front of the reactor up to 5.1 million picocuries, which the model showed, if allowed to migrate all the way down gradient, would break through that envelope that we were legally bound to maintain, and in fact make it through to the site boundary, which was definitely not going to be allowed by the regulators.

So there was a system designed that would extract a certain amount, certain volume, of the highest concentrations, which we did do. And again, the model showed us at what level to start pumping, which was 750,000 picocuries per liter, and when to stop pumping, so that we wouldn't entrain too much clean water. And between the 500- and the 700- the models showed us that if we let the rest of it migrate into its existing envelope, it would remain in that equilibrium that Tom talked about.

And what I should add is that it was very important to maintain as high a concentration of this pumped water as possible, because it cost us $10 a gallon to dispose of it in tanker trucks out of state, because the regulators in our state wouldn't allow us to do anything else with it.

DR. HORNBERGER: Did you take it to South Carolina?

MR. HAUPTMAN: No, we took it to Tennessee.

So again it was pumped it there were greater than 750,000. A total of 95,000 gallons, and about .2 curies out of that original six were removed - I'm sorry, six was the total that leaked, but the one was what we had in the groundwater.

And the system has been inactive since April, 2001, again, because we haven't triggered that number.

So the modeling says, well, if we don't trigger that number, we don't have to do anything.

And because we in the interim had been collecting more and more monitoring data that verified our concept of the model, the regulators and other stakeholders began to be more and more convinced and comfortable with this approach, although these trigger levels still exist. So again there is a safety built into the record of decision that should this be exceeded we have to restart this system's operation.

Just a quick report on the performance of this. This was the modeled goal of how much to be extracted, and this was our actual. And you can see it was about - is that about a year. And this is pretty good. Because what we did was, we used direct push technology to put a geoprobe in the ground and pump from that.

So this is modeling compared to actual. Again, helping build credibility with our stakeholders. And this is very busy. This is just a comparison, or showing us how we're working. So this tells us that our concentrations remain relatively high; average about 500,000 picocuries per liter, so we could justify spending the money to dispose of this water.

Now the third aspect that I talked about is tritium plume management - the whole thing is really tritium plume management, but this would be the passive part that we're in now. So the pump and recharges is over, and the low flow pumping is over. So what we're left with is tritium plume monitoring.

And that relies heavily on monitoring to verify the model plume behavior. And remember, I spoke about that bifurcation of the plumes - earlier - where we had one concept, and the other people, well, we're not so sure. And it did turn out that we were correct.

We used geoprobes, vertical profiles and permanent wells in a mixture to maximize the efficiency. Because if you did all of this in permanent wells, other people have shown that the plume has a tendency to move out of the monitoring network, and then you've got to put it in all over again. So geoprobes are really the best approach that we've found for our plume. That's the low retardation coefficient.

And again, it's an iterative approach. You've got to do first the model, then the monitoring. The model - somebody asked us this morning, the model tells you one thing, are you just going to put the well there and no place else?

Yes, where you put the well, and the data point there, and the model's data do not agree, then you have to ask yourself again, is the conceptual model off? Is my monitoring technique wrong? Both come into account.

So this is what ended up happening from 1997 to 2004. We've had significant success in the plume management. This was the original plume in 1997 with its two tails, and this is the plume in 2004 with one tail.

So as I said, the modeling was born out. This is obviously a monitored result. This is what we drew from the monitoring data.

Okay, lessons learned from this experience is that the downgrading portion of our plume is naturally attenuating. We still have that pumping restart of 20,000 picocuries per liter just in case it doesn't behave the way we have anticipated and the way the monitoring has shown all along.

The upgrading portion is attenuating. However, as Brian alluded, there is the unsaturated zone that sometimes provides a little bit of increased concentration right near the reactor.

But again as long as it doesn't go above 750,000 picocuries per liter, then we just manage it on site, through dispersion and decay.;

And since 2001, that 750,000 has not been exceeded.

That's going to continue for about 10 years until at that point the modeling indicates that everything throughout our site will be less than 20,000 picocuries per liter, less than drinking water standard. And of course we will be every year, we need to verify if this is indeed taking place, and if not, something else will have to be done.

But so far it seems to be on track to achieve that point.

I mentioned this before, permanent wells in our groundwater, and perhaps most unconsolidated has the drawback of - or several - but one is dilution of the contents. The other is that through plume shifting those -- the monitoring network may no longer be applicable.

So we've come to rely more and more on temporary wells, geoprobes and vertical profiling.

DR. CLARKE: Mike and Tom, thank you both.

MR. HAUPTMAN: Thank you for having us.

DR. CLARKE: We have one more presentation before the break, and that will be Steve Yabusaki, a uranium reactor transport in a vadose zone aquifer river system.

Welcome, Steve.

PNNL HANFORD

MR. YABUSAKI: Well, thank you for your stamina. And this is a continuation of death by viewgraphs.

(Laughter)

I'm going to be talking about some work that we're doing on the Hanford site.

My name is Steve Yabusaki. I am part of a larger project called the Remediation and Closure Sciences Project at the Hanford site, informally known as the Hanford science and technology program.

I'll be talking about an ongoing project that we had where we're building, or rebuilding, possibly, and testing the conceptual process models for low transport and reactions in this particular system where we have a hydrologic system that has a coupling between the vadose zone aquifer and the river.

Some take away messages that might be useful to this workshop are this concept that this monitoring and modeling needs to have some consideration and consistency with the scales of controlling processes that are out there.

These are both temporal scales as you'll see in this presentation as well as spatial scales.

The other is that modeling provides the systematic framework that is actually the organizing principle that can assist in the characterization of processes and properties, work hand in hand with sampling and monitoring scheme design, and in the interpretation of monitoring data.

So it provides some hopefully a mechanistic and quantitative vehicle that you can test some of these ideas on.

Mike Fayer gave a pretty good description of the Hanford site. This is once again the Hanford site. We have the Columbia River here.

The 300 area is this tiny little thing on the southeast corner of the site here. I'm going to call your attention to Priest Rapids Dam, which is actually outside the site, but at the northwest end here, and that's because this is a run of the river, hydroelectric dam, and it's releasing water into the Columbia River in response to power demands. And that is going to have, as we will see later in the presentation, that has a significant impact on the river stage and the driving force for a lot of the flow field in the groundwater system of the 300 area.

So once again we're in the south central Washington here. This is a blowup of the 300 area. I assure you it looks much better on the screen of this computer here. And let's see if we can zoom in on that a little more.

Just for scale, this bottom distance is about one kilometer, so it's about one and a half kilometers this way.

As you can see, this is a site with lots of buildings. This is actually the historic disposal ponds. This is the original pond called the south pond here. There's a north pond that was created a few years later.

These were then terminated, and the most recent active disposal facility here is what we call the 316-5 trenches over here.

All these dots here are monitoring wells on the site, and there is a routine surveillance program that is actually providing information that we use in some of the modeling and characterization activities.

This is a picture of the site in 1962. So you can see that the ponds were both active at this point in time. You can see some sanitary leach trenches.

Those trenches, the 316-5 trenches that were not built yet, that were built in 1975, and all this would not recognize at this point in time, these sites have been excavated and backfilled, so a lot of this is completely different landscape than it was back in 1962.

The operational history of these ponds and the trenches, this hole in what we call the 300 area, those buildings that you saw on the map, was the principal fabrication area for the nuclear fuel elements for the Hanford reactors, and the production of these fuel elements resulted in uranium liquid waste streams that were discharged to these unlined waste ponds, the south process pond, from 1943 to 1975, and the north process pond, from `48 to `75.

There are also some other trenches that were being used for a short time period. This is sometimes called the 307 trench, from 1953 until 1963, and that the 316-5 trench, which I showed you earlier, which was the most recent disposal surface facility that we had there.

It's 10 meters to the water table. We have a fairly poorly documented waste disposal history. But some of the estimates, just for the ponds alone, were that we had 70,000 kilograms of uranium discharged there; very high discharge volumes associated with that. And with this fairly shallow distance to the water table, it's not surprising that we ended up with some very large uranium plumes over the entire aquifer of this site.

So this contour here, at least at that time, was above the 20 microgram per liter standard at that time. It's now 30 micrograms per liter.

You can see that the dominant feature from this is a hot spot right at the south end of the 316-5 trenches.

In response to this situation, that they had with the contamination of the groundwater, there was an expedited response action that was invoked in 1991. Contaminated soils from these process trenches were removed, and there was an end of the discharge of uranium to these process trenches.

Based on some of these assumptions, and the development of a groundwater flow and transport analysis modeling, it was predicted to be cleaned up to less than 20 micrograms per liter in three to 10 years.

This is the 1994 footprint of the site, and as far as the uranium plume. And it doesn't show up very well, but that is the 30 microgram per liter concentration level. And this is that same contour level in 2005.

So in the 11 years intervening between 1994 and 2005 we did not see this level of cleanup in the aquifer itself by natural flushing. And so that brought up the question, the dilemma that we're in right now, which is, what is going on in the site, and how did it differ from the 1993 conceptualization of the process of what is going on in that site?

As far as that modeling study, it was a three-dimensional saturated unconfined aquifer. The vadose zone was not modeled. They were instructed not to model that system, because they were told that any contamination would be taken care of by the excavation.

They used monthly time steps in the modeling of the river stage fluctuations, and the uranium mobility was controlled by a best estimate constant Eekl of one to two milliliters per gram.

There was no interaction between the aquifer and the river, and there was no interaction between the aquifer and the vadose zone. So that's how they ended up with the three to 10 year estimate for the cleanup.

One indication that the vadose zone is a potential factor in the longevity and persistence of the uranium flow, on the top here is the water levels in the well closest to that 316-5 trench. It's well 399-1-17A. And these are the uranium levels.

And you can see that after this expedited response action, you can see every high peak of water level in that well - well, hopefully you can see it - is associated with a high peak in the uranium concentration at that site.

So you can imagine that water level moving up, possibly into contaminated sediments, and an increase in uranium concentrations in the groundwater.

So based on that information, we developed this vadose zone aquifer river system modeling. There's both 2 and 3-D modeling going on at the site. Some of it is actually being done on an NRC project also.

We wanted to take a look at some of the behaviors caused by this river stage fluctuation, and so we're using - I'm going to be showing you modeling results from this 2-D cross section here in this system.

You can see that this is based on our best - or most current hydrogeology. It's constantly being updated based on new information that we get.

In this case the modeling is now going to be driven by hourly river stage fluctuations. One of the impacts of incorporating or including the vadose zone is that we now have river bank storage, and we need a seepage base, or a dynamic seepage base boundary condition in order to have that behavior right at the river interface.

And one of the most important things we're looking at is this sort of leaching or release of uranium from the lower vadose zone-contaminated sediments due to these water table fluctuations.

This is the cross section that we're modeling, the most notable unit is this Hanford gravel unit that's on the vadose zone, as well as the top of the unconfined aquifer. This is about 10 times more permeable than the unit beneath is.

And you can see some of the effect of that. This is a - these are velocity vectors from the modeling that show that the water table is right around here, that this is the dominant flow path to the river through this Hanford formation.

As I mentioned, this power peaking release of water from the Prince Rapids Dam, and what you can see here is, these are the water level - the river stage elevations in the Columbia River at the 300 area, and this is during a period from 1992 to `93, and you can see that everyday here there is a significant variation. The average fluctuation range in the river is half a meter. As Mike said, that can easily go up to one and 1-1/2 meters. It's very common to have it over a meter in a single day.

So the consequence of this large degree of fluctuation on a diurnal basis is that what you have here is 24 hours - every two hours we're showing the simulated flow direction, so if you see a blue, that means the flow is going to the river; if you see oranges and yellow, that means it's going inland.

We begin with flow going to the river here. It's approximately one to five meters of flux rates. And you can see that by 2:00 a.m. we actually have a reversal. We have an increase in the magnitude of that velocity coming in there.

And then later on in the day, at about 2:00 o'clock in the afternoon, we begin to have another reversal going into this system.

And so what we have going on is a sort of what we call a washing machine effect. We have this continuous interchange on a diurnal basis, between the aquifer and the river.

This is hopefully an animation of the tracer transport. And so this includes, this is the water table fluctuation, and one thing I wanted to tell you about, you are going to see a seasonal variation. The water table, the river stage goes up through June, as the high peak for the snow melt discharge. And you can see that it actually moves backward into the inland before it starts moving towards the river as the seasonal water level drops.

So you can see both the impact of the diurnal variations in the fluctuations in the water table there, as well as this sort of seasonal effect that is moving this water up this way.

You can see that the Hanford formation of course is dominating the flow path here. These are actually massless advective particle indicators showing the direction of flow in there. You can see that it's pretty much moving directly toward the river there. And things are moving much, much slower in the Ringold formation that sits beneath it.

Another point on top is that we end up with a fairly large zone in the unsaturated zone, the lower saturated zone here, where the tracer is sort of maintained and it doesn't move as far as what's going on in the vadose zone.

So this gives some indications of some of the behaviors that we see out there, where you can have this major groundwater flow, but as soon as the water table goes up, you are also mixing it into the vadose zone, and that becomes a longer term reservoir for the tracer in that case.

We actually did check the model against some locations. These wells don't lie exactly on the cross section that I showed you, but they are close enough that we projected them on to it.

And you can see that there's actually two lines here. The green one is the simulator, which we're using as STOMP. And the blue is the actual hourly monitoring data that we had for this particular time interval.

And these red Xs are actually dates that the well was actually sampled and tape for the water level readings there.

You can see it doing amazingly well. We did not do any calibration to achieve this matching here. That's just what we ended up with.

And we can see that also for this well 4-1.

One interesting thing is that another well, 4-9, we are perfectly in phase with it, but our amplitude is off. So this is the one case where we can actually use the modeling to point to things that we need to investigate about the hydraulics around that particular well.

This slide is to address this issue about the need to - people wonder why you are modeling a groundwater system with hourly boundary conditions. Well, there is an important reason in this particular case, is that there is a mixing zone that sets up.

This is actually a river trace if you will, where we're allowing - we're keeping track of how far the river water moves into the aquifer itself, and the size of that mixing zone it sets up.

And so you can see that if you start averaging this thing over daily boundary conditions or a monthly boundary condition, you could easily lose this mixing zone that sets up there.

So this hourly boundary condition is significant in that it preserves that mixing zone.

You can see that there is actually a seasonal variation in this mixing zone, predicted by the model. And you can see that June, which is typically our flood stage month, of highest water levels in the Columbia River, we actually have the deepest penetration and the largest mixing zone of river water into that system.

September is historically one of the lowest months, and you can see that there is a much smaller mixing zone associated with that.

So the significance of this mixing zone is that the - we get a fairly significant influx of water. This is during the 2002 high river stage event. I'm using the nitrate-low boundary here, contour, to indicate how far that river water is actually moving into the aquifer, the system.

So you can see that it's quite significant.

The other issue is that the river water differs very significantly in its water chemistry from the aquifer water. Most notably, the alkalinity is about a factor of three. You can see the alkalinity in the Columbia River is roughly about 40 milligrams per liter, and it's all the way up to 120 in the groundwater that's deeper into the system.

Some of the other points are the same. Similarly with calcium, it's about a three-to-one ratio also.

So as I said this is also part of a much larger project where there are also some experimental studies going on that are looking at samples from the 300 area sediments, and are doing batch and column studies on them.

And one of the observations here is that this is actually the KG of the system, and it varies by about a factor of three over that same range of alkalinity that I was talking about earlier.

So you can see a very significant change in the sorption behavior of the uranium between the N members of the river and the aquifer system.

The other point was that a column study was done where we actually stopped flow in the system.

And every time we stopped the flow of the column, we had a spike in the concentrations, and that indicates that we have a rate-limited behavior that's going on with the flow rates.

So if we have to summarize the key issue here is that we're actually leaching contaminated uranium settlements, uranium out of those settlements, by these water table fluctuations, and we're trying to understand how this geochemical behavior based on the uranium calcium pH and alkalinity dependencies affects the behavior of the sorption of the uranium in that system between this exchange of river and groundwater.

So based on these experiments, two different geochemical process models were developed for the uranium geochemistry. And the first was preliminary three reaction generalized composite surface complexation model, developed by Jim Davis, at USGS.

And as we said earlier it accounts for bicarbonate, uranium, calcium dependencies.

There is actually a list - you have it; I didn't include it in this presentation -- of 21 uranium aqueous complexation reactions. And that's just the aqueous complexation reactions. We actually have more.

And these are the surface complexation reactions, and they are based on this one strong site and two weak site reaction.

The other approach to capture the mass transfer kinetics, which can occur due to reactions as well as weight-limited diffusion, is taking this distributed rate parameters based on the Gamma statistical distribution.

So instead of using multiple sites to do this, or two sites that typically are, we are actually fitting a statistical distribution of these sites, and with different rates associated with each one of those.

And that distribution of rates is based on this two-parameter Gamma distribution.

So you can see, if you look very closely, there's a solid line that is associated with each one of these two experiments, and you can see that this approach is actually matching quite well with the behaviors that we see out there, that we saw in the experiments.

One of the key considerations when we have this laboratory data, and we want to use it in the field, is that the whole sediment size distribution is quite different from that in the laboratory. So the laboratory is typically less than two millimeter size fraction. All the experiments are performed on that.

As it turns out, in this particular case, only eight percent of the total sediment in the 300 area sediments of the sample that we do have is less than two millimeter size. And you can see that 74.5 percent is actually greater than 12.5 millimeters. So this is a very coarse sediment, and it's largely greater than sand size distribution.

So without any additional information, we assigned essentially inner properties to these greater than two millimeter size, and essentially a portion that's eight percent of the bulk density for surface complexation reactions in this particular system.

Once again, this particular approach has led to ongoing experiments in the laboratory, where we are investigating the upscaling of that behavior.

So once we have done this upscaling, one of the immediate interests in addressing the issue at this particular site was the availability of uranium in the vadose zone that could be possibly leached and transported to the water table, and how long that would take.

We actually have a lysimeter out in the 300 area, and we got this sort of annual average of 60 millimeters per year in that system. And for our sediments over there, that resulted in about a .75 meter per year pore velocity.

So this particular example, we have a five meter system we just emplaced, initially a one meter zone of 30 nanoMohls per gram of contaminated uranium, uranium-contaminated sediments, and watched it go, using both this generalized composite surface complexation model from Davis, and this multisite kinetic model from Junction View.

And interestingly enough, they are very, very similar results, and when we actually looked at the reason for this, the actual sorption is about the same in the system, 12.4 versus 14, and the long travel times, this sorption front requires over 30 years to move one meter, that pretty much minimizes this impact of the kinetic set up and identified in the laboratory.

An important consideration from this - we have this multicomponent reaction that worked to describe the uranium, is that we can begin to see what the impact of this river water chemistry versus this aquifer water chemistry is on the uranium sorption.

And in this case we took these representative values from the system. And you can see that with the initial river water chemistry, we're predicting an aqueous uranium concentration of about six to ten to the minus eighth, molar, in that system, which results in something greater than a 500 liter per kilogram KV.

After the influx of groundwater into this system, this concentration is almost 50 times higher than the aqueous. So this is just showing the impact between N members of that aquifer water and the river water on the uranium sorption.

And this is sort of incorporating the uranium transport into the model. The scale now is totally different. You can see this is actually years we're looking at versus the days and hours that we are looking at for the transport simulation.

So I'm going to do about 10 years of this. And once again you can see how the initial distribution of uranium inside the vadose zone will tend to persist up there, whereas within the Hanford formation you see this transport moving beneath it.

So the issue that we see is that this 1993 conceptual model was a very simplified view, and the actual situation out there is much more complex, and there are a lot of things that are probably responsible for the persistence of that uranium plume there, and some of these are this lower vadose zone uranium being accessed by the high water levels in the aquifer, driven by high river stage.

We have this diurnal cycling of high pore velocities in the system. The pore velocities in the 300 area are about the fastest on the entire site.

And then we have this mixing zone of aquifer and river water chemistries that have great implications for uranium mobility, and that is very sensitive. The size of this mixing zone is very sensitive to the temporal resolution of the models, and it's dictated by this river porcing and the hydraulic connectivity in the system.

Once again this is a work in progress, so we're getting new information from recent campaign of sediment cores that have been taken on the site, and we are employing geophysical logging, and we started that this year. And I think I have enough time to cover that, so I will.

We have ongoing laboratory studies. Those initial results that I showed you before, based on samples from the north and south process ponds, this limited field investigation is giving us four more locations with sometimes continuous core to work with to develop a more robust representative model of the geochemistry.

And basically we have the laboratory studies, and we have these field skill studies, and we're trying to couch this in the context of understanding the field scale uranium transport.

This geophysical characterization essentially is being performed by - it's being led by Andy Ward out of PNNL. And Roelot Versteeg is working with us. He's a geophysicist. And we started off with trying to check out the - how successful we might be. And we had single lines of ERTs and SP lines deployed back in March. And I'm going to be showing you some results from this number three - number two and number three, and this number seven ERT lines.

Just recently last month we deployed a full grid of SP and ERT, and polarization electrodes out there.

I'm not going to show you all the different lines, but they are somewhat similar in that they show a fairly high degree of heterogeneity in the shallow zone. Basically the water table is about 10 meters down in this particular system. So take a ride around this level.

Anyway, so we see a high degree. This is the north-south line that I showed you earlier. This is the east-west, and you can see that there are these zones of higher resistivity that are showing up here, and these are potentially channels. But we don't know for sure, because this is just a 1-D line, and we're getting a 2-dimensional slice of this, and what we really need is a 3-dimensional nature of the system.

One of the more intriguing things that we found out from this, we were eating dinner on the night after they deployed the ERT system, and we were asking Versteeg if we could actually see this river water, the difference in the resistivity caused by river water infiltrating - the influx of river water into the aquifer. And he said, oh, why don't we just leave them on over the weekend, and we'll go see what happened later.

And what you see here is this zone that's set up here at different times, when we have infiltration of the river water into the system. So it's indicating that there's a preferential flow path in this particular location here.

So that give us a lot of confidence that we could get something very useful out of this.

So this is the deployment that we have just put out there. We have 120 cell potential electrodes, at 30 meters spacing. This is 30 meters between each of these. And on each one of these lines we deployed 60 ERT electrodes at five-meter spacing between this. And so then we keep moving this line, so we're getting both very high resolution ERT as well as these SP lines.

And the whole idea with the cell potential is that we want to map this whole area for the - get a detailed description of the flow field in the 300 area for this particular site.

There is some speculation about a gravel channel that exists in this area, and about flows that are going on and transport along the system. So this is covering, this is essentially the south process pond here, this is the north process pond, and this zone in the middle is - for a lot of these cases, even though you saw a lot of monitoring wells on that original picture I showed, within these ponds themselves, there are actually no monitoring wells whatsoever. So these are pretty much unknown territory.

So the quick summary here is that we actually have pretty good confidence of the synthetic data, much of the simulated data comparison that we did looks very good. There is some commonalities in the heterogeneous materials distribution near the ground surface.

And we have this time lapse behavior that is giving us better information on what's actually happening at the aquifer-river interface.

This preliminary 2-D grid of the SP-ERT/IP electrodes is going to give us a 3-D imaging of the lithology, and hopefully, sediment properties such as grain size information, surface area, density, porosity.

And the SP is hopefully going to give us this spatially and temporally variable flow behavior.

One of the most important things we need to do is, right now we just have this geophysical information, we need to put that and integrate that with the bore hole logs, and our known water depth variation to make a better interpretation of the lithology.

We are using the hourly water level to help with that identification of the flow field from the SP survey.

The IP is going to be used primarily for material property distribution, and this whole exercise is predicated on developing a list or locations of permanent electrode locations for this particular grid.

And of course we'd like to take this new geophysical information and integrate that into the flow and transport models.

And with that, I'm done.

DR. CLARKE: Thank you, Steve.

It's almost time for a break, so let's take it and resume at 3:30.

(Whereupon at 3:11 p.m. the proceeding in the above-entitled matter went off the to return on the record at 3:32 p.m.)

MEMBER CLARKE: Okay. Let's resume, please. We did have a member of the public that wanted to ask a question. Diane, are you here?

MS. DeRICCO: Yes, I am.

MEMBER CLARKE: Can you come to the microphone now? Thank you.

MS. DeRICCO: Hi, Diane DeRicco with Nuclear Information and Resource Service. I wanted to know what the -- this morning there was a lot of talk about - I'm not sure what the exact term was - but levels of measurement in plumes that were insignificant or not significant enough for the amount of effort that was going into tracking them. And I wondered if you use 10 CFR 20, or what is the determiner of what's significant? And then I also wanted to know if there were examples? We're getting a little bit of that this afternoon, of plumes that the NRC has required licensees to exhume because they were significant, or if it's DOE, then whether through self-regulation it decided to actually exhume, what the conditions are for that?

MEMBER CLARKE: Anyone from the NRC want to take that? Jim Shepherd.

CHAIRMAN RYAN: How about he'll be here tomorrow and we can ask him.

MS. DeRICCO: Okay. I have another person from my office coming tomorrow, so I'm not sure -- if you could let her know that, that would be good.

CHAIRMAN RYAN: Okay.

MS. DeRICCO: Well, no. Tomorrow is Wednesday, I'm not sure. But James is the one that I should ask?

CHAIRMAN RYAN: I believe that's right, yes.

MS. DeRICCO: Okay. But no one else can

address the significance question?

CHAIRMAN RYAN: Probably he's the best to give that answer, and we'll let him know.

MS. DeRICCO: Okay.

MR. LOONEY: Do you want me to make some brief statement about DOE?

CHAIRMAN RYAN: If you want.

MR. LOONEY: I don't specifically speak for DOE, but I can talk about the framework within which DOE does that. Since DOE sites, typically the plumes are regulated by either RCRA or CERCLA. It's done in the traditional ARAR, appropriate regulatory standards. Often that defaults to drinking water standards, and I think that's what you saw at Brookhaven, was the starting point was drinking water standards that required action, or drinking water standards at some defined location. There's all different variations on that, but that's kind of a central way it's done.

MEMBER CLARKE: Okay. Thanks, Brian.

CHAIRMAN RYAN: Yes.

PARTICIPANT: Should I try and give an answer to --

CHAIRMAN RYAN: No, we'll let Jim do it.

PARTICIPANT: The annual report.

CHAIRMAN RYAN: I understand, but let's let Jim do it. Okay. Well, let's get started --

MEMBER CLARKE: Let's press on, and we can catch it at the next break.

CHAIRMAN RYAN: If you don't mind, Diane --

MS. DeRICCO: Okay.

CHAIRMAN RYAN: Jim, we had a question and elected you as the best representative to answer it.

MR. SHEPHERD: I'm honored.

MS. DeRICCO: I wanted to know what -- there was discussion this morning about a lot of effort and resources being used for levels of contamination that weren't that worthy of that effort, and I wondered what are considered significant levels when you're getting into ground water, and decommissioning, and cleanup. Is it the 10 CFR 20 levels, and then for DOE said it was the EPA drinking water levels. And then, if there are any examples of situations where NRC has required licensees to exhume plumes, and what the levels were that were the determiner.

MR. SHEPHERD: This is Jim Shepherd. To address the second part of your question first, several sites, such as Connecticut Yankee, that are currently decommissioning and have ground water contamination, are going through considerable effort to remediate the ground water.

Significant is a word that, as with beauty, lies in the eye of the beholder. Certainly, if there's anything that approaches a Part 20 Appendix B limit, that would be considered significant. For decommissioning purposes, when we do a dose calculation, anything from any pathway that is appropriate for the site would be considered significant. Did that answer your question?

MS. DeRICCO: Yes, I'll call you for more examples. We don't have to take the time here.

CHAIRMAN RYAN: Thanks, Jim.

MEMBER CLARKE: Thank you.

CHAIRMAN RYAN: Dr. Clarke, back to you.

MEMBER CLARKE: Thank you. Our next presenter, and the last case study we have today is Vernon Ichimura, who will tell us about Barnwell.

MR. ICHIMURA: Good afternoon. I'm Vernon Ichimura. I work for a company called Chem Nuclear Systems, part of Energy Solutions. I'm going to talk a little bit about today, again I'd like to thank the ACNW for this opportunity to give you a little bit of background about the Barnwell site, and I'd like to thank Mike, Dr. Ryan, for his input and interest in the subject.

What I'd like to do today, like I said before, I'm going to give you kind of a history of how modeling was used at this Barnwell site. It's not going to be all-encompassing. It will be kind of in general, and what I'd like to do is take a couple of examples of models that were applied to this facility. And, in particular, I think you, as the audience, would like to pay attention to some of the assumptions that were changed as the models were developed for the Barnwell site.

Okay. The facility itself, the way the company tries to operate the facility - first of all, we operate with safety first, followed by compliance, so the talk today that I'm going to expand on in modeling is really a focus on compliance modeling. It's a little different from the standpoint of the kind of modeling that a lot of people are interested in, in modeling the exact features of the system, as you might want to call it. But rather than, in our case, our focus is compliance demonstration.

What I'd like to tell you a little bit about is one of the things that you should focus on, is look at the assumptions, as the assumptions have changed, and judgments and measurements, and how assumptions became measurements, as I work through the evolution of the modeling.

Again, in the process of the model, like I said, the analysis that I'm showing you here today are not all-encompassing. There are many other attempts at analysis for various reasons to demonstrate compliance, but these are some examples.

What I'd like to do is start with the pre-licensing model, 1971 . It's kind of interesting to look at what was thought was to be important at that time, and then step 10 years back in 1982 and look at the USGS and the NRC characterization. I thought I'd better put the NRC in here, because of some of the assumptions they may have made at that time, and it's real important to not let them off the hook, in other words.

And then finally, I'd like to look at the Barnwell site, the current, what we call the environmental radiological performance verification model. It's a model designed to take environmental data and verify that we can meet compliance with information we have.

What I did here on this slide is I added a line, which is really not part of the model, but to give you kind of a time frame of what it takes to do this kind of work. The model development started somewhere around 1996. This is just a numerical modeling, and the simulation of the data. And finally, the culmination of peer review, and the publication of the report. It finished in 2003.

Okay. Pre-licensing model, like I said, the initial characterization began around 1967, and the process by which the pre-licensing study began is you try to use existing information. In other words, there were two facilities in the general vicinity of the Barnwell site that had a lot of information, in particular, the Savannah River site, and the Barnwell Nuclear Fuel Plant Safety Analysis Report.

In the process of actually doing pre-licensing evaluation, you always solicit opinions of experts because you have very little information. What you need to do is you have to start with something, so when you look at the literature on the pre-licensing effort at this particular site, there was a lot of opinions generated, a lot of memos, a lot of letters, and a lot of reports. There was some limited characterization by actual collection of data; in other words, there were some geological studies, bore holes, and my guess would be there might have been a dozen bore holes, initially. There was some information about collection of the water levels beneath the facility, or the proposed facility, very early water chemistry, water quality and water chemistry information. And early on, they already thought of the idea of ion exchange properties. And this pre-licensing evaluation ultimately resulted in development of what's called conceptual migration model. In other words, what the folks were thinking during the pre-licensing process, they already believed that this particular facility, because it's going to accept certain radionuclides in certain kinds of packages that weren't really highly engineered, migration was expected.

Critical here - this is the start of a slide that I put forth to talk a little bit about how the safety analysis was done, and the assumed inventory. Again, I'm saying it's assumed inventory, and what the assumed inventory was based on, it was based on low specific activity waste at that time. The expectation was this particular facility would have approximately 200,000 cubic feet disposed of in over a 25 year period. And the classification of radionuclides, which is fairly interesting, gross beta-gamma, this was given a one-year half-life.

Strontium 90, cobalt-60, and plutonium-239. And the source term itself was calculated from what they considered to be release fraction, but basically what it is, is some partitioning between the inventory and the amount that would be in the solution is kind of like a release fraction in the terminology that sometimes people use today, some partitioning factors. And that the amount of radionuclides diluted by the infiltration process around the facility itself I didn't put on the slide, but there's an absorption process that was assumed.

Critical to the slide here is infiltration of 6 inches was assumed, so you notice as of discussion, we had not even talked about numerical model. And being at the time frame of 1971, numerical models were kind of in their infancy. In fact, they really didn't exist in the literature at the time.

Also, continuing in the pre-licensing analysis, travel distance is something pretty obvious. You can measure that, and so based on what you thought the travel direction was from the proposed facility to an exit point or to a point where a receptor might reside, the travel distance was assumed to be 3,000 feet. The shortest travel time, ground water travel time, this is taken from some preliminary knowledge of hydraulic conductivity data, was assumed to be 75 years. Again, notice there's no numerical model.

The assumed radionuclide travel time was assumed, again, to be a factor of 10 greater than 75, so 750 years. This accounts for the absorption phenomenon that we see today. If you go down the list again, you get an assumed stream flow rate of 10 cubic feet per second. What this implies here, that the people who did this evaluation looked around, and looked at the streams in the area, and found that characteristically, if you go downstream a certain distance, you will receive small streams that will have flow rates of 10 cubic feet per second. Where it was, nobody knew. This is what is in this picture for analysis, they assumed mixing in the stream, and showed finally, with decay. And this is all done using what we would do today, using a hand calculator. All the radionuclide concentrations should be 1,000 to 10,000 times lower than the maximum producible concentration, using the terminology of that day. So early on, this is what the Barnwell site burial model vintage 1971 looked like.

I'm going to step ahead, and I'm going to tell you that this conceptual model is not much different than the one we have today, so the folks that really did this analysis and went through the thought process of developing the conceptual model for the Barnwell site were pretty much right.

One of the things that you might notice is there's a very large vertical component beneath the buried waste, or the proposed buried waste, and there's a very large horizontal component as you get away from it. And there are two types of materials that they talk about here, the miocene sediment, and the terminology that I will use as we progress for miocene becomes zone one, and the eocene becomes zone two. Basically, what they are is, miocene sediments are a little bit lower hydraulic conductivity sediments. The eocene sediments are higher hydraulic conductivity sediments. And the Lower Three Run Creek, eventually becomes Mary's Branch Creek. The Lower Three Run is really a stream that's fed by the Mary's Branch Creek, and I'll talk a little bit more about this, but the concept of the model early-on is pretty much right.

Okay. The USGS arrived on site approximately in the 1975 time frame, and in 1982 they published a report, an open file report. In that report, they list a whole bunch of observations and measurements, and basically what they reported on is the characterization effort that took place over about approximately a seven-year time period.

One of the important things that they did during this study is they dived into more of the detailed characterization, like the stratigraphic interpretation. What were the sediments related to, to other formations around the facility, that is the Savannah River site, and the Barnwell Nuclear Fuel Plant next door. They put in geophysical logs, and I heard people talk about geophysical logs. The idea here is to get relative porosity data, lithology data, in general.

Critical to their measurements was they obtained hydraulic properties of sediments. This is done on a very big scale. They had a full scale pump test beneath the facility. They collected a lot of information on hydraulic conductivity. They made attempts to measure porosity, porosity, and effective porosity are typically very, very hard parameters to measure, as you all know. And they started collecting water elevation data on a bigger scale, that is, on a regional scale, ground water basin-wide scale. They also collected stream flow rates around the facility. All streams they found under the facility that the USGS could get access to, stream flow measurements were collected. They collected water chemistry data, and finally, measurements of radioactivity in core.

Okay. At the end of the characterization period, they developed what's called a three-dimensional regional ground water model, and it was this model that was actually calibrated to ground water levels. Average ground water levels at the time, and what they perceived as the average, calibrated through measured hydraulic properties and other hydraulic conductivities, and measured stream flow rates. This is the first early ground water model of the site done on a regional scale.

There are some differences as a result of doing this model. The recharge rate went from 6 inches to 15 inches per year. To calibrate that ground water model to match the stream flow, to match the hydraulic conductivity data, the recharge rate had to be 15 inches per year. Recharged another number, at least in field of hydraulic is very, very hard to measure on a regional scale, or on a site-wide scale.

Also in the model, they were able to show that, again, zone one, which is the miocene sediments, and zone two, which the eocene sediments that I talked about earlier, were the main contributors to ground water in local streams. So, in other words, we didn't

- from our perspective if we could look at it today - we didn't need to model any deeper than these formations for the Barnwell site location.

They also show as a result of doing this ground water analysis, that ground water movement for the first time numerically is towards Mary's Creek, so when you use the model, and the model allows you to take characterization information, put it all into a tool which enables you to match all the information you have, you only end up with ground water moving towards that creek, which is pretty obvious.

Here, the estimated ground water travel time, based on the information they had at the time, was believed to be 50 years, so it went from 75 to 50 years in this analysis.

Almost concurrent with the USGS study, was the NRC publication on the environmental assessment at the Barnwell site. The information that was published in the USGS study was used in this environmental assessment, so the critical assumption here is now that they know, most of the recharge, which enters the site, basically flows through zone one, and then enters zone two. This is now proven numerically with all the information we had.

The NRC then focused on a two-dimensional finite difference flow model, and I'll talk a little bit more about this, but the two-dimensional model was adequate because the flow in the zone two unit, as you saw before, is primarily horizontal, so you can almost eliminate the vertical flow component, and worry about the transport off-site in a two-dimensional fashion.

They made a number of assumptions. They created some artificial basins to create no flow boundaries around the facilities. It's an assumption. It's not an unrealistic assumption at that time, in that all ground water enters the creek. They calibrated that flow model by matching heads, measured heads with hydraulic properties, again.

The transport was handled a little bit differently, again, two-dimensional, two-dimensional finite difference transport model with retardation and decay. Again, we're looking at an assumed source term of one-tenth of a percent partitioning coefficient, or total activity as of January 1981, at this operating site, would be released of 100 years. And the radionuclides that they took into consideration here is cesium-134, cesium-137, cobalt-60, and iron-55, strontium-90. This is the first time that tritium shows up in any of the performance assessments. If you noticed earlier, the study did not consider tritium to be important. In fact, as history has shown in some of the earlier assessment of other similar facilities like this, tritium was not considered to be important.

The performance assessment was done in such a way that the goal here was to calculate the concentration to radionuclides on the list of source available to a hypothetical user of the ground water at the creek, so in this case, the user of water, the person that uses the water is really taking water from a well at the creek location. In this particular case, it was Mary's Branch Creek. I'll show you in a future slide what this really looks like in a drawing.

This assessment basically showed the most important radionuclide at the creek was tritium. The hypothetical dose rate is approximately 4 millirems. It should be less than 4 millirems. A calculated hypothetical dose rate is approximately 5 millirems for strontium, and this occurs at some future point in time. In other words, tritium washes through, it comes through first, and then strontium at some future point in time. And that there was negligible contribution in terms of dose rates from other radionuclides. The time period of the assessment is not really clear in this publication.

This is the conceptual model. Again, the focus was just in zone two, where the flow is primarily horizontal, and the transport occurs from the site to an off-site location, to a receptor consuming water at the creek.

And finally, I'd like to say a little bit about this current model that we use. The goal in this model is, again, to verify with environmental data that we have, to verify that we could meet radiological performance. The model development basically began around the 1996 time frame. It is based on numerous measurements.

One of the things I want to point out here, the collection of geological and hydrologic data that is on a program at our facility occurs using very high quality processes. In other words, the collection of data that we have been using from about the 1982 time frame have been pretty much consistent. We use the same procedures. We have a data management process. In other words, we are able to retrieve this information. And one of the most important things about data collection that you see at other facilities is there's a change in the management for a lot of facilities, and that the structure to maintain this information doesn't exist, so there's a continuous collection of hydrologic and geologic data as we move and we build disposal units, or trenches at various different locations on the facility.

We have routine environmental monitoring of water levels, radionuclides, and today, most recently, non-radiological constituents. In addition to that, we have special studies that are mainly focused on shoring up some of the weak points in some of the previous modeling efforts, in particular, we don't know, for example, how the stream gains. The Barnwell facility is located at a head water of a little tiny creek, and the creek goes from almost no flow, from a little trickle, to one cubic feet in a very, very short distance. And this really impacts the ground water model. And that particular information is very important in the sense that it can give you things, information about how the water leaves the ground, and actually enables you to calibrate, force you into looking at the model in terms of head drops near the creek, the shape of the contaminated areas right next to the creek, this kind of information that's very important to us.

We did special characterization studies; in other words, since this site has an area beneath the site that is impacted by the site, impacted, by that I mean receive tritium, we did mapping, characterization map to make a determination of where tritium was and was not. This information was needed to calibrate a ground water model.

Finally, not really related to the ground water model, we did what's called a radionuclide inventory characterization. I think there was an earlier speaker that mentioned that early information about radionuclide source or inventories are not as well characterized as it is today, so this is an attempt at bringing information that is missing in our inventory up-to-date.

Some statistics about our ground water monitoring program. We have an opportunity to collect samples from about 400 different locations on the site. We have long-term measurements. For this model, we used about 25 years of data, so just the amount of information is very large, and very hard to manage.

I'm not sure how this shows up on the viewgraph. This is a plan view of the Barnwell site. And, again, the north is at the top of the page. These little squiggly lines are contour lines, elevation, lines of equal elevations, as well as roads. And you can almost kind of see the outline of the disposal area, kind of a uniform man-made contour lines. The disposal area basically is rough shape polygon. Ground water flows from kind of like the north, flows to south, southwest, to the head waters of the creek, which is down in here. The creek flows in that direction, and enters the Savannah River site.

MEMBER HINZE: Could you give us a scale on that?

MR. ICHIMURA: Yes, I can do that. The distance from here to here I would say is about a mile, the distance across a little bit - okay. What I'm going to do is I'm going to take some slices across this site, and I'm going to be looking from the east, which is from this side, looking into the site, and throughout the conceptual model, and look at the geologic section in the following slides.

This is one geologic section. I'm sure the folks next door have a different opinion on what they call formations, but anyway, we have Tobacco Road and Dry Branch formation. But this is basically - the brown is what we consider to be the zone one. The elevation on the site is about 250 feet above mean sea level. The water table is about 40 feet beneath the land surface, typically. The ground water flow is, again, mainly vertical through the brown, and then mainly horizontal for the yellow. It's a very small vertical component, very minor. The approximate elevation of the creek is at the top of the yellow, and it's kind of significant because the yellow is where a lot of water is being transported in the horizontal direction, and it just happened to be the place where the creek formed, and it matches what one would expect in the geology in this particular sense, there's a lot of water, there's a lot of water exiting.

This is a conceptual model of the site. This is what we typically show people. The ground water travel time from the nearest disposal units in the vertical direction to the point where it turns nearly horizontal is roughly 10 years. From the point where it becomes horizontal for the nearest creek is about another 10 years, so in other words, a total travel time is approximately 20 years.

What really happens to the tritium beneath the site - there's actually a small vertical component that causes the tritium to dive down, and then basically come up under the creek again, because of the fact that there's ground water recharge continuous that Brian talked about a little bit. So if we were to look at the -- truly do the conceptual model correctly, it would be kind of a curve down and a curve back up.

I'm going to stop here and tell you a little bit about - kind of lay out how we do the transport assessment. If one were to monitor the site for radioactivity, if one were to put the well in the water table just outside disposal unit, you would see nothing. This water would be very pristine, very clean. If you were to put the well down into what we call the zone two where we find the sands, obviously, that's where you find the contamination. So the flow, from the standpoint of performance assessment, and the approach that we've taken is to only worry about what's flowing horizontally. And the approach that was taken is to look at the monitoring data at the upstream location, and project using stream tubes, multiple stream tubes, and the stream tubes are based on the flow model to the creek, and they're mapped into the creek. So with that kind of a background, this is how the numerical model is set up. And it's based on the fact that we believe that there is a vertical component and a horizontal component to flow.

Okay. The numerical model itself - this is fully three-dimensional. It's a combination of MODFLOW and MODPATH. MODPATH is used to calculate the pathways, and it is used to justify the numerous one-dimensional stream tube approach. One way to conceptualize what this stream tube approach looks like is, it's like numerous RESRAD models being run simultaneously. We only took into account advective transport and decay, as well as retardation.

The source term is based on the maximum average concentration observed in any stream tube; that is, if there is a well, the well that has the highest average concentration of radionuclide in the upstream direction is a sign the concentration in the source term. So this is an observed source term for tritium.

For projection use, what we did was we calculate a source term based on the radionuclide inventory. This is really a separate model, but I'll talk a little bit more about how this is set up. When the stream -- enter the stream, they are mapped into mixing cells. On the stream itself is a series of mixing cells, and we calculate dilution, and then the concentration of tritium is projected to the compliance location. So the model itself is a combination of ground water and stream surface water model.

So the calibration of the model, the flow model is actually calibrated through hydraulic properties. Not all hydraulic properties are going to match, but they're pretty close. We also use average ground water elevation measurements. We decided to pick a long-term average data that was a snapshot of what one would perceive as to be a reasonable average ground water elevation for that site. We calibrated the flow model to measure stream flow rates. Again, we have to match those.

On the site, we have opportunities to calibrate models to different things. Like, for example, we have surface water holding ponds. These are water management ponds that collect surface water runoff from the facility, and some of the water that enters the pond really ends up percolating and entering the ground water system, so the ground water model itself should be able to simulate what happens in the ponds.

We also have in the transport side of the model, we should be able to - on the MODPATH side of the model, we should be able to calculate arrival times. They all have to match. That is, when a disposal unit was constructed. Tritium arrival at a certain sample location downstream have to match, so these are things that we have matched. And we have used measured maximum average tritium and carbon-14 concentrations to project what the dose rates might be at the compliance location.

The model results, this is what this compliance model looks like in terms of the results at the current time. The maximum hypothetical dose rate due to tritium is projected to be around 13 millirem per year. The maximum hypothetical dose rate due to carbon-14 was about -- is actually somewhere around less than two-tenths of a millirem per year, so the same one as I show in the slide.

The measurements, the maximum hypothetical dose rate due to tritium is 5 millirem, is less than 5 millirem. And then, again, hypothetical maximum, the hypothetical dose rate due to carbon-14, in fact, is not detected at the compliance location, is less than one millirem per year. So, again, I want to emphasize the scenario does not exist, the real dose rate is negligible.

Since the model was based on actual measurement information, what we had to do was go and look at all the other radionuclides that may possibly be in our inventory. So the process -- we took a very long, hard look at developing a total radionuclide inventory at the Barnwell site. In fact, pretensive

461 data would list radionuclides, such as tritium, as mixed fission product or something like that, and it would never show up on their inventory sheet, and something like that would have to be recalculated, so this is the estimate, to estimate the amount of radionuclide that might be at the Barnwell site.

Next, we had to determine from the inventory what a source term would be. We used some additional radionuclides. I did not list them here, because they're of lesser importance, but cesium-137, cobalt-60, uranium, and some other radionuclides that was measured in the sump were used to help calibrate this model. But in the ground water, none of those radionuclides are present.

We've assumed, and this is a critical assumption, that the distribution coefficients that's available in Sheppard and Thibault 1991 are applicable. For the most part, I think the numbers that we pulled from the Sheppard and Thibault information appears to work for the site. There's nothing aberrant, with one exception that we can tell, that's very important, is carbon-14. Carbon-14 for this site, with the type of mixed waste, behaves just like tritium.

We determined which radionuclides arrived at the compliance location within a 2,000 year period. I think Mark talked about 1,000 year requirement. We upped the number to twice that, and we calculated the hypothetical dose rate under all the radionuclides that arrive at the compliance location within the 2,000 year period. And the results are obvious, because tritium and carbon-14 are the calibration factor. They have to reproduce the same numbers that we've seen before, tritium and carbon-14 are most important. There are some other radionuclides that we see in the literature that are important, and show up at the compliance location, iodine and technetium, to name two of them. They're very small relative to the other parts.

I believe with this kind of an exercise, and I thought this was interesting for me to look at some of the literature, and some of the background at this facility, and look at some of the assumptions that were made early-on. It was an interesting exercise, and I'm sure right now as we step forward, we're, again, taking a look at new data, and how the impacted area of the site is changing, if any. And we're looking at the process of actually improving some of the models. So with that closing, are there any questions? I guess, Jim, you're going to hold the questions until later.

MEMBER CLARKE: Yes. Thanks, Vernon. I'm going to turn it back to George for the panel discussion, and then we'll entertain questions. It's all your's.

DR. HORNBERGER: Thank you, Jim. Again, I'm George Hornberger, Nuclear Water Technical Review Board. We're running just a little behind schedule, so again, I'll warn people that we're going to have about a half an hour maximum for this panel discussion. And, again, just to try to get us off on hopefully some interesting discussion, let me make an assessment here of my own.

When I was listening to the presentations, I recalled and old song "Love and Marriage", because it's a refrain, "They go together like a horse and carriage, but you can't have one without the other", and we're talking about monitoring and modeling, and that seems to be a theme that progressed through this. And then I was - to carry this bad analogy further - I was thinking that the people who spoke this morning must be proponents of divorce. And I was trying to reconcile this dichotomy in my mind, and I was thinking that, of course, the utilities that exist to sell energy and make a profit, the labs, as Michael said, have a large part of their mission as remediation, so the utilities, I think, have an incentive to minimize the costs associated with modeling and monitoring. And one might argue that the converse might be true for the labs.

(Laughter.)

DR. HORNBERGER: And I grant you, you and me have other explanations, and you may want to posit another explanation, and that's fine. But in the context, whether it's my explanation for the dichotomy or some other, I thought it might be interesting for us to address Question 8 that was a focus question for this session: "Do you have specific recommendations on how to improve the integration of compliance monitoring programs and modeling to increase confidence in model results for NRC licensed facilities?" And we'll go around this way. Tom, you're on the hot seat. You have to say your name for the record.

MR. BURKE: Tom Burke, Brookhaven National Laboratory. To increase confidence between, I guess, the license holders with NRC and other regulators, one of the things that came up early-on in our process, we spent a lot of time on the conceptual site development and the modeling, and we had a modeling work plan. We went out to all the regulators, they reviewed it, they commented it, it went through several reiterations. We performed the modeling setup, which took a lot of money and a lot of time, and numerous meetings. And, also, one of the things we did, is we got the EPA in there, we got the DEC in the room, we got the USGS, and we asked them, do you agree with us? Do you all nod, all raise your hand, do you all say this is what you want us to use? We don't want to just go down the path and start using something, and a year, or two years, or three years they start throwing rocks at us and say, we don't want you to use that model. We want you to use this, so there are models that are very good, that may have additional strengths that we didn't use. But you want to use something that's been in the public domain, that's generally accepted. And the ones I mentioned are the ones everyone could say yes, we're not going to give you a hard time. But to do that took us over a year, took us a year and a half. We had the time available to us to do it. If we didn't do it, you run into pitfalls going forward where people don't believe your modeling, or they don't want to agree with it.

You could fight about your initial concentrations that went into it, but you don't want them fighting about the code you're using. It's hard, but you have to get the up front agreement from your stakeholders, and your regulators, that we're all using the thing we ought to be using. And I think if we did that, it's time consuming, and expensive, but it can help you down the road. And even though we did that, we still ran into some issues.

Earlier this morning, I think someone mentioned about disposivity. That was a major issue for us in different ways. The model that we had selected, we had turned off the disposivity. We didn't include it, even though we had estimated and calculated other ways that our disposivity would have been on the order of about five, but the MODFLOW and MT-3 has inherent numerical dispersion in it that we estimated 5. And to convince others that what we were using was okay - I didn't talk about it - we had to go to something called Method of Characteristics, MOC Analyses. And the MOC Analyses, we did for the same set of initial characterizations, and we turned off disposivity and put it to five. And when we put the five, the factor of five disposivity into the MOC, it basically matched up what we had. But there's a lot of technical going back and forth. And once you get the technical people on your side from the agencies, it makes it easier to sit at the table in front of the public and say not only do we think this is the case, the other experts agree with us, so it helps you when you go have to explain it.

DR. HORNBERGER: Okay. Good. Michael.

MR. HAUPTMAN: This is Mike Hauptman, also from Brookhaven Lab. I'm going to try to answer the dichotomy question, as well as the NRC compliance monitoring in the context of what Tom just brought up. It's all about establishing credibility. And each site is going to be different, as far as how much data has to be collected and what type of model to use. Certainly, you want to pick your battles, too, and what do you want to fight about. Do you want to fight about data, or do you want to fight about models? And as Tom said, pick a model out of the public domain, and that fight is already settled. If everybody agrees well, this is an accurate model, I've used it elsewhere, great. So now you're just fighting about the data.

And then it comes down to, how much data is going to raise your credibility. And part of that is involving the regulators early, involving the public, because it's partially education, also, of what do data mean, and how do we use the data, what is a model, is a model as good as the data you put in? Yes. We all know that, but there's a lot of people in the public that may not know that. They think the model is something that's generated and gives you a true answer all the time, and that's an education that people have to get, again, in order to raise credibility.

So maybe getting back to this dichotomy question - I don't know what the utilities - maybe they already have credibility. I don't know, but the National Labs, especially Brookhaven on Long Island, at that point in time had very little credibility, so we had to really bite the bullet, and collect a lot of data, a lot of date. And as Tom said, we probably wouldn't do that today, and if we didn't have, as someone said this morning, social and political pressures, if those weren't driving those - those designs I talked about, those were done in two months, from concept to the in the ground. That type of thing is to be avoided, so again, maybe the utilities have been successful so far at avoiding that sort of thing.

And as far as, I guess, compliance monitoring, those issues that you have - yes, we did a lot more. And, again, if you can use the data that you have judiciously to grow that credibility, which comes down to calibrating the model, validating the model, making sure the output matches what you see in the field, and making sure that the public and stakeholders know that the model output matches what you see in the field regularly, do that with a minimum amount of data, that's what you want to do. But it varies from site to site.

MR. FAYER: Mike Fayer, PNNL. Just to comment on the last comment about models. The debate about models is ramping around the country in the meetings that I've been in, and I've heard that comment about picking a model off a shelf, and everyone agrees it's okay. But there are a lot of models on the shelf, and all are not appropriate, so you actually do have to make sure you choose the right model. And sometimes it may not be on the shelf.

I know what drives us to do what's right. That's what we feel like we're doing, doing what's right, is that we have to have public and regulatory acceptance, multiple agencies, the State Department, there's EPA, and, of course, there's DOE. There's always the threat of NRC some day coming in somehow. And there's also peer reviews. I mean, we do have external reviews. Mostly academics will come in, and we've got to get it right to satisfy that whole clientele. And we have stakeholders, as well, Indian tribes and whatnot, so we're always driven to minimize as much as we can the uncertainties, and not take that risk.

I don't know if NRC has incentives built in for contractors to go beyond just doing the compliance effort. That would be something to consider. And then I'm not familiar enough with the structure of NRC, but is there a regulatory component and a industry proponent/component? Is there two heads to NRC? I'm looking at you, but --

DR. HORNBERGER: It's regulatory.

MR. FAYER: I'm looking at you, but -- it's all regulatory. Okay. I didn't know if that would be an issue. That's all I have.

MR. LOONEY: This is Brian Looney from Savannah River Laboratory. There's always a risk in carrying an analogy further out, but I was intrigued by the "Love and Marriage" being an analogy for monitoring and modeling. And one of the things that's important about "Love and Marriage" is that in order for a marriage to work, you have to invest in it. You have to invest time in it, and you have to work at keeping that relationship fresh. And I think the same is true for monitoring and modeling. And I think that in the case of monitoring, if you basically have a very rigid prescribed approach, it's like going into a marriage and not really have any excitement. When you come home at the end of the day, you always do the same things. So I guess, if I had one, going back to Question 8, specific recommendation, I would try to resolve this tension. The point I made about trying to match solutions to problems - this tension of trying to answer the question with creativity and flexibility, I think goes right down the line of the analogy that you brought up.

I think you need to maintain discipline and quality. You don't want to come home at the end of the day and have no clue what's going to happen, either. So, to me, the real lesson that I take home from this, is that there is a possibility of essentially incorporating new ideas into the monitoring paradigm, and what I would propose is that the emphasis be on early warning systems, and systems that are robust to kind of the known ways that contaminants behave in the subsurface, especially for new facilities where you have very little expectation that you're going to see something. You need to show that you've made your level best effort to put in a system that's going to actually detect the failure mode. And I think Jody Waugh and others are going to get into that when we get into this tomorrow. But, basically, I think that this paradigm that was set up where you have existing plumes, and you kind of think about them a certain way, and you have new facilities, and you want to have something that's very sensitive was a really, really good one. And I guess I would propose that we try to come up with some kind of balanced approach to resolving those tensions.

MR. YABUSAKI: Steve Yabusaki, PNNL. I agree with a lot of the comments that have been made. I think the environment that we're in at Hanford, it does sound different from the NRC. I guess, I didn't realize it, but we do - actually do have a closer tie to the people collecting "monitoring" information on the site. And maybe there's a common objective, or acceptance of the need to do some of these things, but they have accommodated us not all the things that we've asked for, but they have essentially instituted more rigorous and more comprehensive sampling in the 300 area, for example, on the project that I was talking about. And I think maybe what it has to be is that you need to agree on your use of the model, and the modeling objective. And everybody sort of emotionally buy into that, and once you do that, the modeling can actually help you design the monitoring and sampling strategies behind that. But I think someone said it earlier about it's not the modelers over there. I mean, we're all in this together, and that model is essentially the embodiment of our current understanding of the system. And when we have problems with the model, it's essentially a defect in our understanding of what's going on. And that's part of the beauty of modeling, but it also means that you have to use that to your advantage, also, in adapting your strategy out there when you come upon this new information.

MR. ICHIMURA: I'm Vernon Ichimura. What I would like to do is say a little bit about - from our standpoint as a commercial entity, and look at how we link modeling and monitoring together. One of the things that I've begun to realize as I've watched some of the bigger facilities, there's a difference in how the monitoring folks operate, and then the modeling folks, they seem to be sometimes in a separate environment, at least that's compartmentalized, and at our facility it's a little bit different. We're small, so we have a small group of folks, so there's a lot of communication going on between the folks that do the monitoring, and the folks that do the modeling.

So there's a continuous connection, and as we find a need to change our approach, and change our directions in collecting specific data, in a lot of cases they're driven by model, but sometimes they're driven by the fact that our monitoring data seem to say something that we're not really sure of, and it doesn't show up in the model, so it goes back and forth.

DR. HORNBERGER: Good. One other of the questions that I'd at least like to make sure that we've heard everything that you have to say to us on the question of are there new techniques or methods that should be brought to bear. And Brian mentioned geophysics, gas sampling, push/pull techniques. And (A), are there others that should be considered, or I was thinking (B), are there specific things that should be recommended? For example, is an SP array a cost-effective thing to do, even in a relatively - not a huge issue, such as the uranium disposal areas at Hanford. Does anyone have anything to add here on new techniques, or approaches that you would recommend?

MR. ICHIMURA: I'd like to try one. And I notice there was a common theme among some of the speakers regarding the collection of information, in particular, contaminant information, and was talking about some of the advances in geoprobe and rotosonic drilling. I would say like maybe perhaps five or six years ago, maybe 10 years ago, these techniques weren't prevalent, they weren't that important. And one of the things about these new sampling techniques is they're relatively inexpensive. And you can go into a new area and actually put a hole down, and actually cut the cores into little sections, and you will find when you cut these cores - and I don't know if other people are seeing it - that if you were to evaluate each individual specimen in that core, you will find that the contaminant levels in that core is highly variable. So what does it tell you immediately, and when you compare that to a monitoring well, it's quite different from the monitoring wells. And I heard someone speak earlier on the issue of as you broaden the well screen from the standpoint of the economics of environmental monitoring, you tend to smear the contaminant levels. So recognizing that the approach of actually collecting soil samples using these new techniques need to be looked at in more detail, and I think this is particularly useful, not necessarily from the standpoint of modeling, because modeling tends to smear the data, because we tend to average - say, for example, in a finite element, or in a finite difference. But in the sense that if you're looking at the microscopic properties, and understanding how the contaminant transport is taking place, this is an area which is rich for research.

MR. HAUPTMAN: This is Mike Hauptman from Brookhaven, again. Maybe two things that we kind of had our lessons learned over time was certainly the smearing effect of - I mean, we used to have five foot well screens when we first started, for example. And taking three well volumes out of that really was not a representative sample. It was a consistent sample with what had been done in the past, but it was no longer representative, so that's one reason we went to geoprobes, and the other was cost. But in the geoprobes, I don't think we explained it in that much detail, but we took samples every foot, so it was a very detailed picture of the vertical distribution of the tritium, and we found that that was really a much better way to approach it than say putting in a nest of five foot well screens.

The other technique that we started to use for all our sampling, actually, was low flow pumping. And I think that's common now, I know it's common throughout DOE, I'm not sure about NRC. But instead of taking well volumes to purge a well, we just put either a dedicated well, or a new one in and take the top, or you can do stratigraphic sampling within an existing well. If you've got a five foot well, you can put it in the middle, or the bottom, and try to get a better picture of what's exactly going on in the aquifer.

MR. LOONEY: This is Brian Looney from Savannah River, just a couple of quick ideas. Several people mentioned something about essentially incorporating some kind of tracer, or using the characteristics of the process water to give you more information about what's going in near source, and I think that's a really good idea. I think given the importance of at least the appearance of tritium outside nuclear facilities, either through the fact that curies per liter on the inside, and pecocuries per liter on the outside is important, or even activation outside in the soil, there may be some creative things that can be done there. Just one example would be just running a continuous low volume SVE underneath your facility for almost no money. That would do two things. First of all, it would give you a real-time access to the humidity to collect tritium samples, and essentially give you an almost immediate signal if there was any leakage out of your facility.

I think you can work with your stakeholders to let them know that that is the thing that's going to give you an immediate reading, and maybe use that to not do nearly as much, lots of ground water sampling and things like that.

DR. HORNBERGER: For our reporter, you might just say what SVE is.

MR. LOONEY: I'm sorry, Soil Vapor Extraction.

MR. BURKE: Tom Burke from Brookhaven. One thing I had mentioned briefly before, the difference that we ran into is that the volume and detail level of analytical data we collected far outstripped, maybe by an order of magnitude, our understanding of the hydraulic connectivity variations. And I think over the last five or ten years, that has been better understood on how - at one time what we thought was homogeneous - over very short ranges, is not as homogeneous as we once thought. I mean, the Waterloo fellows have certainly done some very interesting work and some other people, to show the real variations over very short distances. And if I had to do it again, I would collect less data, and more hydraulic connectivity data, and the geophysical techniques to do that are better and cheaper now than they were ten years ago. That's reflected in our modeling.

Our modeling is pretty good in the far field. In the near field modeling, the variations over 100 feet, it doesn't make sense, over 1,000 or 3,000 feet it's okay. So, overall, it's homogeneous going forward in longer distances, in short things, those hydraulic connectivity variations, little embedded things going on in the subsurface will have an effect.

DR. HORNBERGER: Well, thanks very much. I know Jim needs to turn to the committee to let them have questions, so I will turn it back to Jim.

MEMBER CLARKE: Thank you, George. We are running a little short on time. Let me ask the committee to limit themselves to one question, and Ruth, will you start?

MEMBER WEINER: One, maybe one and a half. I have a question for Steve. How did you account in your uranium data, how did you account for the uranium that comes down in Columbia from the uranium deposit on the Caldwell Reservation?

MR. YABUSAKI: So you're saying the background uranium from the river?

MEMBER WEINER: Yes, it's background -

well, it's uranium in the river as it comes into the -- across into the Hanford reach.

MR. YABUSAKI: I haven't done anything with the uranium in the river itself. Everything that we've modeled has been from the ground water or the vadose zone system into the river.

MEMBER WEINER: And you don't get any infiltration the other way?

MR. YABUSAKI: Well, there is a background level of uranium in the river, but that is much lower than the aquifer concentrations that are there.

MEMBER WEINER: And my question is - I have to ask it again - you're not getting any flow from the river into the aquifer in the vadose zone that carries with it, because the background at that point, and my recollection of the background at that point, is that it's certainly not insignificant, because you're getting a constant leaching from the Caldwell deposit.

MR. YABUSAKI: Yes. I think the levels at least that I'm familiar with, with the exception of those taken in the river bed sediments, are that the concentrations of uranium in the river that are interacting are much smaller than the aquifer concentration.

MEMBER WEINER: But you did account for them.

MR. YABUSAKI: No.

MEMBER WEINER: Okay. If I'm limited to one question, that's it. Thank you.

DR. HORNBERGER: Thank you, Ruth.

CHAIRMAN RYAN: I'd like to get back to Dr. Hornberger's analogy. I think the marriage comes together around the prize of the compliance principle, whatever it is. I noticed that in all the presentations, Vernon is the only one that looked at dose, because that's the direct measure of a compliance point. And he shared in his morning presentation that requirement. I think when Eric Darois spoke earlier, he talked about specific ground water requirements that were perhaps not strictly in some table in NRC regulations, but what were negotiated as the right answer for that particular setting. So I see that as, perhaps, a little different kind of measure in the NRC world, or agreement state world.

By the way, there's thousands and thousands of licensees, more in the agreement states than there are at NRC. There are 109 reactors, and there are 20,000 licensees at various levels elsewhere, so let's don't forget that part of the world, too. And I just would like a reaction to that idea, that really how do you translate all the monitoring and modeling into a coherent whole? My view of it is, it has to come together to address how you're demonstrating whatever compliance you're asked to demonstrate. Is that a reasonable theme for me to take away from this conversation when I try and integrate it myself?

MR. LOONEY: This is Brian Looney from Savannah River. I think that's a very reasonable theme, and the answer we gave earlier was that a lot of DOE sites, they're concentration-based standards, but it's also true that at the radioactive waste disposal facilities, per se they're doing the performance assessments in the standard way with doses, as the goal. And that is the basis for this determination that the question was on earlier, of what is significant and what is not? And, ultimately, it comes back to that calculation.

I think that the other issue is this issue of averaging in point samples versus broader samples that integrate over volumes. But I think that for -- it becomes really important as we get better and better characterization monitoring techniques, so we've heard geoprobe samples, where they're taking very short screens. And what you can get is you can get a very, very high concentration in a small interval, that is not representative of anything that could come out of a monitoring well.

It becomes even more important if you go to your public and you say well, I'm going to have this really early sensitive early warning system, and you measure 100,000 pecocuries per liter in a vadose zone moisture, that has nothing to do with with what's going to come out of a monitoring well. So you need to go in with this idea that measuring 100,000 pecocuries per liter in a vadose zone doesn't mean that you're exceeding a dose standard, or whatever.

CHAIRMAN RYAN: And that's a great caution. I mean, I think you have to characterize each and every one of your sample techniques, points of sampling for the specific purpose it's designed. And your vadose example is a good one, one that's not designed to measure directly against your compliance, but to give you some other insight into the behavior of the system. So the behavior, the system kinds of things, there are radionuclide measurements, which are relatively straightforward in whatever sample you send to the lab, and then there's putting it all together in a package. And, to me, again, I see that whatever the compliance program is you're trying to meet, is really the theme you're aiming at. And sometimes that's clear, and I think in front of folks, and sometimes that way down the line and somebody else's job, so it ranges across the map to whether it's a point of focus, or not a point of focus. With that, I'll stop. Thank you.

MR. HAUPTMAN: Can I just add to that? Mike Hauptman. I think, too, it's a great theme to take away. And I was going to add that what we didn't really talk about, because it was in the background, was the whole risk assessment and risk pathway concept that goes into establishing what the compliance point is, and what the compliance level is going to be.

In our world there was EPA drinking water, social aquifer, 20,000 pecocuries per liter, but it could be a different standard, or it could be a negotiated standard, depending on different situation. Thank you.

CHAIRMAN RYAN: Fair enough.

MEMBER CLARKE: Thank you. Allen.

VICE CHAIR CROFF: I'd like to thank you all for some very interesting presentations. In lieu of a question, I'd like to reinforce George's observation that he made at the outset, and sort of the difference, I might call it, in tone, or in approach between the morning and the afternoon. And I think that sort of leaves me with scratching my head as to, to some extent, why there were the differences in viewpoints, should we try to do something about this and change this, and provide incentives in various directions, and can we? I mean, is there a way to do it? I don't have any answers, and I don't expect any, but I think that's something I've taken away from the first day, a major point.

MEMBER HINZE: No lecture.

CHAIRMAN RYAN: That's a first. Let this be recorded.

MEMBER HINZE: I am extremely heartened by what I heard late morning and this afternoon about the use of tracers, dyes, geophysics, complementary to the more conventional monitoring schemes. And I guess my question is, what is the NRC doing about this, about how to implement that, and how to provide guidance to the energy people that are doing the decommissioning, of how the substitution of these techniques can be brought in, and how they can be used properly? I don't expect an answer to that, either, but it seems to me that that is something that the NRC, and perhaps this committee should be thinking about.

MEMBER CLARKE: Okay. Thanks, Bill. I may have over-reacted.

CHAIRMAN RYAN: Why don't you --

MEMBER CLARKE: Well, no, that's fine. I'm still digesting all of those, but anyone else on the committee have a follow-up? Anyone from the staff?

MEMBER WEINER: Can I ask my other question?

MEMBER CLARKE: Okay. Go ahead, Ruth.

MEMBER WEINER: This is a considerably more general one, but it's along the same lines. Some years ago at Hanford, we had a presentation from the Washington State Department of Ecology, that compared the tritium from fallout with tritium from various sites, I mean, fallout looked at tritium in lakes that had nothing whatever to do with any site that could be releasing tritium. And I wanted to ask, particularly the Brookhaven folks, did you look at that, as to whether any, or anyone as to whether the tritium that you're seeing is from fallout, whether any of it is from fallout, what percentage is from fallout, and so on?

MR. BURKE: Tom Burke from Brookhaven.

Yes, we did. And the answer was that we came up, was we had a number of people look at it for us, and our athropogenic, our background, or fallout tritium. Sometimes depending on who we talked to, it was 50 to 100 picocuries, maybe up to 200 picocuries, are routine detection limits, or MDAs, for tritium, were in the three to five hundred picocurie range. And we would mention this in our meetings with the public, but it became not an issue because it was little, and we're looking at bigger numbers, and our analysis range was 300, 500, and up.

One of the issues we came across, and we resolved it somewhat over time, was that we spent a lot of time talking about 650 picocuries, 750 picocuries, and in our mind it wasn't that much of a concern. We actually got help from one of our local regulators, and it was because of what was going on. They were force to go far afield away from us and start sampling public supply wells on their own. Hydrologically at distance, no connection whatsoever, and they were getting numbers 800, 1,000, 1,200, 650, and they said oh, let's not open this can of worms. It's confusing, it's difficult, so even though we weren't made to do it, the Suffolk County Department of Health Service said let's talk about 1,000 picocuries. Below that, let's not be too much.

What it ended up having us to do, good, but also bad, was that on many of our contour maps, we're drawing 1,000 picocurie contour lines, which is much different from if you're in the chemical VOC land. Most VOCs are five parts per billion, the most you would draw is a five part per billion contour line. No one ever draws a half a billion contour line unless you've got EDB or something. Here, we're being forced to not draw a 20,000 drinking water contour. We're being forced to draw 10,000, 5,000, and stopping at 1,000 contour line, even though we didn't have to chase the 600, 750 as much.

Also, through time and effort with the public, we were able to minimize their concern over the lower numbers. And the big difference is, five parts per billion for VOCs, your detection limit is one-tenth at .5, but at 20,000 picocurie drinking water standard, our detection limit is one-fortieth of that, so we're way down there.

CHAIRMAN RYAN: If I may just add, when I think about 1,000 picocuries per liter, I think about 20,000 being 4 millirem per year, if that's your only source of water. So everybody do the math, and figure out what 1,000 pecocuries per liter means, and dosemetrically it's of no consequence. And I guess I'd agree with you, just from my own experience, that anything around 1,000 plus or minus, whatever you like, is well within the range of tritium you measure on the face of the earth.

MR. BURKE: We would have liked to just stopped at our 20,000 picocurie contour line, but there was a lot of concern, a lot of interest. Okay, what's the next line, just as any time you have two wells, someone could come across and say I want you to put a well between them, just as we have a contour line, someone says I want another contour line.

CHAIRMAN RYAN: Sounds right to me.

DR. HORNBERGER: Go ahead, Latif.

DR. HAMDAN: Yes, just one question. I hear you talk about credibility of modelers going to 10,000 years, and on maybe more - do you think it would improve confidence in models if the modeling committee said something like this - our models are good only for 50 years, or 60 years? And we expect that these models will be revisited at some point in the future, and updated?

MEMBER CLARKE: Anyone?

CHAIRMAN RYAN: I'm not sure exactly what the question was, Latif.

DR. HAMDAN: The question is, here we - even this meeting, we find out that we don't have confidence in models when they predict to 2,000 years or more. And yet, we are not doing anything about it, and we also hear that the credibility is a big question for the technical community. And the question is, if the technical community were to take the notion that okay, our models are good for 20, 30 years at most, and we expect - a report for every model that 30, 40 years from now - we expect by design or otherwise, that models will be updated. Would that -- do you think that would enhance confidence in models and modeling?

CHAIRMAN RYAN: Let me react if I may, Latif. I think you've got to shape that question a little bit more with a finer point. There are some models that are quite good for 10,000 years. I would imagine models of how the core of the earth is behaving are pretty predictable. Surface hydrology, you might not get so far down the line in terms of time, so it's a matter of where you are as to what kind of time frame you can actually claim. So I think you really have to help us understand, are we talking about deep geology, are we talking about surface geology and hydrology, and each system, I think, you have to then ask the question, and what time frame you can actually speak about with confidence.

DR. HAMDAN: How about the performance of Smith models that we have been discussing all day?

MR. LOONEY: This is Brian. Let me just take a quick crack at that. The challenges that - the 10,000 was just kind of pulled out as a number that seemed reasonable in like a long time. And in fiction, dispersion, and retardation modeling on its surface should be perfectly reliable, but the real challenge is that things are changing during that period of time, up to and including a climate change, I mean, sea level changes and all kinds of things like that, so I think it's a valid question. What I'm hoping is that tomorrow when we get to like Jody and some of the other folks, we get some creative ideas on how to approach the problem from a different perspective.

MEMBER CLARKE: Okay. Let me thank all of you. It's been a very interesting day, and we begin tomorrow at 8:30. And let me turn it back to our Chairman.

CHAIRMAN RYAN: And with that, I think we'll adjourn for the day. And as Dr. Clarke has said, we'll start promptly at 8:30. Thank you all very much for your participation and attendance.

(Whereupon, the proceedings went off the record at 4:57:42 p.m.)