UNITED STATES

NUCLEAR WASTE TECHNICAL REVIEW BOARD

HYDROGEOLOGY & GEOCHEMISTRY PANEL MEETING

GROUND WATER TRAVEL TIME (GWTT)
and
FLUID-FLOW PATHWAYS

September 12, 1994

Holiday Inn Crowne Plaza
4255 South Paradise Road
Las Vegas, Nevada 89109

BOARD MEMBERS PRESENT

Dr. John E. Cantlon, Chairman, NWTRB
Dr. Edward J. Cording
Dr. Donald Langmuir
Dr. John J. McKetta

CONSULTANT

Dr. Patrick A. Domenico

NWTRB STAFF

Dr. William Barnard, Executive Director, NWTRB
Dr. Carl Di Bella, Senior Professional Staff
Dr. Victor Palciauskas, Senior Professional Staff
Ms. Helen Einersen, Executive Assistant
Ms. Linda Hiatt, Management Assistant

I N D E X

P R O C E E D I N G S

(1:00 p.m.)

DR. LANGMUIR: I'd like to welcome you all. I'm Dr. Donald Langmuir, a member of the Nuclear Waste Technical Review Board. I'd like to welcome you to the panel meeting of the Hydrogeology & Geochemistry Panel on Ground Water Travel Time. I'm Professor Emeritus of Geochemistry at the Colorado School of Mines, and I chair the Board's panel on hydrogeology and geochemistry.

Let me introduce my Board colleagues who are members of the Hydrogeology & Geochemistry Panel. Dr. John Cantlon is chairman of the board and an ex-officio member of all Board panels. His field is environmental biology and he's retired as vice-president for research and graduate studies at Michigan State University. Dr. Edward Cording is Professor of Civil Engineering at the University of Illinois at Irvana. Dr. John McKetta is Professor Emeritus of Chemical Engineering at the University of Texas in Austin. Dr. Patrick Domenico is Professor of Hydrogeology at Texas A&M University. Presently, his term on the Board has expired. He has been nominated for reappointment to the Board and is being retained as a consultant pending action by the White House. I'd also like to introduce Dr. Bill Barnard. Bill is here. He's Executive Director for the Board. And, Dr. Victor Palciauskas who is a member of the

Board's Senior Technical Staff and who supports this panel on hydrogeology and geochemistry.

Several other Board staff members are with us today. Let me introduce them briefly. Dr. Carl Di Bella who is senior technical staff member supporting the panel on engineering barrier systems. Linda Hiatt and Helen Einersen, back in the corner next to the table, are in charge of meeting arrangements.

The theme of this meeting is ground water travel times and fluid-flow pathways. Ground water plays a key role in almost every aspect of the nuclear waste disposal system. It strongly affects the corrosion rates of canisters, waste form dissolution rates, and is the principal medium for the rapid transport and dispersal of radionuclides in the subsurface. So, it's not surprising that the ability of a geologic medium to transmit ground water is an important consideration in the regulations. We will discuss one of these today which is a criterion on the geologic subsystem for isolating waste, ground water travel time.

I'll now hand over the gavel to Pat Domenico who will chair today's session on ground water travel times. Pat?

DR. DOMENICO: Good afternoon. As Don Langmuir just told you, the first theme of this meeting is ground water travel time. Ground water travel time is an integral component of the regulations dealing with DOE's site suitability determination and license application. We have been hearing about ground water travel time for quite a while, and I think that's quite an understatement. And, if history is any indication of the future, we will probably hear about it quite often in the near future.

So, it seems appropriate that we discuss this ground water travel time and the associated regulatory criteria to see if we can agree or disagree on the following items. What do we mean by ground water travel time? Can we measure it? If we can't measure it, can we calculate it? And, do we have the appropriate data and models to perform this calculation? When we have calculated it, how do we interpret the results? What does it all basically mean?

We'll take a top down approach to today's agenda by starting with an overview of the regulatory background and history of the ground water travel time criteria from three perspectives. These perspectives will be presented from the Nuclear Regulatory Commission, the Department of Energy, and the affected Government viewpoint, namely the State of Nevada and local Governments. There are many conceptual and technical problems associated with travel time criteria and we hope to become more aware of them and discuss their merits. We'll end the day with a general discussion among the panel and speakers and comments from the audience.

Now, I know that each speaker has much more than can be said in his or her topic area than the time allowed it. I would expect a lively discussion on several of the controversial issues. So, I will try to keep on schedule to allow ample time for questions. Later, I will be soliciting questions from the Board, the staff, from the floor, and from each speaker. If, by some chance, I don't get your question or comment, please try to hold it until the public comment period at the end of the day.

Right now, I am pleased to introduce our first speaker, Dr. Michael Bell, of the Nuclear Regulatory Commission who will review the history and original intent of the 10 CFR 60 ground water travel time criteria.

DR. BELL: Thank you, Dr. Domenico.

I'm please to be here with you today to start off this session to try to give you some understanding of the regulatory perspective on the subsystem performance requirements in 10 CFR Part 60 and, in particular, the ground water travel time and how it fits into our concept of the overall system and how it helps to contribute to insuring that isolation of high-level wastes is successfully achieved.

As Dr. Domenico said, my name is Michael Bell. At the present time, I'm chief of the engineering and geology branch at NRC. About 10 years ago when Part 60 was being developed, I was the manager who had overall responsibility for putting together the technical criteria and the rule. I have with me today two staff members from our performance assessment and hydrology group; Dave Brooks who is the section leader of the hydrology section, and Jeff Pohle who works in his section who I hope will be able to help answer some of the more detailed questions that might come up.

When we were developing Part 60, our concept of the repository isolation system involved essentially three opportunities in order to isolate the wastes and keep it form the accessible environment. First, containment of the waste within the waste package for a period of time. After containment was breached, we still understood that it would be possible to control the release rate of the radioactive materials from the waste package system into the accessible environment or into the natural systems surrounding the repository. And then, finally, you had the natural systems that could delay and isolate the radionuclides as they were being transported from the repository to the accessible environment. And, in developing Part 60, we wanted to insure that all three of these mechanisms for isolation contributed and we deliberately chose to have quantitative criteria for the performance of each of these systems or subsystems.

As you probably know, through the rulemaking process, we came up with a containment period within the waste package of 300 to 1,000 years and a controlled release rate after waste package failure of 10^{-5} of the inventory of radionuclides in the waste packages at 1000 years. And, what I'd like to go through today is the deliberations we went through in coming up with the quantitative performance measure that we've placed on the natural systems which was the 1,000 year ground water travel time.

Now, this work was going on in the early '80s and some of the important information in the literature that we considered at that time were international recommendations by the IAEA on site selection factors for geological repositories, the American Physical Society Report, USGS Circular 779, and the National Academy Report on Geological Criteria.

The kinds of recommendations that were being made at that time--and recall this is back at a time when all the sites that were under consideration were in the saturated zone. The salt domes in the southern United States, the Hanford site, the sites that were under consideration on the Nevada Test Site were, in fact, in the saturated zone, not in the unsaturated zone. And, there was at one time a second repository program where sites in saturated media in crystalline rocks were being investigated primarily in the northern and eastern United States. And, one of the universal understandings, say, regarding waste isolation was that the most likely process for moving radioactive waste from the repository to the biosphere was transport by ground water.

Other recommendations that were made in the various literature involves trying to find a dry formation, one with little or no movement of ground water, negligible migration, a site where the hydrogeologic properties are predictable with reasonable assurance for about 1,000 years. And, 1,000 years was considered an important time because it was sufficient time for some of the large inventory of highly radioactive fission products to decay to negligible levels.

Again, continuing, some of the considerations in USGS Circular 779, some of the things to be sought in a site that was good for isolation of high-level waste. And most of these deal with ground water, although some of them deal with geochemical absorption; low permeability of the medium, high effective porosity, low gradient, and long flow path.

Based on these considerations, the staff in developing the proposed Part 60 came up with these preliminary conclusions or basic concepts that were embodied in the proposed rule. But, ground water transport was the most probable release pathway. A criterion based on quantity of ground water flow would be a very site and design specific question and we, in fact, concluded it would be difficult to set a generic number for the quantity. That while the long-term performance of the repository again would involve the geochemical system and how it performed, again that was considered to be very site-specific. Many combinations of parameters, such as permeability, porosity, gradient, and flow path length can result in long travel times and transport times, but it wasn't considered practical to set discrete values for each of these. But, the ground water travel time was a way of combining what was recognized in the literature as the important parameters controlling ground water flow. So, we proposed ground water travel time as the quantitative measure that would be a measure of performance of the geologic setting.

We did consider a number of alternatives. Require the geologic setting to essentially provide whatever margin was needed to compliment the engineered system to insure the overall performance criterion. At that time, there was a draft EPA standard that we were working with that was similar, but not identical to 40 CFR 191 that was promulgated and then withdrawn. Another alternative was to consider a minimum radionuclide travel time from the underground facility to the accessible environment or the limit on the ground water travel time for the undisturbed geologic setting. And, I'll talk a little bit about the pros and cons of each of those alternatives.

Basically, a requirement that the geologic setting provide whatever margin is needed to compliment the engineered barriers to meet the overall system performance, basically is already a requirement. I mean, that's just another way of saying if the--essentially 1 and 1 is 2. This wouldn't really provide any redundancy or additional assurance that in the event one of the systems didn't perform as expected that the waste would still be isolated from the accessible environment for long periods of time which was, essentially, the objective we were trying to achieve. An alternative, such as this, essentially, in order to know what the geologic setting would have to do to compliment the performance of the engineered system would essentially require the total system performance assessment to be done and it just did not seem to be a good way to go about getting a simple measure for whether or not you had a good site.

The second alternative was recommended by several parties during the rulemaking. Essentially, rather than a minimum ground water travel time, a minimum radionuclide travel time which was considered, but not adopted because we felt that it was almost as difficult to do that analysis as it would be to do the total system performance assessment. We did not have sufficient confidence in our ability to understand and model the geochemical behavior of the transport system that we thought we could specify in the rule in numerical value that would have to be met by the combination of the flow and transport systems.

The Alternative 3 of setting a numerical criterion for ground water travel time for the undisturbed geologic setting was considered relatively simpler. That, basically, it was something that the staff considered would be a measure of a site that could be independently checked by things like tracer experiments, ground water dating, other techniques that did not, in fact, require complicated assessments of thermal and geochemical behavior of the total repository system. And, basically, this was the measure that was proposed and it was intended that basically, even if other parts of the system did not perform in the actual case as the rule required and the assessment said they would perform, but in the event that there was something overlooked in the engineering, there would at least be 1,000 years of protection provided by the hydrologic systems alone. We had good reason to think that there would be additional protection provided by geochemical retardation and the behavior of geochemical systems and that the combination of the various subsystem requirements would, in fact, lead to an isolation system that would provide for protection of public health and safety with a fair degree of confidence.

Now, in coming up with the numerical value, essentially we're looking at different orders of magnitude; 100 years, 1,000 years, 10,000 years. And, in our thought process, basically, we thought it was fairly likely that a number of sites with the travel time of 100 years would be available, but that that was such a short travel time that you would end up placing too much reliance on the other parts of the system that perhaps we didn't have as much confidence that we could predict the behavior of with high liability. The 10,000 year travel time, if it could be achieved, was considered sufficient. In fact, it all by itself would have met the EPA standard of the time and, in fact, at one time in a draft of the proposal rule a favorable condition was to find a site with a 10,000 year travel time. That was later changed to be just well in excess of 1,000 years. And, the travel time that we eventually proposed based on this reasoning was a ground water travel time of 1,000 years which we thought was achievable at a number of sites and different geologic media and would not place so much reliance on the geochemical systems to essentially insure the EPA standard would be met.

Now, due to the public comment on the proposed rule, there were some refinements made in the final rule. Basically, the arguments that I've been making lead you to conclude that you cannot count on portions of the geologic setting that are disrupted or affected to a great degree by the construction of the repository and the emplacement of the wastes. So, in the final rule, the concept of a travel time from the edges of the disturbed zone to the accessible environment was introduced. And, again, this is because we wanted to get a measure of the performance of the geologic setting and we did not want to have to do a systems analysis of all the thermal perturbations and the disturbances close to the waste and the source of the heat.

To support the final rule, we did a sensitivity analysis of the contribution of the various subsystem performance criteria to meeting the overall EPA standard and showed that basically a 1,000 year ground water travel time was--and, I think this is interesting wording--it can be of significant value in providing reasonable assurance that the assumed standard can be met without placing undue reliance on the ability of the underground facility to minimize relief rates. In other words, having a 1,000 year ground water travel time did not by itself insure that the EPA standard would be met. But, for a range of containment times, release rate times, and with some consideration of contribution from the geochemical systems, in most cases if the ground water travel time was in excess of 1,000 years, the EPA standard was met. There were some cases with either very little retardation or large release rates where the standard would be exceeded.

Now, one of the things that the Board has raised questions about is the provision in Part 60 that allows for the Commission to approve or specify other numerical values.

In other words, as I said, the 1,000 years was selected on a consideration of order of magnitude type differences. It did not mean that a site that only had a ground water travel time of 900 years would necessarily fail, or that if the ground water travel time was 1100 years, it was going to be obviously superior. And, the Commission put a provision in the final rule that allowed it to approve other numerical values for the various subsystem performance objectives based on a number of considerations. And, I've listed what these considerations are.

Basically, the EPA standard as it's finally promulgated, the age and nature of the wastes and the design of the underground facility; and, what we had in mind here was that if DOE adopted the strategy, for example, where they would store the wastes to allow it to cool down significantly before disposing of it, that might be a reason to approve another containment time, ground water travel time, or engineered system release rate. We would certainly take into consideration the geochemical characteristics of the host rock which, when we had an actual site and design proposed and a site-specific analysis, the Department might be able to show and convince the Commission they had a great deal of confidence that they had a geochemical system that would retard the radionuclides significantly and that could be a basis for approving some different ground water travel time.

And then, a final consideration, basically, various sources of uncertainty in predicting the overall performance. In fact, what we had in mind there, it could even lead the Commission to require some part of the system to perform at a higher level than the numerical values in the rule.

Now, as I had mentioned earlier, the initial promulgation of the Part 60 technical criteria was done when the DOE program was still looking at sites in the saturated zone. Shortly after--well, shortly, I think it was about two years after Part 60 was promulgated--the DOE program changed to focus in on Yucca Mountain. And, there were requests and, in fact, a USGS circular dealing with disposal in the unsaturated zone where USGS asked the NRC, as well as DOE asked the NRC, to consider whether the rule should be amended to better consider disposal in the unsaturated zone. The staff thought it was a reasonable request and went through a rulemaking where it revisited Part 60 and, basically, came to the conclusion that the numerical criteria as they were and, in particular, the ground water travel time, were sufficiently generic that they would apply in either the saturated or unsaturated zones, but we thought some clarification of terms was needed. So, definitions like "ground water", I think a new definition of "unsaturated zone", and some of the favorable and potentially adverse conditions were modified. And, basically, as far as the rule is concerned, that's--I think that amendment took place about 1985 and that's essentially the same form Part 60 is in today.

More recently, DOE has written to us and I think the Board has been provided a copy of that letter with proposed approach for how they would demonstrate compliance with ground water travel time at Yucca Mountain. They indicated they thought this would not require changes in the text of either Part 60 or Part 960. And, NRC responded to that letter that, basically, we believe that what they were proposing, if we understood it properly, would be an appropriate way to evaluate ground water travel time at Yucca Mountain. And, at this point, all that has happened is an exchange of letters. They have something in mind and, I think, maybe Jim Duguid later will be telling us more about what it is. We think we understand what they have in mind or are willing to consider it and, essentially, that's what we've told them; that we need to have some more meetings and detailed exchanges on a number of technical questions that we identified in our response letter. There is a meeting scheduled for November 28 between NRC and DOE. I think it's here in Las Vegas--in Denver. And, basically, that's where we stand as of today in the regulatory establishment of the ground water travel time criterion and the progress that we're making on addressing it.

DR. DOMENICO: Well, thank you very much, Dr. Bell.

Any questions from Board members?

(No response.)

DR. DOMENICO: Staff?

DR. PALCIAUSKAS: I have one question. At the time of the regulation, how much thought did you put into the fact that there is going to be a wide distribution of travel times, and that this will cause a significant, perhaps, problem in the evaluations and interpretations of the regulation?

DR. BELL: Well, in fact, I think even though at the time the regulation was promulgated we were looking at sites in the saturated zone, we were anticipating a wide distribution in travel times. For example, the Hanford site was under consideration and, if you have flow through the basalt matrix, it's almost non-existent. But, the basalt is a fractured, calmer system and another pathway for ground water flow through the fractured system was possible. And, during site characterization, there were very--well, I don't know that we ever got them fully characterized, but there were brecciated zones of unknown extent that might have been even more significant pathways. So, we were looking at systems that could have, you know, extraordinarily long ground water pathways through the matrix with probably no water going through that way and then a combination of fracture flow and flow through localized brecciated zones that would be what we would consider the fastest likely pathway. And, I think it's very analogous to the situation that we might have here at Yucca Mountain where you have alternatives of flow through the matrix, flow through an interconnected fracture system, or maybe a very fast flow through the Sun Dance Fault if that's a pathway. And, what we had fully intended was if the Sun Dance Fault is a significant flow pathway, then that would be the pathway that you would evaluate to judge the ground water travel time criterion.

DR. DOMENICO: Any further staff questions?

(No response.)

DR. DOMENICO: I have one, Dr. Bell. It says action taken--that is once you accepted the unsaturated zone through the USGS discussions--action taken included new definitions of the terms "ground water" and "unsaturated zone". Did you consider or have you considered the fact whether or not you're going to consider vapor transport through the unsaturated zone as part of a travel time criteria? The discussions got that far?

DR. BELL: Well, at that time, you mean?

DR. DOMENICO: Well, it says action taken--so, I guess actions have been taken--included a new definition of the term "ground water".

DR. BELL: Yeah.

DR. DOMENICO: Unsaturated travel time doesn't have to deal with vapor. It becomes quite an issue in the unsaturated zone.

DR. BELL: The definition of "ground water" in the original Part 60, essentially, was water below the water table. The change that was made was, essentially, to cover all water below the earth's surface. And, Dave is getting up to help me. I guess, what we need to clarify is did that just mean liquid water or did it mean water in vapor form?

MR. BROOKS: Yeah, I'm David Brooks, NRC. At that time, all we were doing was combining ground water which was that water below the water table and the vadose water or phreatic water. Considerations of transport by vapor was handled by the addition as an adverse condition, radionuclide release in the vapor phase.

DR. DOMENICO: We're a few minutes ahead of time. Is there anybody out there who wants to say something?

Bill?

DR. WILLIAM BARNARD: Mike, could you describe your plans for what sort of action you might be taking at the end of the year when the National Academy report comes out? Are you going to be reviewing the regs or what?

DR. BELL: Well, when the Academy report comes out, we will start to look at it immediately. But, there's another party which is the EPA which has to decide based on the Academy report what they'll do with their standard. And, I'd say while we could start to think about things when the Academy report comes out, until we get an indication what EPA might be likely to do, I don't think we can do anything very definitive.

DR. DOMENICO: Don Langmuir?

DR. LANGMUIR: Mike, the discussion of the disturbed zone is what I'm curious about here. My understanding was the original concept of the disturbed zone was a fairy small fraction of the mountain. If you take the word "disturbed" in its broadest sense, one or two degrees Celsius means disturbance of some kind. We're now talking about temperatures that are up by several degrees at the surface of the land. The disturbed land becomes a very large part of the whole repository block and more. Does its size lead to some thinking by NRC about how to handle the regs or how to handle the travel time issues differently perhaps than you originally conceived?

DR. BELL: Well, let's say that we never had quite the situation at Yucca Mountain in mind when we were formulating the concept of disturbed zone. A degree or two of heat rise wasn't what we had in mind. Basically, what we were concerned about was something that would give you much different ground water flow patterns than the condition that existed before the repository was put there. And, well, let's say the hot repository concept, we never envisioned the system where you would try to keep the entire underground facility above the boiling point for 1,000 years. That is thermally a much more complicated system to evaluate than the sorts of things that were envisioned a decade ago where, in fact, the attempt was to keep temperatures even in the near-field below 90 degrees Centigrade, so that backfill and buffing materials didn't lose its subversion properties and things like that. So, I think, Dave and the performance assessment people were having, say, to break some different territory than what we had in mind in evaluating the disturbed zone concept as you have to apply to Yucca Mountain.

MR. BROOKS: And, I can just add to that. We are presently studying our implementation of disturbed zone. We haven't come to any conclusions about it. One of the keys though is, as Mike mentioned--and I don't have the definition in front of me--but it's properties that are changed and it's those properties that we change the flow characteristics that we are focusing on.

DR. DOMENICO: I think we'd better move and, if we have any further questions, maybe we can address them at the panel wrap-up later today.

Right now, we'd like to welcome Steve Brocoum who will give the DOE's historical background and perspective of 10 CFR 960.

MR. BROCOUM: I'll try to do a historical background. I didn't actually live through this because at the time we're talking about, the early to mid-'80s, I was in nuclear reactor regulation. I was at NRC from '79 to '81 involved with some of the stuff Mike Bell was talking about and then I moved to nuclear reactor regulation from '81 to '86. I didn't come back to this program until 1986. If anybody needs to correct me or something or add something to what I'm saying, I wouldn't mind. So, if anybody has anything to add from a DOE perspective, please do so.

The Nuclear Waste Policy Act required DOE to issue guidelines for the recommendation of sites for repositories. So, these are the guidelines we're following for our site suitability or technical site suitability evaluations. Such guidelines shall specify factors that qualify or disqualify any site from development as a repository, including factors pertaining to hydrology. Notice that when Mike was talking, he didn't talk about disqualification. In fact, he even said a 900 year ground water travel might not disqualify a site. So, we issued in response to this requirement the 10 CFR Part 60 general guidelines for the recommendation of sites for the nuclear waste repositories towards the end of 1984.

When we issued the draft, which I believe was in

1983, the ground water travel time disqualifier read like this and I'll read it. A site would be disqualified if the "expected pre-waste-emplacement ground water travel time along any path of likely radionuclide travel from the disturbed zone to the accessible environment is less than 1,000 years,"--a big qualifier--"unless the characteristics and conditions of the geologic setting, such as the capacity for radionuclide retardation and the ground water flux, would limit potential radionuclide releases to the accessible environment to the extent that the requirements specified in 960.4-1 total system performance could be met."

The NRC made their comments and stated that we should not put our guidelines such that the 1,000 year ground water travel time would be adjusted--and, in fact, they repeated that in their letter to of August 23, interestingly enough--especially in the early stages of site selection. Because from the NRC point of view, the only people that can change the ground water travel time requirement is the Commission itself. So, to be consistent with them and the fact that the NRC had to concur on our guidelines, we deleted that text that was underlined on the previous viewgraph. So, starting with the word "unless", we deleted that text. We did make one other change. And, it now today reads: "A site shall be disqualified if the pre-waste-emplacement ground water travel time from the disturbed zone to the accessible environment is expected to be less than 1,000 years along any pathway of likely and significant"--that phrasing was added; that's not in the NRC, for example, language--"radionuclide travel."

DOE maintained that that wording "and significant" was important. It was important to avoid disqualifying an otherwise adequate site when early predictions indicated that the small amounts of water that would not be capable of carrying significant amounts of radionuclides might reach the accessible environment in less than 1,000 years. So, again, it's that issue you don't want to throw away a good site because of some minor amount of water that has a ground water travel time of less than 1,000 years. And, the NRC's comments on our rule is it did not object to a difference of phrasing between the DOE guideline and its counterpart in 10 CFR 60 and concluded that our final revision, the one I just read before, was not in conflict with Part 60. One of the reasons they said that was because the purposes were different. Our purpose was to see whether a site was suitable to be submitted for a license application.

We were required to evaluate Part 960 as a basis for nominating sites for characterization and the environmental assessment for Yucca Mountain which we did through '86. We included a lower-level finding that ground water travel time disqualifying condition was not present. Remember now, a lower-level finding is that the information in this case indicates that this condition is not present, but there's no assurance about future information. Future information may change your mind. Whereas, a high-level finding, you have enough understanding of the uncertainties that you believe that you--you don't believe that additional information will cause you to change your mind. So, this was just a lower-level finding.

For those that might be interested in looking at that evaluation in detail, it's on Pages 6-120 through 6-160 in the environmental assessments in the first volume. Okay? And, one of the diagrams shown was this diagram which has a contour of the ground water travel time based on the calculation that was done and that ranges from about 20,000 years in the northeast corner to 70,000 years on the southwest corner of the repository block. And, the unsaturated zone is 200 meters thick here and it's 300 meters thick there. I think that's the right numbers. The thing that correlates most is the thickness of the unsaturated zone. They assumed a flux of .5 millimeters per year. The travel time was a minimum of 9,000, a mean of 43,000, I think there was a median of around 41,000, and a maximum of about 80,000 for the unsaturated zone. And then, for the saturated zone, it came up to about 150 years. So, a conclusion was--

and, I won't read all this--"therefore, the evidence does not support a finding that the site is disqualified." So, it was a Level 1, a lower-level finding.

What's our current status? Our focus now in developing an approach that provides a technical basis for evaluating both the NRC 10 CFR Part 60 performance objective for the geologic setting and our 10 CFR 960 disqualifying condition. You will hear a lot about that, I assume, today from these three gentlemen on the end of the table here. We did present that general approach to the Board in Reno on April 11 or 12. Jean Younker did that. We did also summarize that approach in a letter which we sent to the NRC on June 10 and we requested their comments and we did receive their comments very timely on August 23 from the NRC, and Mike summarized those comments. One of the interesting comments the NRC gave us was that it's--I'm not sure I'm using the right word--but, you know, the fastest. There's the word "fastest" in there. And, the NRC considers the fastest path to be significant unless we can show that it's not. And, that was one of the other comments that you didn't mention, but was in the letter.

So, that's where we stand right now. So, if anybody has any questions, I'll be glad to answer them.

DR. DOMENICO: Thank you, Steve.

Questions from the Board? Don?

DR. LANGMUIR: Your 1986 analysis of flux and travel times, Steve, suggested means of, say, 43,000 years. Is that pretty much where you still would be, looking at what's been learned since then about the site?

MR. BROCOUM: I could ask one of these experts here to tell what's the latest. Do we have any latest estimates or does anybody feel like making a comment on that? I don't want to speak out of turn here.

DR. RALSTON BARNARD: Ralston Barnard from Sandia Labs. Unfortunately, it depends greatly on the flow model that you choose to use. If you use a composite porosity model, then indeed tens of thousands of years is an expected time. If, on the other hand, you use models which specifically attempt to model fast path flow, then you can get considerably shorter times. We'll actually be able to show this in some detail between Jim and me a little later on today.

DR. LANGMUIR: And, will you also be discussing the max and min, the earlier rivals, the general rival time ranges that are proposed here at least in the early--can you talk about that again?

DR. RALSTON BARNARD: At the risk of giving away the juiciest part of our talks, we really need to stress that the results we come up with are distribution of times and that it's the tail of the distribution, in fact, the early time tail, is that which is of most interest to us.

DR. DOMENICO: Further questions from the Board or staff?

(No response.)

DR. DOMENICO: We're a few minutes ahead. Does anybody out there have some thoughts or questions about what's going on here?

(No response.)

DR. DOMENICO: Thank you very much, Steve.

The last perspective before the break is that of the affected local governments, their viewpoints of the regulatory background, and now Mal Murphy is going to help us out there.

MR. MURPHY: Thank you, Pat. I'm Mal Murphy, as most of you know. I'm the regulatory and licensing advisor to the Nye County Nuclear Waste Repository Office. And, the views I'm going to express here today are those of Nye County, although I think I can say with a fair degree of confidence that there is virtually no daylight between what I'm going to say and the views on the regulatory question surrounding this ground water travel time held by the other units of local government and the State of Nevada, as well, I think.

Just a quick summary of what I intend to cover, again it's the regulatory perspective. I'm not a scientist. I'm not going to talk about scientific data needs with one small exception later on in my presentation. It's not specific to DOE's new ground water travel time computational methodology nor to the PPA, although again I'll have some comments germane to both of those later on. I'm going to go over the ground travel time provisions very, very quickly. There's a lot of repetition here obviously between what I have in my materials and which Steve Brocoum and Mike Bell covered. I'm going to go over then what my view of the regulatory background and history is of both the DOE guidelines and the NRC licensing criteria.

I'm going to start with the DOE guidelines. Although I think they're probably less significant than the NRC criteria, I'm going to start with them because DOE has to start with them. They come first. They have to determine suitability before they can file a license application, obviously. Then, just some general concepts and considerations, I think. And, Pat, I'm going to get into the question of whether or not it includes vapor, as well as the liquid phase when we talk about ground water. And then, very quickly our views and interpretations of what some of the stuff means.

The ground water travel time provisions you're all familiar with. I think both Mike Bell and Steve Brocoum put them up on the board. I do want to point out, however, what neither one of them did and that is the most significant difference between the NRC and the DOE in this and a difference that clearly has some serious implications for licensing and that is DOE hyphenates ground water and the NRC does not. Those are not typos; that's the way they are in the regulations. The dictionary of geologic terms that I've had in my office for 10 years says DOE is right, Mike.

One other thing that I wanted to very, very quickly point out, we have to remember that these are not just disqualifying conditions or licensing criteria within the geologic setting. Ground water travel time also applies to the favorable conditions. DOE's favorable condition is that if the ground water travel time is substantially in excess or in excess of 10,000 years. The NRC, on the other hand, makes a favorable condition if GWTT is substantially in excess of only 1,000 years. So, on that point, the application of whether or not a favorable condition exists, that point in my view at least the Department of Energy has taken a more conservative approach than the NRC has.

Some definitions, again you're all familiar with these. Let me just point out a couple of things very, very quickly again with respect to the disturbed zone, very key in this area as you all know. There will be much more discussion of that later on, I think. I think, as far as I can recall and again from viewing the regulatory background as I prepared for this, it's absolutely correct that when the definition of the disturbed zone was--the two definitions were written by both DOE--this is DOE's definition--and the NRC, people didn't take into consideration the impact of thermal loading, of the thermal effects. I think that's absolutely beyond question. They just didn't think about what impact that might have. But, be that as it may, the definitions say--and unless the regulations are somehow changed or some other interpretative action is taken, such as the issuance of the GTP that the NRC has under consideration for a long time--the definition does say the result in change of properties could have a significant effect. And, again, using what we always insist is necessary, principles of scientific conservatism in this area, we have to--I think we have to take a much more serious view of the thermal disturbance problems than anybody thought about back in 1983.

Let me point out another thing real quickly, another difference between DOE and the NRC. DOE defines ground water flux, as well as ground water itself. DOE also defines in its guidelines ground water travel time; the NRC does not. The NRC stops and, before the unsaturated zone amendments were adopted in 1985, they stopped at ground water, although the definition was a little bit different. Again, DOE defines ground water travel time. How does that affect the status of the program right now? It seems to me and I think Mike Bell alluded in one of his last remarks about how there needs to be some further discussion between

DOE and the NRC and all the program participants on the question of summing the travel times in the saturated zone and the unsaturated zone. Whether or not that's a scientifically sound idea, I'm absolutely not commenting. I'm not a scientist and that's well beyond my qualifications. But, it does seem to me that with respect at least to the ground water travel time definition in DOE's guidelines that this definition allows DOE to do that, it seems to me. From a regulatory perspective, not from a scientific perspective. And, again, only in getting to site suitability, not necessarily as it applies to licensing once this gets into the NRC's lab if and when license application is filed.

I'm going to go through this very, very quickly. I think Steve did a very good job of going over the background of the DOE guidelines. Let me just point out a couple of other things that he didn't mention. There was a lot of criticism in the comments. A lot of people insisted that the GWTT should go up to 10,000 rather than 1,000. DOE and the NRC, both, accepted 1,000 versus 10,000. Oh, and the other one. The definition of ground water travel time in the guidelines was as a result of these comments on the proposed rule that came out in '82, I believe it was. A lot of commenters said you should explain to us in the ground water travel time--in the geohydrology disqualifying condition, explain to us how you're going to calculate GWTT. DOE said, well, we're not going to do that. We're going to change it a little bit in response to the NRC's criticisms and their concurrence condition, but we will add a definition of ground water travel time which will tell you how we intend to calculate it and they did that.

Again, we're now here talking about why the words "and significant" showed up. Steve covered that adequately, I think, with the exception of a couple of very quick points that I'd like to make. The first is that I think DOE correctly at this stage of the process insisted that there needed to be some flexibility and I'll get to that in just a second. In its concurrence condition, the NRC, as Steve pointed out, said we want you to take the "unless" and all that language out--the "unless" out because that offends us in a variety of ways, the most important of which is that it assumes our licensing responsibilities. DOE insisted on having some flexibility. So, they put in the words "and significant". NRC accepted those changes finding that "and significant" was just redundant and not in conflict with their licensing criteria, but as Steve pointed out, in 1984 --and, this is the citation where you can find it; the page of the Federal Register in which NRC's final concurrence document is published--the NRC did say that they would expect the fastest pathway to be significant. In other words, when DOE says in its guidelines the fastest path of likely and significant radionuclide travel, NRC said in 1984 and repeated it again in their August 23 letter to DOE responding to DOE's request for input that NRC expects that the fastest pathway will be significant. And, if it's not significant, DOE has the burden to show that. Again, this is in the licensing context, remember; not at the stage of site selection or site suitability. But, in the licensing context, DOE will need to show that a fastest pathway is not significant in terms of repository performance by the clearest and most compelling showing to the contrary. And, that, I think, is of extreme regulatory significance which I'll get into in a little bit.

Again, now, I'm talking about the DOE guidelines here. It's very important, I think, to keep in mind that the DOE guidelines are site selection guidelines. They were written when several sites were under consideration. They were written in order to--or the purpose of the guidelines was to allow DOE to select from among and between several sites; nine sites at one time for the first repository, 16 or so sites for the proposed second repository before the Department caved in to public pressure on that one. But, that's very, very important and, to me, at least, means that the "and significant" language is perfectly reasonable, perfectly appropriate at that point in the repository program. As the NRC itself pointed out in its concurrence conditions, it would not be indeed a good idea to prematurely disqualify what might later on turn out to be a good site if very preliminary data showed that you have or might have some pathways that were significantly faster than 1,000 years. So, it was in the context of selection of sites. And, remember, that's not only selection of a site which was to go to licensing to the NRC, but it's the selection from among nine sites of three sites initially or finally one site to be characterized. So, when you're picking a site to get lots and lots and lots of data on in site characterization, it's not a good idea to prematurely throw a site out because, again, preliminary data indicates that you might have a fast pathway. So, you look to see whether or not that pathway is significant; a perfectly reasonable approach and the NRC recognized that.

NRC licensing criteria, they started out talking about the far-field in 1981 and the proposed rule. They went to the--and, this was average, the travel times I think initially in 1091. There was some comment on that and criticism. They changed the final language and it talks about fastest pathway of radionuclide travel and their preamble to the final rule in 1983, I believe, says that while that was implied in 1981, we're going to make it clear and just say the fastest pathway. They again went from the far-field concept to the disturbed zone concept.

Mike Bell, I think, explained very adequately why pre-waste-emplacement and the concept of independence and why it was very important to the NRC that this be considered and be applied as an independent test of the overall repository performance in order to contribute to the high-level of confidence, to a level of confidence which the Commission is required to have before issuing a license. Again, a much more different public policy problem, as well as scientific problem, if you will, in deciding whether or not you're actually going to allow the thing to be built and operated rather than if you're preliminary--in the early stages selecting sites to characterize or then selecting a site to take forward to the Commission.

The GWTT requirement, some comment--there's actually suggested when we got to adopting the unsaturated zone amendments in 1985--they were proposed in 1984--some comment has suggested and I think--don't hold me to this; I could be wrong, Steve--but, I think the Department of Energy may have been one of them that suggested dropping the ground water travel time requirements as a rigid licensing criteria in the comments on the '84 proposed rule. But, the NRC said, no, no, no, we're going to keep them. The GWTT requirements are important because they do give that independent standard of performance which is necessary. By independent, the NRC meant not dependent upon the effects of waste emplacement and it's intended to help provide the assurance of isolation beyond the first 1,000 years that they felt the Commission would need. These, of course, again, are citations to where this language appears in the Federal Register. The NUREG 1046, I think, Mike Bell pointed out is the staff's further in-depth explanation of the rule, as well as the comment/ response document.

The flexibility or such other language in the NRC performance criteria that Mike Bell pointed out and Steve alluded to has been very important from the outset. That did not creep into the NRC licensing criteria by accident. It was important from the very beginning of this process to the Commission and to the Commission staff that they be given enough flexibility to look at these problems including ground water travel time, on a case by case basis as they relate to the ability of any particular site to isolate waste. But-- and, this is an interpretation of mine; this is not the regulations or the supplementary information published at the time the regulations were adopted and don't say this in so many words. But, it's my interpretation that in order to get to the reasonable assurance standard, which I'm going to talk about in a second, if you have a ground water travel time pathway of less than 1,000 years, that's not disqualifying. But, in order to get the license, in order to persuade the NRC that there's still a reasonable assurance that the repository will perform as it is intended to perform and required to perform, if the ground water is going to travel at less than 1,000 years, they're going to have to make the clearest and most compelling showing under that or such other language. And, that should have at least, as I will get to in a little bit, some significance for how the Department conducts its business from now on.

Are you paying attention now, Patrick?

DR. DOMENICO: Yes, I am.

MR. MURPHY: Ground water includes both saturated and unsaturated zones; that's a given since the amendments. In my judgment, ground water includes both the liquid and the vapor phases and this is not necessarily just from a scientific point of view, but it's from the regulatory perspective. When the NRC adopted its unsaturated zone amendments in 1985 and when they first proposed the unsat zone amendments in 1984--and, incidentally, they did that almost immediately after adopting the final technical licensing criteria in 1983 because in the comment process leading up to the adoption of the final Part 60 technical criteria in 1983 a lot of people pointed out that there was a gaping hole here in the regulations in failing to address unsaturated zone. I think, as I recall, because the Department was already, if it hadn't made the decision, it was already seriously considering moving the proposed repository horizon at Yucca Mountain up into the unsaturated zone and, therefore, that needed to be considered. But, in the supplementary information in the discussion of the proposed rule in 1984 and again in its adoption of the final rule in 1985 and in NUREG 1046 which accompanied the unsaturated zone rules, the NRC staff said very clearly, as far as I'm concerned, that vapor transport of contaminants, it was identified by the staff as a potential concern associated with disposal in the unsaturated zone. This is a quote from one of these pages. I think the quote appears identical in both the preamble to the proposed rule and the final rule. "In unsaturated geologic media, water is transported in both liquid and vapor phases." And, this is at the same time, remember, that they were amending their definition of ground water to include all water below the land surface, I think it is. Relative contribution of transport via both phases and their direction of movement directly influence containment. Again, this is a paraphrase, not a quote. This is another quote: "Vapor transport, particularly when a thermal gradient is imposed, may provide a possible mechanism for radionuclide migration from a geologic repository."

Now, in the final rule which was adopted in 1985 as opposed to the proposed rule which was published in 1984, they took consideration of vapor phase out in the regulatory language itself and I think the potentially--I didn't set it out here in my prepared material, but I believe the potentially adverse condition in the final adoption in 1985 refers only to gas, not water vapor. But, the concern which prompted that and a concern which was on the NRC staff's mind--all during this little over a year period in which they were considering the unsaturated zone amendments--what do we do about vapor? Water travels in both the liquid and the vapor phases. It contributes or has the potential, at least, to contribute to contamination and so it has to be considered. And, there's also some language which I didn't set out saying, hey, this is a big problem; we're going to have to study it further.

So, my position, at least, is that until something with finality is done with the regulations or until some NRC Commission sanctioned official interpretation to the contrary is adopted, ground water includes both the liquid and the vapor phases. That's our position. And, obviously, as you all recognize, this may very constitute the fastest pathway of radionuclide travel and it's going to be a lot quicker than 1,000 years, a lot quicker. But, again, that doesn't necessarily mean that Yucca Mountain is going to be disqualified because it will be considered under the such other language of 60.113(b), but if you have a pathway--if vapor constitutes the fastest pathway and that's going to carry some radionuclides, DOE is going to have to make to the NRC the clearest and most compelling showing that that's not going to constitute significant radionuclide migration and will not push Yucca Mountain over the EPA limits.

Again, very quickly, some points. Obviously, the accessible environment includes the land surface. That's significant in the vapor phase. The argument in my view, at least, the disturbed zone extends well beyond the repository boundary. It includes the entire thermally affected area so long as the change of properties may have or could have--depending on whether you're reading DOE or NRC's language--a significant effect on performance. The guidelines initially defined disturbed zone in terms of permanent change. When I say DOE's concurrence guidelines--I don't know what the heck I'm talking about there, but--well, DOE's siting guidelines --really, that's got to be a typo--initially defined the disturbed zone in terms of permanent change. The NRC in its concurrence condition said, no, no, no, that's not good enough. DOE removed "permanently" in response to a NRC concurrence condition. The NRC pointed out that in its definition of the disturbed zone, it's not limited to areas that have changed permanently; and the NRC was concerned that DOE might neglect transient changes that could have a significant effect on the repository. I'm suggesting one of those transient changes obviously is thermal effects.

I want to talk a little bit about reasonable assurance and my view and how it impacts ground water travel time. In my view, reasonable assurance may very well be the least well understood aspect of the Nuclear Regulatory Commission's licensing process; probably with respect to reactor licensing, as well as the repository, but they aren't very much into that business any more. The reasonable assurance standard--and a lot of people that I've talked to informally in the last 10 years, 11 years, I guess that I've been involved in this program initially had the assumption that this was something that the NRC cooked up with respect specifically to the repository program. That is absolutely not the case. The reasonable assurance standard has its roots in the Atomic Energy Act itself. It's been around since the very beginning of Atomic Energy licensing activities. It comes from the NRC's, the AEC's in the old days, requirement that whatever they do, any license they issue, any activity that they permit under the Act not have an unreasonable or undue impact on public health and safety.

The term "reasonable assurance" and the standard itself and its application in the regulatory concept, a context has been judicially approved. Not only has it been approved, it was approved by the United States Supreme Court in 1961, not '81 or '91; '61, 1961 in the first contested AEC licensing proceeding. The first time anyone contested an application for a license to operate a reactor, the case got to the U.S. Supreme Court and the concept of reasonable assurance rather than some other more rigid, more compelling, more numerical sort of approach was specifically approved by the U.S. Supreme Court. So, anybody who thinks in the context of the Yucca Mountain licensing case, for example, that reasonable assurance can be attacked because it's either too rigid, as some people I think who were involved in writing the NAS White Paper a few years ago thought, or because it's not rigid enough, as some people on the other side of this program might feel, I think would be wasting their time. This is a standard that's been around a long time. The NRC knows how to apply it, the staff does, the Commissioners themselves know how to apply it. It's been talked about in case after case after case at the Atomic Safety and Licensing Board level and it has some very well-thought out application to this process. It's also, incidentally, incorporated in the Nuclear Waste Policy Act itself by Congress. So, it's a standard that we're going to be dealing with in licensing.

It was criticized by both sides, reasonable assurance, as too rigid and too lax when Part 60 was initially proposed and adopted. It will control the determination and effect on licensing of the fastest pathways. It's explained by the NRC staff or by the

Commission itself because they adopted the regulation in 60, Section 101. Complete assurance is not required. And, you've all read these. This is not coming as any news to any of you, I'm sure. Proof of the future performance of the engineered barrier systems and the geologic setting over those kind of time periods is not to be had in the ordinary sense of the word. Make allowance for the time period, hazards, and uncertainties, et cetera. Neither implies--and this is important as far as I'm concerned--it does not imply a lack of conservatism. What I have always insisted is required in the repository program; that is scientific conservatism is not implicated by reasonable assurance, but on the other hand, it doesn't create a standard which is impossible to meet. And, that's the citation where this language comes from.

Two principal elements that you'll find in the NRC's language in its application; the PA must indicate that the likelihood of exceeding the EPA standard is low, and the Commission must be satisfied that the performance assessment is sufficiently conservative--again, that notion of conservatism--and its limitations are sufficiently well understood that the actual performance of the repository will be within predicted limits. That's how reasonable assurance is going to be applied. I view it as the same kind of standard which we apply in a lot of other licensing contexts.

It's nothing really different.

Again, I think this is language which we need to keep in mind that the Commission's task is not only a mathematical one, et cetera, but we need reasonable assurance it's going to allow the Commission to arrive at that bottom line and the Commission is concerned that its final judgment be made with a high degree of confidence. A high degree of confidence and that's also significant language in my judgment.

Some general views and interpretations. I think everybody agrees with the first one, the GWTT standard is independent of repository operation. That's clear from the language of the regs themselves. It has to be, I think, a meaningful measurable test of the suitability of the site in the first step and licenseability in the second step. I've always considered ground water travel time to be a minimum standard. I sometimes refer to it as the retch test that if you don't get past that ground water travel time, you have a retching sort of reaction toward Yucca Mountain or any other repository location and it means you have to take a much more close look at it.

You can and should rely on the multiple redundant barriers, such as the EBS, retardation, et cetera, to get the performance objectives once ground water travel time is demonstrated, but you don't rely on redundant barriers or retardation to establish ground water travel time. I don't think there's any real argument about that.

Another point I think I'd like to convey. It clearly is that ground water travel time is not a potentially adverse condition. It's a disqualifier in the DOE guidelines subject to the "and significant" language, of course. In the NRC licensing criteria, it shows up only in the geologic setting and in the favorable conditions. And, in other words, if ground water travel time is less than 1,000 years, it's not a potentially adverse condition; it is adverse in fact, i.e. disqualifying. Unless DOE can under this clearest and most compelling showing standard, demonstrate factors which would warrant the NRC invoking the "or such other" language as in 113(b).

Now, let me tell you here's where I'm going to violate my rule about not talking about data needs because I'm not a scientist. Let me suggest that one way--let's first assume that you're going to have some pathways faster than 1,000 years. That will clearly be the case if the disturbed zone extends all the way, for example, into the saturated zone. As many people will argue, if all of the thermal effects are taken into consideration and if the disturbed zone definition is construed liberally and the language "may or could affect" is given its full flavor and meaning, you could have a disturbed zone that starts or that goes into the saturated zone and you could have Steve's ground water travel times of 150 years, not 43,000.

What then? Well, then, DOE has to make its clearest and most compelling showing, I think. One way I would suggest that you do that is by the use of multiple models, lots of data, gather data from all points on the compass, do your modeling and performance assessment, as is being done--I'm not suggesting that this isn't being done today--do your performance assessment and your modeling from a variety of approaches, don't discard any scientist's notion about how we might attack these questions, don't give up on anything too early because you may need in order to get to this clearest and most compelling showing later on in licensing, the Department may need all of the modeling and all of the help it can get. If you've got four different modeling approaches or six or three or however many they're going to have, and they all show that within a fairly reasonable sense of comfort the ground water is going to travel at more than 1,000 years, the release criteria are going to be met, et cetera, et cetera, or even though the ground water travel is less than 1,000 years, the release criteria are going to be met, then you can make that clearly and most compelling showing. But, if we have one model which shows that Yucca Mountain passes and another model--and there will be such a model in licensing, I guarantee it, from somebody. Somebody is going to have a model showing that the site flunks clearly, unequivocally flunks. And, if you've got one balancing another, that's not reasonable assurance. 50/50 is not going to get you the licensing, I guarantee. So, it seems to me it would be incumbent upon DOE to do all the modeling they can, do the performance assessment as widely as they possibly can at this point in time, so that if they do have fast pathways, they will be able to at least have a crack at meeting the clearest and most compelling showing.

So, I guess I've talked about all of that stuff already. The final analysis again then, the bottom line is that you can license Yucca Mountain with a fast pathway, but you need to get to this--in order to demonstrate to the Commission's satisfaction reasonable assurance, you're going to have to be able to meet the clearest and most compelling showing standard if you have a pathway faster than 1,000 years.

That concludes my prepared remarks.

DR. DOMENICO: Thank you, Mal.

Now, I have one question. This is what I think I heard from you and Michael and Steve. If the EPA criteria are met or demonstrated to be met in model studies, this--I think I heard--is this overrides the release from the barrier criteria the NRC has put up, as well as the ground water travel time. Is that a fair assessment of what I've heard from you, at least? I don't want you to speak for the other gentlemen.

MR. MURPHY: You mean, meeting the EPA criteria is the ultimate test? You can flunk the ground water travel time, you can flunk the Part 60 performance objectives or the criteria--

DR. DOMENICO: I think that's what I heard.

MR. MURPHY: --and still meet the EPA standard and pass? No, I think they're all independent. I think the NRC could say, okay, your modeling demonstrates that you're going to meet the EPA standard, but that's not good enough for us. We've got to be satisfied that you've got slow pathways and that you can meet our criteria. I'm talking about what will happen in the regulatory context assuming that there are no outside forces that come to play in this repository program. I think the NRC could still say that--you know, you've got to give us a little more comfort level than that.

DR. DOMENICO: So, you still consider it a disqualifying condition?

MR. MURPHY: No.

DR. DOMENICO: Less than 1,000 years, that is?

MR. MURPHY: No, no. At that point, the NRC says go further. Make this showing to us under the clearest and most compelling standard that even though the water is traveling faster than you had hoped it would and that maybe even though there isn't quite as--you know, some other factors aren't satisfied, you've got lots of retardation, you've got a foot and a half of copper, and all sorts of other things like that and you're still going to satisfy the ultimate release criteria, and--

DR. DOMENICO: Well, that's what I thought I asked you first that you said no. I thought I said if you meet the EPA standard, it was overriding on the other. I think you said they were all independent.

MR. MURPHY: No, the criteria are independent in order to get to that ultimate--maybe I misspoke myself. In order to get to that ultimate EPA standard, yeah--

DR. DOMENICO: Okay.

MR. MURPHY: --you have to look at all of these criteria independently. But, remember, it's a level of confidence. You can show that you meet the EPA standard, but the NRC could say, okay, but you haven't shown us with that high degree of confidence. We're not comfortable that there's still too much uncertainty here, I guess is what I'm saying.

DR. DOMENICO: Questions from the Board?

DR. LANGMUIR: Mal, you referenced NRC's studies of '84-'85, their documents on liquid and vapor transport. And, the sense was that I got from what you quoted from the NRC regs was they intended to mean water vapor transport. I'd like them to clarify whether that's, in fact, what they were limiting themselves to or they intended to talk about gaseous radionuclide transport, as well as water vapor transport. Would someone from NRC comment to that?

DR. BELL: Well, I'll start and then I'll let Dave pick up. But, I think one of the things I would point out is you need to look at the whole requirement, the fastest path of likely radionuclide travel, and ask what radionuclides are going to be traveling with water vapor. Tritium with a 12 year half-life, I mean, what--it just does not seem to me the fact that you have water vapor being able to diffuse through pores is, you know, contributing to a pathway of likely radionuclide travel. One of the concerns is carbon dioxide, I guess, migrating through the pores. Carbon dioxide will migrate through bone dry air. In fact, it will migrate slower if water is present because it will be--

DR. LANGMUIR: Yes, I'm aware of all this, but I wondered if the language--I was interesting in whether the language you used identified those radionuclides.

DR. BELL: You know, fastest path of likely radionuclide travel is--it's important to keep it all together. And, that also is true when you look at these other potential pathways like flow through fractures and things like that. If you can show, yes, there is a fast pathways through fractures, but really not very much radionuclide transport takes place because of that, then you could still meet 1,000 year ground water travel time criteria even with this fast pathway that isn't really contributing to transient water.

DR. DOMENICO: I think these are questions and discussions that we should reserve for the latter part of the day when we have our panel meetings. Does the Board have anything further--I'm sorry, did you want to respond to that?

MR. MURPHY: Yeah, let me just respond to that quickly.

DR. DOMENICO: Sure.

MR. MURPHY: I don't disagree with the words Mike said, that all of that is absolutely true. But, it does invoke, it seems to me, if you have the--and, I still believe that ground water includes vapor, as well as the liquid phases, under the current language. It does invoke that clearest and most compelling standard. That does mean that you're going to have to have these multiple approaches and it seems to me --and this is going to be talked about further by the scientific and technical experts in the next day and a half--it does in my mind, at least, mean that you can't come to the NRC and meet the clearest and most compelling standard by cutting off site characterization prematurely and going to licensing with incomplete site characterization data and say, trust us, we'll make a more clearer--the clearest and most compelling showing 100 years from now after the end of our confirmatory testing phase. It seems to me that's where the impact comes on DOE's program. Sure, you can meet this standard. You can invoke the "or such other" language and you can clearly show that not enough radionuclides are going to get out to hurt people, but you're going to have to do it under that greater burden, and you're going to need lots of data and complete data in order to do that, it seems to me.

DR. DOMENICO: Well, good, I think this is something we can put down and we can be discussing a little bit later.

Is there any further Board questions to Mal?

(No response.)

DR. DOMENICO: Staff?

(No response.)

DR. DOMENICO; I have a few more minutes if anybody out there has a question.

(No response.)

DR. DOMENICO: We declare a break, 15 minutes.

(Whereupon, a brief recess was taken.)

DR. DOMENICO: We have a change in schedule giving the program overview of the ground water travel time assessment. Now, this is the program overview. Instead of Claudia Newbury, we're going to have Eric Smistad and that would be the program overview of ground water travel time.

MR. SMISTAD: My name is Eric Smistad and I'm going to be giving a very brief introduction to the ground water travel time program and the working group.

The ground water travel time group is a subset or a subgroup of the issue resolution organization. It's down here. The group is comprised of myself as the DOE lead and --I've got this backwards here--Les Berkowitz is the regulatory lead, Jim Duguid is the technical lead. Sorry about that guys; didn't mean to scare you. Rally Barnard is out of Sandia and he's going to be doing the bulk of the implementation of the approach. There are other resources. The USGS, obviously, with their modeling components; Dwight Hoxie is the main contact we have there. Los Alamos and the M&O are also resources.

We've seen an awful lot of regulatory talk earlier. So, I won't really dive into this too much. Just to point out that the approach we have--and we'll see today--is based on the DOE regulatory basis which is the 960 disqualifying condition and the NRC regulatory basis, the ground water travel time performance objective in 10 CFR 60. It's also based on DOE and NRC definitions of the disturbed zone and you will hear a little bit more about that with Jim and company.

There's just a few key points I'd like to bring to your attention. The detailed approach that you're going to see today is just really recently been fleshed out. You saw Jean Younker give a presentation in April which was not in as much depth as you'll see today. But, basically, it's remained unchanged from what Jean brought forward.

The determination of ground water travel time is going to be an iterative process culminating in the final iteration in calendar year '97 in time for the '98 TSS. We'll have preliminary results mid-calendar year '95, the first iteration we'll have in late calendar year '96, and then the final iteration in late calendar year '97. Follow-on Board meetings, we intend to bring forward the individuals that are doing the detailed modeling to give you more insight into how we're actually modeling ground water travel time.

And, that's all I have.

DR. DOMENICO: Thank you very much, Eric.

Then, the first discussion here will be by Lester Berkowitz giving us the interpretation of the regulations and calculational philosophy.

MR. BERKOWITZ: Good afternoon. I've been asked to talk about the interpretation of the applicable guidelines and regulations and how they get us to the approach that we are taking to develop a methodology for evaluating ground water travel time at the Yucca Mountain site. And, we believe that that methodology has to be based on an interpretation of DOE's guideline, NRC's performance requirement, and DOE and NRC's definition of the disturbed zone. And, in preparing for this presentation on Friday and after listening to Steve and Mike Bell and Mal Murphy talk this morning, I decided that I ought to share with you some things from Through the Looking Glass because what we're really talking about is what words mean.

We believe that in order for us to do a good job on developing the methodology, the methodology has got to be consistent with not just our own meaning of the guidelines and the regulations, but the Commission's meaning of the guidelines and regulations. And, we've had the benefit in the last couple of months after the April TRB meeting of sharing with the NRC in a letter that the Department wrote in June, the Department views on the approach it was taking. As Mal pointed out, the staff responded to that letter just a couple of weeks ago. The staff's response was that they agreed with DOE's interpretation, in part, and it saw the need for further discussions with the Department in order to make sure that it understood what the Department wanted to do. And, we think that's good because that's exactly what we have in mind. We believe that there's going to be a need for a lot of doing and a lot of talking in order to make sure that we're all on the same wavelength.

The thing that we're pleased about today is that in developing this methodology, the Department and the M&O and Sandia and the USGS are all working together to develop this methodology and we think that this is a good thing and as it should be. The interpretations that I will be presenting and that Jim and Rally will be talking about are DOE's interpretations. And, we understand what's clearly written in NRC's regulations; namely, that only written interpretations by NRC's general counsel are binding on the Commission. Our job, we believe, is to tell NRC what we propose and to do everything that we can to convince them that that's the right thing to do.

Now, DOE has got to make an evaluation as to whether or not this disqualifying condition is applicable at the Yucca Mountain site. We think, DOE thinks, that its use of the words "likely" and "significant" in the language of this disqualifying condition provide the basis for its belief that ground water travel time should be thought of as a distribution and not as a single value parameter. NRC's performance requirement contains similar language and, in particular, it talks about fastest path of likely radionuclide travel and it talks about such other travel times as may be approved or specified by the Commission.

Now, what DOE advised the Commission in its letter of June 10 was that its intent is to determine the applicability of the disqualifying condition in 10 CFR Part 960 and, if the site is determined to be suitable, its next objective would be to determine whether ground water travel time at the site is in compliance with the requirements of the Commission's subsystem performance requirement. We are not at this time talking about the 60.113(b) approach.

When we looked at the definitions of the disturbed zone in the Commission's regulation and in the Department's guidelines--and when I say we looked at them, we tried to look at the plain meaning of the words and we tried to look at these things in the context of our understanding of their physical site. We came to the conclusion that DOE's definition of the disturbed zone and the Commission's were almost identical and both definitions talk about the disturbed zone constituting "that portion of the controlled area the physical or chemical properties of which have changed as a result of underground . . . construction or heat generated . . . such that the resultant change of properties may have a significant effect on the performance of the geologic repository."

As I said earlier, we believe that the use of the word "likely" in DOE's disqualifying condition means that ground water travel time is a distributed parameter, not a single value. And, when we looked beyond the plain meaning of the disqualifying condition and we looked at NRC's site characterization analysis, we found that our interpretation was consistent with the staff's recommendation in the site characterization analysis. We also believe that the use of the word "significant" in DOE's disqualifying condition means to us that some pathways and some travel times may not be important to repository performance. They may not be significant. And, in fact, evaluating the significance of such pathways and travel times would also be consistent with the staff recommendation in its site characterization analysis.

And, the phrase that "such that the resultant change in properties may have a significant effect on the performance of the geologic repository in the definition of the disturbed zone" implies to us that only disturbances and changes in properties having a significant effect on post-closure performance need to be considered in defining the disturbed zone boundary and affect the extent of that boundary. Now, Jim and Rally will be talking about what we will actually be doing to go way beyond that and to actually try to define the boundary. But, this interpretation of the definition of the disturbed zone in our mind is consistent with the staff's recommendation in the site characterization analysis that the significance of changes on repository performance should be ascertained and the delineation of the disturbed zone boundary be based on those changes significant to repository performance.

Now, these are DOE's interpretations and you've heard Mike Bell and Mal Murphy interpret them in somewhat different ways. But, for the time being, at least, these are our interpretations and these lead us to the approach that

Jim and Rally will be describing this afternoon of the GWTT methodology the Department is developing. And, that is that ground water travel time is a distribution of water particle transport times. It isn't single value. The second point is that the methodology involves evaluating the significance of changes in the chemical and physical properties of the controlled area to define the boundary of the disturbed zone.

Next, the methodology that involves determining the expected distribution from the disturbed zone boundary through the unsaturated zone, and then, the saturated zone from points below the repository horizon to the accessible environment. That is that ground water travel time in our mind takes into account water particle transport irrespective of the hydrologic regime through which ground water might be moving. And, that is also consistent with the Commission's position in it's statement for consideration when it was modifying the rules for use with unsaturated sites.

Next, the methodology involves evaluating the significance of short travel times, those that might be less than 1,000 years, in the event that they are part of the distribution. This evaluation of the significance of changes in properties and the significance of short travel times will be based on the assessment of the performance of the system as a whole.

And, finally, because the methodology is performance assessment based, DOE's approach to developing the methodology and to using it will be iterative. Eric's schedule that he presented just a couple of minutes ago indicates that. That in about a year, we will have preliminary results. A year beyond that, we'll have our first iteration and the second iteration should be available towards the end of calendar year 1997.

That's all I would like to have to say.

DR. DOMENICO: Well, thank you, Lester. I think you've addressed the answer to our fifth question that we asked here; when we have calculated, how do we interpret the results? As I understand then, you're going to focus in on ground water travel times of less than 1,000 and work out what the means in terms of performance. I presume you will look at ground water travel times in excess of 1,000 that will also be part of the performance. But, I guess, if you could make it for less than 1,000, you're pretty much assured to make it for greater than 1,000. Is that philosophy--

MR. BERKOWITZ: Yeah, I mean, part of the thing that's driven us is that there has been concern, real or imagined, that if any value of ground water travel time is determined to be less than 1,000 years, the world would come to an end. When you think of the physical characteristics of the Yucca Mountain site, or of any other site for that matter, the conclusion that you have to come to is that ground water travel time is going to be a distributed parameter. If it's a distributed parameter, then the values that may be determined will cover a range. Depending on how much uncertainty there is, the range might extend below 1,000 years. Then, you have to ask yourself the question what does that mean? How important is that? Is that real and significant? And, the conclusion that we've come to is that in order to make that determination, we have to develop the methodology and do the kinds of evaluations that generally you're going to be talking about later on.

DR. DOMENICO: My question and maybe it shouldn't be directed to you; maybe it should be to the following--

UNIDENTIFIED SPEAKER: Yeah, I think we'll cover it.

DR. DOMENICO: Okay. Then, is there any questions from the Board? John?

DR. CANTLON: With this late calendar year '97 target date and trying to derive a system from a total system performance, how much real heating data are you going to have to fit into this system to get a performance based assessment of what the heating effects are going to be on radionuclide retention, for instance?

MR. BERKOWITZ: I'd like to defer that one to Jim and Rally.

DR. CANTLON: Well, if you're going to talk to it, why, I'll wait.

MR. BERKOWITZ: We'll wait and--

DR. CANTLON: All right, fine.

DR. DOMENICO: Thank you. Any further Board questions? Ed?

DR. CORDING: This might be a question that we need to consider later on, as well; I don't know. But, I'm just wondering at this point what the boundary of the disturbed zone is thought to be? I mean, I can see the boundary of the disturbed zone having almost nothing to do with whether or not, you know, you take that as a start of the ground water travel, from that to the accessible environment, and the key is where it starts, you know, at its source. And, you can talk about thermally prepared environment in which small changes can occur out to large distances, but you can also look at conditions where the largest changes are within a few meters of the tunnel and everything else at that point is probably not--may not be very significant in terms of the flow path, as long as you take into some account possibly some of the physical changes, but that may occur out further distances. To me, it's something that doesn't fit very well with what's really going to happen in the mountain and may be somewhat an artificial constraint that's been built into this regulation.

DR. DOMENICO: Well, I think we should have the advantage of Jim's presentation before Jim gives us his answer.

MR. BERKOWITZ: Well, if I may, I would like to say this. The approach that we're trying to take is one where we're doing what we can to evaluate the extent to which the disqualifying condition in 10 CFR 960 is applicable and to determine whether we comply with the existing subsystem performance requirement. Now, that's the basis for the proposed program approach that the Department has presented to the Board. We're not here to talk about what we're doing to convince the Commission that it should come up with an ultimate performance requirement or anything like that. Our focus is on trying to live with the current guidelines and the current Commission regulations. That's where we're coming from and that's what Jim and Rally will be talking about later this afternoon.

DR. DOMENICO: Any further Board questions?

(No response.)

DR. DOMENICO: Staff?

(No response.)

DR. DOMENICO: Well, we're on time. So, I presume we should go forward and hear what's been promised we're going to hear now. We're going to hear about the calculation approach. This is Jim Duguid giving the presentation.

DR. DUGUID: I don't think I've ever been so well set up in my life, but we'll see what I can do with it.

Now, as you've already heard and it's been implied, we've been working on this approach for some time and the work on the approach was the basis for Jean Younker's presentation back in April. It was the basis for the letter to NRC and, along the way, we have refined that approach to the point we're now able to share it with you. I might add that the last page of your handout has a flow chart that if you tear off and turn up on the table, it might help you follow the presentation a little. I won't try to show that as a viewgraph because it's very busy.

The outline of what I'm going to say, first, I'm going to talk about what causes the ground water distribution; the domains that we have to consider. Then, I will show three sections on the approach to the various domains that we're considering; the disturbed zone, the unsaturated zone, and the saturated zone. I'll talk about the total ground water travel time distribution. Determination of significance of pathways; should we find pathways that are less than 1,000 years? Then, I will discuss a bit about, we're putting a lot of effort in this, "Is travel time the only thing we're getting out of it?" And, I'll show you a proposed schedule.

The travel time distribution is caused by heterogeneity of flow and transport properties, variability of percolation flux, dispersion and matrix diffusion along the flow path. It is also caused by the areal extent of the disturbed zone and the particle entry points on the water table. In other words, when we're at the accessible environment, we're not far enough from the repository so that it looks like a point source. We also must remember that there's an areal extent of the accessible environment. The distribution is also caused, in part, by the uncertainty in boundary conditions, conceptual flow models, and parameters.

The domains that we are considering: the disturbed zone, the volume in which post-closure repository-induced changes have a significant effect on performance; the unsaturated zone, between the disturbed zone and the water table; the saturated zone, between the area of the water table below the repository and the accessible environment.

The approach to the definition of the disturbed zone, I will walk you through these bullets and then I will talk to each one of these points in detail. First, we define the potential for repository-induced changes. We evaluate the repository-induced changes. We evaluate the effects of these induced changes on transport properties. We evaluate the consequences of the altered transport parameters on performance. And, here's something that comes up that you haven't heard today; we develop criteria to determine significance of those consequences. Based on those criteria, we can then determine the extent of the disturbed zone.

Going into detail on each one of those points, we only consider changes that may have an effect on post-closure repository performance, i.e. radionuclide transport. The parameters that we need to look at; hydraulic conductivity, retardation, percolation flux. Processes affecting transport parameters; mechanical and thermomechanical, hydrothermal, thermochemical which are broken down into mineralogical, dissolution/precipitation, and Eh/pH.

Evaluation of repository-induced changes, we conduct mechanical, thermomechanical, and hydrothermal analyses to determine physical changes caused by construction and heat, and the volumes in which they occur; temperature, stress strain, moisture content, and percolation flux. We conduct analyses to determine the geochemical changes caused by construction and heating, and the volumes in which they occur; mineralogical, dissolution/precipitation, Eh/pH. Now, as you look at these, I think you know that the upper group is much more a calculational group of items. The bottom group on the geochemical changes, we have less calculational tools down here. We have some laboratory values, we have a few models, but a lot of this is going to be expert judgment for the geochemical aspects. So, there's a little more uncertainty in the geochemical side of this.

Evaluation of the effects of repository-induced changes on transport parameters, we need to determine the zones of altered hydraulic conductivity, percolation flux, and retardation: effects of mechanical and thermomechanical changes on fracture aperture and matrix porosity; effects of temperature on moisture content and percolation flux; effects of geochemical changes, fracture aperture, porosity, and radionuclide retardation.

Then, we conduct performance assessment using altered transport parameters and their associated incremental volumes. And, here, like Humpty-Dumpty, I must define incremental. What I mean here is that this is a gradational change and we will go out in some sort of an increment to define these volumes, like a 50% change, a 40, and on out where it's small enough that we don't have to consider it or at least we think we're at that point. Determine the incremental change in cumulative release to the accessible environment or dose to an individual at the accessible environment. In other words, we're defining the effects of these transport parameters on performance. Conduct sensitivity analyses to evaluate the effects of uncertainty on the range of performance. We've got a big uncertainty in the size of this disturbed zone. You'll see how that comes in in a moment.

We need a yardstick of some sort to determine whether a change in performance is significant. This is another place that we will likely use expert judgment. We need some set of criteria to apply to this changed performance to determine if it's significant so that we can set that boundary of the disturbed zone. Example criteria; remember, we haven't done this yet. Here are a couple of examples. An increased change of some percentage in mean integrated release or mean dose to an individual. We could also have some percentage of the standard deviation of these two performance measures.

Once we have this yardstick, we can apply it to determine whether the consequences are significant. If they are, they define the boundary of that disturbed zone. And, what I didn't show here is the sensitivity analyses and, remember, there's a lot of uncertainty because we don't know the thermal loading of the repository. That hasn't been set yet. So, we're going to have to do this for different thermal loadings and define a range of possible extent. In other words, like we did in '86, we guessed at 50 meters. What we need is some documentation to back up the size of this zone. It will still be pretty crude after we do the documentation, but it will at least have a basis for where we set the disturbed zone. I think at the end of both computations, we'll be somewhat better than guessing on the first iteration, we will at least have some basis, and I think depending on thermal loading, the size of the disturbed zone may limit the temperatures you can run the repository because you may, as has been pointed out by some of these disturbances, go out far enough that you will have travel times that would be less than 1,000 years.

Our approach to the unsaturated zone, we'll evaluate flow paths using deterministic models; select flow paths for stochastic analyses based on those deterministic models and the flow paths will be one-dimensional columns or two-dimensional cross sections depending on the type of flow that we see. Some of the flow as Bodvarsson is starting to show with the scale model is truly two-dimensional. In some places in the mountain, we can get away with one-dimensional columns. We will probably use both. Develop travel time distributions using the stochastic models; conduct sensitivity analyses on the columns and cross sections; and I show a brief schematic example and I'll walk through each of these.

For our deterministic modeling, we will initiate flow paths from discrete locations corresponding to the repository as an initial cut; evaluate travel times along flow paths; and conduct sensitivity analyses of travel time and flow paths. We will look at the sensitivity to the properties of faults, spatial variability in percolation flux, conceptual flow models, spatial heterogeneity in material properties, and spatial averaging of flow parameters. What I mean by this last one is that we're scaling up the parameters from core size to model grid blocks that are on the scale of tens to hundreds of meters. We need to do some numerical tests to see if the input of the heterogeneity in the model really makes a difference. Or can we use simpler models in a stochastic mode and get similar distribution?

We use the results of the sensitivity analyses to select the representative columns and cross sections between the repository and the water table, and each column and cross section, based on its location, has representative properties; stratigraphy, percolation flux, and property distributions.

Using the stochastic models, we conduct multiple realizations of travel time at each selected location, whether it be a column or a cross section, for each parameter set to produce travel time distributions. Evaluate the sensitivity to conceptual flow model; we have four we can apply and I think we need to talk about all of them and look at all of them and understand why or why not we consider them. The models are equivalent permeability, dual-porosity, dual-permeability, and discrete fracture. I would imagine with a bit of work we can throw out the discrete fracture model. That's probably the easiest one to eliminate. Flow and transport properties, we'll look at that sensitivity. Percolation flux, stratigraphy is fairly uncertain--it's only certain if we happen to have a drill hole on the particular column we're looking at and that won't happen very often--and correlation among parameters. In other words, what we're doing with the stochastic models is looking at the sensitivity and uncertainty to generate the whole unsaturated zone distribution of ground water travel time and try to convince somebody that we understand that entire distribution.

My schematic example, I have some breakthrough curves which is just a schematic of breakthrough curve that shows you clearly why you get a distribution. At any percent of particle arrival, as you go across this, you obviously get a distribution of travel times and this only represents a few realizations. If we were running a stochastic model, we'd probably run 100 and we'd have some distribution for any line we go across there. And, I just threw that in to point out why you get the distribution.

Approach to the saturated zone travel time: we evaluate site-scale boundary conditions using a regional deterministic model; we analyze flow paths using a deterministic site-scale model; then, we evaluate travel times along those flow paths using stochastic models, very similar to the unsaturated zone only we have the added wrinkle in here that we have to go out to a regional deterministic model to set our site-scale boundary conditions.

We conduct analyses using the regional-scale model to test different hydrogeologic conceptual models. Conceptual models that I discussed before were the flow models. These are the hydrogeologic models. In other words, what model, general hydrogeologic model of flow causes the steep hydraulic gradient? There are several proposed models for that. You want to look at both and see how it changes the boundary conditions for the site-scale. Develop site-scale boundary conditions for each of the conceptual flow models, those conceptual hydrogeologic models.

Then, we analyze flow paths using deterministic site-scale models to evaluate the effects of parameter distributions and uncertainties on flow path direction and travel time. Location and type of boundary conditions; geometry and properties of faults; flow conceptual model, fractured continuum, equivalent continuum; transport parameters, dispersion, matrix diffusion. Select representative flow paths for stochastic analysis. Because most of the site-scale models are too large to run in the stochastic mode, we need to select the important flow paths then analyze them with a simpler stochastic flow model, one that we can do a lot of realization with to test all of the sensitivities of the various flow models and parameters.

Conduct the multiple realizations from points on the water table below the repository to the accessible environment. And, we want to investigate the uncertainties with conceptual flow model, flow and transport properties, correlation among parameters, and boundary conditions. Conduct sensitivity analyses using one-dimensional stochastic models along selected flow paths. This last bullet, we may or may not be able to do. We may find that there's such a fluctuation in the direction and length of flow path as we changed parameters that it doesn't really make sense to use a one-dimensional stochastic and they may be all two dimensional in the saturated zone.

Now, with those analyses, we have two buckets of travel time distribution, sensitivities and uncertainties, and we have more distributions than we know what to do with by the time we get through the sensitivity and uncertainty analyses. We need to talk about the total travel time distribution. We convolve the travel time distributions for the unsaturated and saturated zone considering the; conceptual flow models, parameters variability and uncertainty, correlation among parameters--now this is across the water table--and location. Somehow, it doesn't make sense not to take a one-dimensional column and start the particles in the saturated zone at the end of that column. So, location should be considered. One of the simplest ways to look at this--and some of these may not convolve directly or mathematically. In other words, if you have a different conceptual flow model in the unsaturated zone and the saturated zone, I'm not sure that they convolve directly. One of the simplest ways would be to take the short travel time in the unsaturated zone, simply add the short travel time from that location in the saturated zone, and if they're greater than 1,000 years, you don't have to worry too much about it. If we start having a lot of distribution that are less than 1,000 years, we'll have to worry about this convolution a lot because we need to look at the effects of the different convolution schemes on short travel time.

Now, once we have these short travel times, should some occur, I expect that these short travel times would not be the expected value of a distribution at the Yucca Mountain site, but they would be the tails of the distribution. And, I agree with the NRC that if you have a likely travel time that's less that 1,000 years, and in other words something like the expected value, that that is significant and it would be. But, we're more likely talking about the tails that are less than 1,000 years. We will look at those tails. We have significance criteria that we developed earlier, we can look at the significance of those tails. Now, if you consider the tail of the short travel times, do the performance assessment, find the consequences, and see if they're significant.

Now, I just showed you a large body of work that is going to take about three years and you ask yourself is it worth it. And, what we get out of this, the primary products out of these analyses, we get an uncertainty analysis of aqueous flow at Yucca Mountain. A subset of that is ground water travel time. We get sensitivity analyses of aqueous flow at Yucca Mountain. Those feed right back into the site characterization program. We get analyses of ground water flow uncertainty applicable to post-closure performance for low thermal loads or long times. In other words, if you have a cold repository or if your standard goes out to long times, this whole set of travel times applies to performance assessment.

Our proposed schedule--and, here, I want to only point out about three things on this schedule. As you might guess, the schedule is somewhat uncertain. I have shown you an approach that we haven't been through yet and I'm sure, as we go through it, we'll modify it here and there. I think the gist of the approach will stay the same. But, there are three dates and they've also been pointed out. We will have preliminary results by 9/95. In those preliminary results, we will not have a disturbed zone. We will have looked at significant criteria. We will look at the disturbed volumes, but we will not have applied that to put a disturbed zone in the model. So, the preliminary results there will just be the raw travel times excluding a disturbed zone.

In the next year, we will begin to define the disturbed zone. We will do the first iteration of ground water travel time and we will start to look at the significance of short travel times or the ones that are less than 1,000 years and we will put out a report at the end of the first iteration. This report will contain all of the work from here right on through and will be widely circulated for comment so that everybody can take a good shot at our methodology, tell us how we could improve it, tell us what doesn't make sense. Then, we'll start with those comments, do it all again, and come up with the second iteration in 9/97 for input to the site suitability report. So, we'll go back through our definition of the disturbed zone in that one. In the first iteration, we should get a pretty good handle on what sort of data we'd like to have in here which makes a lot of feedback loops in the characterization.

Thank you. That was pretty quick, but that, in essence, is how we will approach it. And, the hardest part, and it looks like to me the most uncertain part, is the disturbed zone. But, I think based on our approach we can get some sort of defensible handle on it.

DR. DOMENICO: Thank you. I think you just tried to diffuse Don Langmuir who has a question on that. I'm sure

DR. LANGMUIR: I had a more fundamental question. I have the sense that given you want to do this in three years, which curiously fits right into the 1998 suitability decision, that somehow expert judgment being used is a moving input--

DR. DUGUID: Yes.

DR. LANGMUIR: --and that if you can't get data or don't have data, we bring in the experts to guess what we should find if we had the time and the money and took the time to learn some things about the site.

DR. DUGUID: No, I said--that's true, yes.

DR. LANGMUIR: And, I worry about defending this--

DR. DUGUID: We have to repeat it. And, really, what we want from the experts on the expert judgment, there are two things on the geochemical side. We really want the experts to take the laboratory analysis that they know about and whatever else in geochemistry that they know that might help them with the temperature regimes you might see and estimate the volumes where geochemical changes might take place that would affect retardation, Eh/pH, or hydraulic conductivity. And, that is pretty crude, but there's a bit of site data out there; some of the increased hydraulic conductivity from the heating of core, some of the mineralogical changes in zeolites. So, there's a little bit of data. There's not near the basis I'd like to have, but we'll have to initially work with what we've got and that will give us a better idea when we come through the second iteration what we really should be looking for and maybe some areas that we are missing a lot of data.

DR. LANGMUIR: One has to assume that there will be very large uncertainties attached to the results of such an analysis and the more expert judgment you have to use without data providing information for the experts, the larger that uncertainty is going to be. I presume Rally will be presenting us an example of this with uncertainties later on.

DR. DUGUID: It depends on how big the disturbed zone starts to get. And, I think that the disturbed zone for any reasonable repository loading--and, you're going to ask me what reasonable means in a minute--that the disturbed zone is pretty small. I also firmly believe that the geochemical changes probably extend the furthest out from the repository where the mechanicals from construction are probably the smallest ones, thermomechanical being next, and then geochemical extending further out. And, those will be the hard ones. If we find that the disturbed zone where we can bound it doesn't make a lot of difference on the calculation, then we're in pretty good shape. If it starts to make a lot of difference, then we'll need a better definition of it. So, the more difference it makes, the more you need to know about it in other words. I can't tell you now how that's going to turn out. After we get some insight in that preliminary work, we might have an idea. And, as I said earlier, as you start to look at this disturbed zone, there may be some repository loadings that get thrown out because of how big the disturbed zone might get. So, there are a number of feedback loops in there.

DR. CORDING: Your assumption is that the--I mean, there might be a significant flow time through the disturbed zone itself, but you're basically--I mean, you're looking for criteria that says we have to take it from the outside of whatever you define as the disturbed zone as a conservative estimate?

DR. DUGUID: Right, whatever you define. And, as you do the travel time with the stochastic models, that is not a fixed, firm boundary because that has uncertainty. So, that's one of the sensitivities that you're going to look at in those stochastic travel times, the starting point of the party.

DR. CORDING: Are you also looking at the thermal effects on the actual--actually driving the flow, even though there's no geochemical or thermomechanical changes in the medium, there can be temperature changes that will drive fluid flow and there's nothing--you haven't done anything to the medium except impose a driver--

DR. DUGUID: That's right. But, we are interpreting the disturbed zone to only mean a permanent change in properties that affect long-term performance. And, the fluid flow is more or less a temporary change because the thermal pulse is over. It's similar--if you looked at some of the calculations that we presented--I don't know whether we presented enough of them here--where we showed that if you consider the release from the waste package at zero time and 100,000 years, all you've done is move the dose peaks over and that 100,000 years is well within any thermal pulse you might have. So, a thermal pulse that took place in 100,000 years wouldn't affect the height of that peak. So, it wouldn't be significant.

DR. DOMENICO: Jim, if we didn't have a ground water travel time regulation and we only had the EPA meet a standard, would you do this?

DR. DUGUID: We'd have to do most of this material anyway is my view.

DR. DOMENICO: How many permeability values do you need for a stochastic analysis?

DR. DUGUID: I need to--

DR. DOMENICO: As many as you can get.

DR. DUGUID: Yeah.

DR. DOMENICO: How many do you need in your PA models which are constant velocity models, I believe, right?

DR. DUGUID: No. In our stochastic model, we will select--we will be running from ranges of parameters. So, at each realization, you will pick a parameter; a set of parameters to run the realization.

DR. DOMENICO: So, what you're saying is all the information you're getting in for this is convertible directly to your performance assessment?

DR. DUGUID: Right. The only thing that you wouldn't be doing in that performance assessment is defining the fictitious boundary. And, that fictitious boundary, you would have to do a lot of the geochemical work anyway to feed into the total system performance assessment to understand the behavior when the waste packages fail.

DR. DOMENICO: I see your last slide, is travel time the only product? Well, I think, kind of, it is. These are mostly--mostly the other products deal with the mountain, how it behaves in the absence of any thermal load. So, it's--

DR. DUGUID: Uh-huh, uh-huh. Yeah, you're going to learn a lot on the behavior of flow through the mountain. That's probably going to be the biggest thing. You'll start to understand the sensitivities of that flow to certain conceptual models and hydrogeologic concepts.

DR. DOMENICO: My last question here is why is dispersion and sorption--why are these important parameters in ground water travel time? We're not talking about moving the contaminants now. We're talking about what we all know is a Darcy sort of velocity.

DR. DUGUID: Because we view the water travel time to be a transport phenomena. So, we're looking at the transport of water particles.

DR. DOMENICO: And, the transport of water particles are gong to sorb into the matrix driven by what the concentration gradient--

DR. DUGUID: No, not sorb, but diffuse--

DR. DOMENICO: Diffuse--

DR. DUGUID: Diffuse into a slower path is all.

DR. DOMENICO: What's driving that if it's water? I just have a hard time coupling how ground water travel time has been defined which is Darcy flow with--

DR. DUGUID: Yes. But, that's the way to think of it is the water particle transport without chemical retardation.

DR. RALSTON BARNARD: It gets a little contorted, Pat. But, admittedly, nobody will deny that ground water travel time, you're talking about pure water being moved and so the concept of sorption is a little difficult to add in there. But, the point is that when you talk about paths which are likely and significant--and, I'll put the accent on significant here--for radionuclide transport and thus repository performance, then in that case sorption does enter into it.

DR. DOMENICO: Nobody disagrees with that.

DR. RALSTON BARNARD: But, that's the only way that we are planning to actually include any aspect of sorption.

DR. DOMENICO: So, it's part of your PA study, not necessarily this.

DR. RALSTON BARNARD: It's part of the PA, that's right.

DR. DOMENICO: Thank you.

DR. RALSTON BARNARD: That's right.

DR. DOMENICO: Do we have any further Board questions?

DR. LANGMUIR: Having done a lot of modeling myself, but not anything quite as grandiose as this which you'll quickly find out as you obviously know, is that there are some parameters within your models that are very sensitive to how well you know them. And, I wonder whether you've got any flexibility, at all? If you're going to have results in "three years" and say something about suitability and travel time, you're clearly going to find out certain things that you've suggested are really important in this whole discussion. What's the cause of the steep hydraulic gradient, for example, north of the site? Are you in a position to be able to recommend additional site characterization work if it seems appropriate to reduce your uncertainties which well may take more than three more years as part of your analysis and the development of your results?

DR. DUGUID: Yes. And, I think you would do that and it depends on how uncertain you really are as to--you know, you're going to go forward with a safety analysis, but you'd want to start those site characterization efforts, so that when you're doing this in licensing and further down the road, you would definitely have more information if they turn out to be really important.

DR. DOMENICO: You mentioned the uncertainty with the size of the disturbed zone. I have a question for you. You know, right now, you can ask the question what size disturbed zone do I need to assure failure at ground water travel times less than 1,000 years? You'll give a number?

DR. DUGUID: It's somewhere about the water table.

DR. DOMENICO: Somewhere about the water table, okay.

DR. DUGUID: Because the saturated travel times are running, you know, 900 to 1200 years in the deterministic modeling with--and, those had major diffusion in them, didn't they?

DR. RALSTON BARNARD: And, dispersion.

DR. DUGUID: And, dispersion. So, it's about the water table. So, once you get a disturbed zone going all the way to the water table, you're history probably or pretty close. But, I don't know; as we define the travel time in the saturated zone, I think they'll get somewhat longer.

DR. DOMENICO: You think so?

DR. DUGUID: But not--they won't double.

DR. LANGMUIR: One last one from me. If, in fact, the disturbed zone going to the water table might disqualify the site, doesn't that immediately tell you you don't want a high thermal loading?

DR. DUGUID: That's right and that's a feedback loop, also. And, as I said, some of the thermal loadings, as you look at some of these disturbed zones, may start to disappear.

DR. DOMENICO: Vic?

DR. PALCIAUSKAS: There is a very strong implication that you'll be able to evaluate the effects of, let's say, thermal loading on the physical properties like the hydraulic conductivity. And, in my experience, that's an extremely delicate subject.

DR. DUGUID: That's very uncertain. We will be--

DR. PALCIAUSKAS: And, you're starting with the most difficult part first, it seems.

DR. DUGUID: That's right. We will be able to look at some of the effects of the thermal loading on fracture aperture, but then relating that to hydraulic conductivity is no easy feat, as you know. So, there's going to be a lot of uncertainty there. But, as you look at some of the fracture aperture change from the thermomechanical models, those don't extend too far out. That is going to be--probably the thermomechanical one, you can almost neglect because the sensitivity of our tools--you have to remember that the performance assessment tools that we're using to evaluate significance with aren't very sensitive. It takes a pretty good change--you have to have pretty good change to make--you have to have somewhere in the neighborhood of a factor of 2 to start seeing it, start seeing the change with the crudeness of the tools you're applying. And, you start subtracting off of a 250 meter unsaturated flow path, you start to subtract off, you know, 25, 50, 60, 70 meters, you should start to see it somewhere in the latter parts of that. But, you know, the first 25 meters, you're probably not going to see the change.

DR. DOMENICO: Bill, did you have a question?

DR. WILLIAM BARNARD: Jim, how realistic is this proposed schedule that you've laid out?

DR. DUGUID: I think it's going to be a lot of work and I think we'll have something at the end of it but I think it's doable. If we run into some brick walls in there, it's not; if we get some real surprises. But, most of the tools are starting to be in place. You've heard from Bodvarsson on the unsaturated zone site model. That's going to guide the unsaturated zone selection of where you do stochastic analyses. We are probably a little further behind in the saturated zone in one sense because the models aren't up to the state that Bo is, but we know a lot more about saturated zone modeling. So, we're better off there and we can catch up pretty quickly. So, I think we'll make it. And, we should know by the end of '95 when we start to look at the results that we have at that time. We should know where the real problems are going to be.

DR. DOMENICO: John?

DR. CANTLON: Let me pursue my schedule question. It's an extension of Bill Barnard's question. As I look at the '98 site suitability determination, you're not going to have very much heating data for that determination.

DR. DUGUID: That's right. Most of this is going to be calculational. There's not going to be much confirmatory information on it.

DR. CANTLON: Now, let's crank you up one further. You got a license submission date, 2001. How much actual heating data are you going to have when you go into that?

DR. DUGUID: We'll start to have some preliminary results by then out of the draft, but not very much.

DR. CANTLON: How long will it take you to crank the data in?

DR. DUGUID: It shouldn't take that long because we will have used the thermal models and the thermomechanical models. In other words, you just have to put the new data in and run it unless you start seeing things that we haven't predicted in the model.

DR. CANTLON: Exactly.

DR. DUGUID: And, that's--yeah. Understand that the temperature--probably, the temperature calculations are the most certain ones we do. The rest of them get more uncertain.

DR. DOMENICO: Further questions? Anybody?

(No response.)

DR. DOMENICO: Well, thank you, Jim.

We'll go to our last speaker before the discussion. Ralston Barnard will inform us how they're going to implement all this stuff.

DR. RALSTON BARNARD: I'm going to kind of try to wrap things up by giving an illustration and discussion of the work that we've been doing at Sandia Labs for the past year. I'm just the spokesman for this. There's quite a large team working on the ground water travel time and, in addition to the people listed there, we have some new people added to our team. So, we're attempting to move forward smartly.

What I'm going to talk about is the implementation of the calculational approach which Jim just finished discussing for both the unsaturated zone models and saturated zone models. And, to do it, I'm going to talk about the current work that we've just about completed for the year. What this represents is the first stage of a ground water travel time analysis strategy. And, we have calculated this year an unsaturated zone fast path flow result including some sensitivity studies, but what we have not done, as Jim pointed out quite clearly, is included a disturbed zone in this. We have not yet been able to define it. So, we don't have one. And, what I want to emphasize again for John's benefit, as well as others, that we are using the best available data. That's all that we can do. Our models can use literally any amount of data. So, as we get more, the models will improve.

Well, to review for just a second what our analysis method is, we want to look at water particles and we want to transport them through the unsaturated and saturated zone to see whether the distribution of particle transport times meets the criteria and the regulations. Our transport is modeled by advection and molecular diffusion and, as we discussed momentarily ago, no particle retardation is included. In the unsaturated zone, we consider dispersion, mechanical dispersion, to be modeled by variations in the parameters of the models. In the saturated zone, we use an explicit parameter for dispersion. Advection, of course, is the most important aspect of transport and so we used ground water flow transport models in both the unsaturated and saturated zone to model that. And, what we find is that the models are sensitive in the unsaturated zone to the degree of saturation. The amount of fast path fracture flow that you get is quite sensitive to the saturation.

And, we are attempting to generate areas of local saturation by looking at heterogeneities in materials' properties and in other parameters of the models. The heterogeneities arise because of variations in thickness of the stratigraphic units and because of variations in hydraulic and physical properties. They can also arise because of stratigraphic effects or faults or fractures and so forth like that. And, what we do is we look at realizations, stochastic realizations, of the different values of the parameters to generate these heterogeneities.

Okay. In order to generate stochastic parameters or simulations of the parameters, the place we start is with a three-dimensional model of rock types. These three-dimensional models honor the data that we have while estimating unknown values from the nearby data. In other words, where we don't have data, we don't completely throw the dice, but we try to get some insight from the values that we do have. Any time there are deterministic features or trends, such as the irrefutable fact that the stratigraphic units are dipping and are quite strongly layered, this will appear in the 3-D model. Sometimes, the units pinch out or vary in thickness and we try to make sure that that aspect is reflected also. Just as a gee whiz figure takes about 7 million nodes to model a volume roughly the size of the potential repository.

Now, the rock types that we're talking about are chosen to represent different unique hydrologic properties. We don't choose rock types just for the sake of having various rock types, but there is an--we consider there to be an indication between rock types and hydrologic properties, since it's hydrologic properties that we're fundamentally interested in.

A typical simulation looks something like this. This is for Drill Hole G-1. The rock type simulation uses three major indicators; general welded, nonwelded, and zeolitic. And then, there's a couple of sub-indicators; Prow Pass welded and the Calico Hills nonwelded vitric and the Bull Frog nonwelded. Generally speaking, in the area of Yucca Mountain of interest, there are 10 stratigraphic units which we identify. Here in the example I've shown, the Tiva Canyon welded is not present. So, there are only nine showing here. And, the bottom, the Tram unit and the alluvium, the undifferentiated alluvium on the surface, are not modeled.

Having a three-dimensional rock model which is indicated by the dotted line here--and, you can see in comparison the shape of the old SCP shaped repository overlaying on this--what we do is develop some two-dimensional transects within the rock model within this volume here. And, shown here are the three cross sections which were used for the 1994 fast path flow analysis that we did. The intention of these, although they are not chosen with very much more insight than what we did, was to roughly represent the portions of the area of the repository on either side of the Ghost Dance Fault. Faults were used as no-flow boundaries on either side of the transects for computational expediency, I guess you can say, for our analyses.

Now, the 3-D rock model applied along a transect gives a result such as this. The hydrologic units which are defined are now defined stochastically. The Tiva Canyon is the lightest zone up here. The Paint Brush tuff is shown next. The Topopah Springs is this massive yellow zone. And then, you can see others going down to the Bull Frog down here, the--actually, I guess, the Bull Frog--yeah, the Bull Frog welded is this one here. These are derived completely stochastically. If you were to look at Simulation A or B, you would see roughly the same, but not exactly the same. And, Transect 2 over here would show something completely different, and Transect 3 again would show something even more different.

Having rock types--and, you remember the purpose of coming up with different rock types was to be able to identify different hydrologic properties--we do simulations of porosity and what we're going to do is stochastically simulate on the transects within the rock model different porosities. And, addressing Pat's comment at the end of the previous talk a little bit, by using a parameter distribution function which has a range of values and a mean, we can attempt to reflect the variability of the parameters of the property that we have in mind, as well as its central tendency, as well as our uncertainty in this parameter. The larger the range of values, it can either reflect a knowledge of a greater variability or a lack of knowledge and a greater uncertainty in the values that we think.

One thing that we need to do--this is more a hope than something that we're doing right now--is that the values of the parameters that we have measured were generally done on core scale, something roughly the size of your fist. But, a site-scale model requires a scaling of the parameters to significantly larger scale to reflect the greater variability and the greater uncertainty in the range of values that you can have in a large scale than you do in a small scale. So, we will need to modify the PDFs to account for the difference in scale between the measurements that we can make and the simulations that we need to use.

Okay. Having a PDF, you roll the dice and you select a value randomly for each geostatistical cell within a transect. What we attempt to do is to spatially correlate the values that we choose to reflect the stratigraphic structure; meaning that if the area you were working was here and you drew a value and the next value you drew was here, you would not restrict the range--you would not restrict your choice of values as strongly as you would as if you were drawing values within a single unit.

For doing a flow calculation, the cells are actually what are shown here and each cell may contain numerous geostatistical cells. There's clearly not anywhere near 7 million or even a small proportion of 7 million cells shown in that picture there. So, what is done is that the numerous geostatistical cells at which a porosity is assigned are grouped into flow cells and then an attempt is made to minimize the heterogeneity within a flow cell for numerical calculation purposes and the result of that is the rather weird shaped cells that you get, each of which has minimized the variability of the porosity in there.

DR. LANGMUIR: Rally, just a quick one. How much data is in that figure? I mean, how many of those corners represent real measurements on a plot like that?

DR. RALSTON BARNARD: This is a very scarce plot, but every one of these things is a drill hole, a well from which we have data. There's actually more than that. There are really considerably more than that, but they didn't happen to show up here. So, we have drill hole data. We also have, you can call it, soft data. For example, looking at outcrops where they appear along the Solitario Canyon Fault. You can get other information which also helps to condition the simulations. And so, those are the data that we use.

DR. LANGMUIR: You don't expect to be surprised by an exploratory facility?

DR. RALSTON BARNARD: Yes, I do expect to be surprised in the exploratory facility, but anybody who doesn't probably shouldn't be on the project.

Okay. Here are the hydrologic units. Here are the distribution of porosities that we get having applied the porosity simulations to the hydrologic units. And so, porosities vary from about 1% up to about 65% and you can see some of the variations that we get. This is the same simulation just to make life easier. What you can see, for example, is in the Paint Brush tuff here. It's relatively high porosity showing. Down here, this is going to be the Calico Hills. This may be the Calico Hills basal vitrophere down here. You see it's dry as a bone and that can have considerable implications.

Okay. Now, we have a model domain on which to apply our flow models. And, we recognize that it's important to consider alternative numerical flow models for unsaturated zone flow. And, the reason for that is that we want to try to bound fast path flow using--and, the way we expect variations in fast path flow to occur is going to vary with the sensitivity to the degree of saturation. For example, the composite porosity model which we don't have to talk about too much has a very strong coupling between fracture flow and matrix flow. Until the matrix is fully saturated, fracture flow doesn't occur. When you move to a dual-permeability model, you relax that restriction somewhat and you can have fracture flow in cases where the matrix is not yet fully saturated. If you go to a discrete fracture model and consider things like flow and fracture codings or something of that nature, you can relax even further the requirement that the saturation be high. And so, something like that can radically change the results that you get based on the model that you use for the same degree of porosity and, thus, saturation.

Okay. What do you get when you apply the flow code to the model domain? You get something that looks like this. This is again Transect 1, Simulation C. And, what you can see is that the average saturation actually approaches 1 over here and then you've got a couple of blobs where it approaches 1 here. But, this is kind of a significant point for you to keep in mind for what I'm going to show you next. How did this arise? Well, it arose as a confluence of effects including the specification of porosity over here and also the boundary conditions that we used. One thing I haven't mentioned and I won't mention any further is that we have been applying different boundary conditions along the surface of the earth's surface here, the surface of the problem, to reflect what we know from work by the USGS and others to give us values for steady-state water saturation immediately under the surface. Okay. Let's remember this one here, the average saturation distribution. As you can see, it's highly so here. It's pretty darn reasonably dry over here and that's going to make for some interesting goodies.

Okay. Now, I'm going to completely shift gears for a minute and quit talking about the unsaturated zone and talk about the saturated zone. And, really, what this is to a large extent is a rehash of what was done in TSPA-93. I'm going to review for you the TSPA-93 saturated zone model because that's the place where we are starting for our ground water travel time. The reason for that is it seems like a very good place to start. It's based on the USGS interpretations of their regional model and the two major factors that we have considered are the large hydraulic gradient which appears in the model and some vertical zonation and inhomogeneity. That's another word that will probably trip me up.

The way we model the large hydraulic gradient is with two different features; the diversionary and non-diversionary feature. And, what we did with the vertical zonation was to limit the depth of the model that we felt we needed--the depth that we felt we needed to model for TSPA-93 to about 200 meters. Probably, should have gone to 300 meters, but we only went to 200 meters. But, that is an indication of the model that we had that we could probably get away with that. We included faults as hydrologic features, but I must instantly add that the faults were just used parametrically. We don't know what their properties are, but by torquing with the properties enough, we can get results that we like, but there's no indication that the values that we have used are necessarily based in reality. The faults we found most beneficial to making the model work are the Drill Hole Wash and the Solitario Canyon Fault.

How are we going to go about the saturated zone flow modeling? With STAFF-3D which is what we used in TSPA-93, but we're also planning to use FEHM in the future. For TSPA-93, we had an 8km x 8km x 200 meter vertical depth volume. And, the significant number, if you want to remember one number about what we did, it took about 1,000 years for water particles to reach the 5 kilometer boundary from the potential repository. However, the travel times were not uniform along the accessible environment boundary and I will illustrate that here. This is the 8km x 8km x 200 meter depth. This smile on here with--you know, a smile--is the accessible environment boundary 5 kilometers away. Potential repository located there. I've had these two yellow dots put on and they correspond to these spots along a breakthrough curve whose total path length corresponds from there to there. So, what you can see is there are considerable variations in the extent of breakthrough that you get depending on where you go to look for it. So, the two yellow dots are locations where there was essentially no transmission, no water flow from along a path from here to this point here. In other places, you can see there was considerable. So, the point of that is that we cannot make a simple--we can't arbitrarily pick flow tubes or other means of modeling the flow in the saturated zone from locations here to locations down there without knowing considerably more about the structure.

Okay. That ends the talk on the saturated zone. Now, let's return to talking about how you finish up a ground water travel time analysis. And, the way you do that is with what we're using, a particle-tracker. We use a flow field produced by the flow code and for the work that we've currently done, we're using a steady-state, composite porosity code called DUAL in the saturated zone. When we do this, in addition to what I just showed you, we have done it with STAFF-3D and then FEHM will be the other one. I'd like to point out, especially for our UZ work, that we can use other codes for generating the flow fields. We hope that it will merely require alterations in the input deck so that we can use TOUGH or another code like that to generate the flow fields. And, we do expect that eventually we'll be able to include some form of transient effects, such as variations in temporal, of changes in boundary conditions, and so forth like that.

So, the flow code calculates the advective transport of water particles. Those are due to matrix flow for low saturations and fracture flow for high saturations; thinking now in terms of a code like this. And then, after we have used advective processes to move the particles, you apply molecular diffusion to fuzz them out and give yourself a slight random aspect to their motion. The particles are launched from the disturbed zone.

Sandia has now gotten into the movie making business, but I'm not going to show you one. I'm just going to show you one frame of a movie that represents the particle-tracker output. What this is, it's for the same old simulation that you've come to know and love. This is at 110,000 years and what is shown on here is, now in addition to showing the porosities which are the color coding of the cells in the transect in the model domain, the average Darcy vector in each cell is also shown. So, what you can see is a nice lot of diversion occurring up here. You remember this really saturated area? A lot of flow is occurring here. It looks like it's downward flow and so it looks like the flow field generated is quite consistent with what you would expect from over there. A 100 particles were all launched from a line right across here. It happens to be the location of the potential repository horizon, but if you were to have some kind of blob around there representing a disturbed zone, you'd launch them from the edge of there.

You should see this one; it's a movie. It looks like you're playing space invaders because you've got these big green thunderbolts coming down. The green lines represent paths that were taken by fracture flow. The blue triangles show motion that was strictly in the matrix. And so, what happens is a particle moves along until it moves by matrix flow into a saturated cell and, boom, it exits the problem because fracture flow is fast enough that on the scale of the movie that we're showing they just leave like that. So, what you can see is after 110,000 years, there's been considerable fracture flow occurring, but the matrix flow really isn't too much. We've got one particle which manage to make it down here and the way it did it was that it took a shortcut--it took the down elevator in a fracture down to there--and then started chugging along in the matrix down to here. This one moved a shorter distance.

I'd like to point out that in our analysis, we've been fairly conservative about what we do because a particle which finally gets into a fracture can be transported a considerable distance in a time step. If the distance that it's transported within a time step does not take it out of the problem already, then you have to decide what to do about it in the next time step. Now, when you're talking the composite porosity model, the distance that it's transported, most likely, is transported to a cell in which the saturation is much lower. So, do you just stop it like you did here? That, I think, would cause almost no particle to leave. This is one of the restrictions of the composite porosity model. So, what we do is we say if it's in a fracture already, we're going to give it a high probability of continuing in the fracture which is certainly a more conservative way of treating the particle. So, that's why you see what you see, as many failures as you do.

DR. LANGMUIR: Rally, you're saying the repository horizon is on the right over there where all the fractures are shown? Where would the repository be on this?

DR. RALSTON BARNARD: Oh, yeah, actually it runs from about here all the way over to here. There's a little tiny --if you got up close, you could see an itty-bitty purple triangle and that's the last mortal remains of a particle where it was located at the time it was launched. Okay?

DR. LANGMUIR: What's the evidence for all the fractures in the repository horizon? Are they inferred from the water contents? And, where's the--

DR. RALSTON BARNARD: Remember, composite porosity model does not strictly--does not really model fractures. It says that when saturation is great enough, it flows as if it were a fracture flow. So, we have no evidence, whatsoever, that there are really fractures there, but if there were, we have enough saturation so the water would overflow from the matrix and flow in those fractures. That's why we see what we see. Remember, this is an artifact of the composite porosity model.

Okay. Well, what I've shown you is one frame from one example from one realization in one transect. And, remember, there could be a number of transects. What we can generate from this is a cumulative distribution function from the simulation. And, I want to emphasize this is artistic license in the extreme as to the actual values that you see here. But, let's suppose, for example, that the blue line here represents what is shown over here, the CDF. And, what it shows is, for example, after 150 years, you have about 5% of the particles have moved out, and so after 1,000 years, it's up to about 12%, something like that, okay? Now, that's just for one realization. But, it is a distribution. But, since it is very specific as to the parameters that we used and the area in the repository that we are modeling, it isn't adequate. So, we have to do several more of these. We have to do them at Transect 2 and Transect 3. We have to do it for Simulations A, B, and C and so forth. You can get a whole bunch of these. You finally combine them and you get a combined cumulative distribution function which might look something like this. Now, finally, in this case, you can start to say, well, I have about 10% of my values occurring less than 1,000 years. Now, I must look at what caused that to see if those are significant, if they are likely paths and if they are significant paths. When you finally get to this step, this is what Jim is calling the stochastic analysis. It's where we'll be able to start making evaluations of what is likely and what is significant.

Okay. Some other factors in the calculation, Jim has talked at length on the disturbed zone, but what I'd like to point out is that in our 2-D transect, we can explicitly model it if we choose to. Remember, we introduced water at the top of the problem and maybe we want to have a disturbed zone which is really dry or something and causes water to be diverted around it. Will that change the results that we get for water paths below it? Okay. Water particles can be distributed in a number of ways at the repository. As what I showed you was a random distribution, but kind of a clever idea might be to weight the number of particles by the amount of nuclear waste in the potential repository that they represent.

As Jim pointed out, there's no way we can avoid doing a lot of sensitivity studies because that's what's going to give us the confidence that we have in the analysis that we produce. Some of the things that we're going to look at in this next year are what happens if you use a homogeneous hydrologic property, what happens if you use units of uniform thickness? Most importantly, we feel it's a necessity to get going on the problem of scaling the parameter PDFs. This could be an area where until we understand this better, we will not have much confidence in our ability to take itty-bitty samples and apply them to hundreds of meter volume analytical areas. You saw the choice of grids that we used, was one choice. What happens if you use a much finer grid? You will certainly have a lot more vectors to worry about in your flow field. Will that change the results? All this will be used to try to help us to understand the uncertainties better.

Now, John has a couple of times raised questions about whether we can complete our work, whether we can provide feedback, whether we can understand everything we need to understand in time. And, one of the things that we are doing is we are attempting to link very strongly to site characterization efforts and to other modeling efforts. And, the USGS is giving us--I mentioned the boundary condition work that we were using. This is specifically at near-surface measurements from the N-holes, are going to tell us water content, and hopefully we will be able to get information on transient and non-equilibrium fracture flow which is necessary for the dual-permeability model since they represent two separate continuum in which you independently model the fracture flow and the matrix flow. There's evidence that there is perched-water at the site and so any information that we can get on that will be useful in helping us understand the porosity values we should assign to various strata within the model. And, we can certainly use information of the chlorine-36 information and so forth. It will also be valuable. For the disturbed zone, we'll need some information on retardation.

Now, it was mentioned a little while ago that the disturbed zone may rely considerably on expert judgment. Sandia is proposing for the '95 budget to do some coupled thermomechanical hydrologic modeling to help to resolve some of the questions and better identify and delineate what the area/the important volumes of the disturbed zone are going to be. This work would be done, for example, with TOUGH and will use all the features that we have in that code to attempt to link these three processes to get an idea of what size these effects of the disturbed zone will be.

A number of times, the USGS/LBL site-scale model has been mentioned. The way we plan to use that is to help us get boundary conditions for the transects because right now, as I said, we're using the faults as no-flow boundary conditions, but certainly that's somewhat unsatisfying to use them that way. However, for a model which incorporates the faults' interior features, hopefully, we can start to get some hydrologic properties of the faults. In that case then, we will be able to more with a little better insight include them if they are boundary conditions to really reflect their hydrologic properties. The other thing we're going to do is locate transects where the site-scale model suggests that they're the most appropriate and that can be a two-fold type of appropriateness. One is that the site-scale model says in this area it looks like you can have considerable local saturation. So, that looks like it might be a good place to investigate the possibility of fast paths occurring. The other thing it can do for us is to say in this region over here the flow is essentially 3-D, it looks like a two-dimensional transect in this area, will not be particularly useful or insightful.

Okay. Let me summarize. What we've done, so far, supports the general approach to the ground water travel time evaluation because we include flow paths in both the UZ and the SZ. We're incorporating alternative conceptual models and alternative numerical flow models. We're going to incorporate a disturbed zone which is consistent with the most general interpretation. And, we have tools now for evaluating the uncertainty and the consequences of travel times less than 1,000 years. And, all these are going to be important components of ground water flow and transport analyses for other performance assessment needs.

Our 1994 work has demonstrated progress towards this analysis program. We have developed what looks like a fairly reasonable modeling domain. We've applied one flow model on the domain. We have, I must modestly admit, a pretty slick particle-tracker going here. You should see the movie; it's really great. And, we also have identified future data needs and linkages to other programs.

So, that's it. If there are any questions, I'll make an attempt.

DR. DOMENICO: Thank you very much, Rally.

Any questions from the Board? Don?

DR. LANGMUIR: Rally, in the TSPA-93 document, there was quite a lot of discussion of using the WEEPS model which, I presume, is a fracture-dominated flow model versus a composite porosity model.

DR. RALSTON BARNARD: That's right.

DR. LANGMUIR: And, very significant implications to performance of a repository which if you had one or the other.

DR. RALSTON BARNARD: That's correct.

DR. LANGMUIR: What you're telling me today is that at least in some of these models you're using the faults as no-flow boundaries which is ignoring the very significant differences, perhaps, in these models and not even considering fracture flow. How are you going to approach this and how much data do you need before you can realistically assess WEEPS versus composite porosity, before you know which way the flow actually is occurring in there? How far are you from deciding which one you want to pick? You certainly don't have any data on the fractures or very little. You're assuming--

DR. RALSTON BARNARD: That's correct. We are starting to get some data from the USGS to give us information on the relative saturation on one side of a fracture versus the other. It happens to be at the near-surface. So, it's coming from the N-holes. So, this will be some information that we have. This first analysis, I really feel was restricted by the fact that we used the faults as no-flow boundaries. And, the LBL model, I think, is going to be much more effective. It's going to allow us to include faults in the middle of a transect and then we can start to look at the effect of the fault, see whether it acts like a complete conduit, whether it acts like a barrier, what kinds of effects it may have. I can't answer you right now as to what we're going to find, but it is clearly an extremely important element of what we're going to do that we will include faults as, I'll call them interior features, also, rather than just boundary conditions.

DR. LANGMUIR: I worry that if you've got to decide on what their significance in the next three or four years, it will be expert judgment that decides their properties rather than enough measurements to have any confidence.

DR. RALSTON BARNARD: Well, as I mentioned for the saturated zone, we used the faults parametrically. We allowed ourself complete freedom to tweak the parameters to get fits to the observed data that we had and what we came up with, as long as it was remotely reasonable, was considered an acceptable value. That's not going to be an acceptable way for us to do this and we are relying on site characterization efforts that we expect to give us something in the next year to allow us to get some insight. The thing to remember is about these models, these models will function with anything from one datum to the most complete set that you could have. And, the more data that you have, the more insight that you have. The saturated zone model had very few data for us to work with and we've made a proposal that we get more data because what that will do is it will help us refine the model. It may radically alter the model, it may not. We won't know, but we certainly have something that we can use right now using best available data.

DR. CORDING: You indicated some modeling of faults.

I'm just kind of interested in what sort of scales you're looking at because I mean you have fractures at much smaller scales and spacings and you may get to a level where you're not discretely modeling certain characteristics in the fractures, but trying to model them in some sort of a smeared porosity, but then you may be modeling some discretely. I was trying to get a feel for what you thought you'd be able to accomplish with the type of models you're going to be getting into.

DR. RALSTON BARNARD: I would expect that in a transect something like this, if we introduced the fault here that there would be--it would be modeled to the level of a flow cell. This is 10 to 30 meters across. We might be able to tweak that down for a fault to make it only 5 meters or something like that. I would expect that's the best we can do. Certainly, to get more detailed on a feature like that could make the problem too complex to handle. I don't know if that answers your question. I'm really not the guy to ask about fault modeling. Hopefully, the GS guys will be here tomorrow and can do a better job of that. So, I'd actually like to defer--

DR. CORDING: You could have some features that aren't maybe as through-going as some of the faults vertically through-going and might terminate at one level or another, particularly against low permeability zones--well, I should say lower--less zones, you know, like some of the nonwelded zones.

DR. RALSTON BARNARD: We do not intend to reject any data that we have. If somebody tells us of a feature down here that's limited in vertical extent or something, we feel that we can include it in some fashion.

DR. DOMENICO: John, do you have a question?

DR. CANTLON: Yeah. You mentioned that you were incorporating some of the perched-water. Since we don't really know the pathway by which that water got there, how is that being incorporated?

DR. RALSTON BARNARD: Since we don't have data, the answer is that they have not been incorporated yet.

DR. CANTLON: Okay.

DR. RALSTON BARNARD: Clearly, just to have an isolated saturation value, something like that, will not be of use. I think it's going to be part of the regional-model. If there is some aspect of the USGS regional-model that reports something about the--for example, the high-gradient area may be the source of the perched-water flowing across an impermeable zone into an otherwise unsaturated area. When we have information that indicates that, that's the way we will incorporate it. It's just not scientifically defensible to go, poof, here's perched-water otherwise.

DR. CANTLON: So, the short answer is you haven't really

been able to use the perched-water--
DR. RALSTON BARNARD: We don't have that information and we haven't included it just yet.
DR. CANTLON: Okay.
DR. DOMENICO: Don?
DR. LANGMUIR: Rally, let me get some idea of the thought process here. We do have limited data and I hope we have more than I've seen recently on chlorine-36 and some $^{14}CO_2$ data which infers things about gas and liquid together, chlorine-36 being the water alone. Do you look at that data yourself or do you let the GS interpret it and then provide you with information on filtration rates or assume pathways based on the dates and then you go from there? What's the tie-in on that data and your modeling?
DR. RALSTON BARNARD: What I'd like to think is that we rely on the GS to make an interpretation. We look at that and, as customers, we see (a) if the data are useful, fit our needs and (b) if it passes the reality test. And, we try to work with the suppliers of the data to--if there are questions, to resolve them. Maybe asking stupid questions, it oftentimes provokes some interesting insights on everybody's part. So, we'll probably ask stupid questions and see where that leads. But, otherwise, I would think we would probably not try to use the raw data ourselves.
DR. DOMENICO: Further staff questions?

(No response.)

DR. DOMENICO: Well, due to the skill and cunning of the moderator, we've finished 25 minutes early. So, I'm going to declare a 10 minute break, and then we'll come back for some discussion, questions, and comments from the Board, the presenters, and hopefully the audience.

(Whereupon, a brief recess was taken.)

DR. DOMENICO: This, of course, is the part where we like to have a discussion and we like to have questions/ comments from the Board, from the presenters, from the audience. So, we're not going to stand on any protocol. If you have something to say, don't let me wait and ask you. Just when there's an appropriate, you step and fire.

I have one. I have, at least, one. It's a statement and a question and I'd like a serious answer to this. But, because licenseability will ultimately be determined by meeting or not meeting some EPA standard--I think we agree on that--is ground water travel time as we know it a non-issue in itself or merely an issue as it pertains to performance assessment modeling? And, I think probably the people who spoke on the regulation this morning, Mal and the others, NRC might help me out on that. Do I have to repeat that or is that pretty clear what I'm saying, what I'm asking?

UNIDENTIFIED SPEAKER: Repeat it.

DR. DOMENICO: Yeah, sure. I said because license-ability will ultimately be determined by meeting or not meeting some EPA standard, as yet undefined, is ground water travel time a non-issue in itself or only an issue as it impacts that performance assessment? In other words, is it just another input into performance assessment or does it have some value in and of itself?

MR. BROCOUM: DOE is on the record, I think, at least in our presentations to the 801 National Academy of Sciences where we recommended in our report to them that quantitative subsystem requirements be replaced or eliminated and be replaced by qualitative substance requirements. I mean, it's a substance requirement. And, one has to ask themselves as we develop our models, as we develop our performance assessment capabilities, to look at the total system and how it's going to behave picking an artificial measure, such as ground water travel time, which was originally intended to help us select a good site to characterize and compare among sites "What relevance it has for the future," as our models become better and as our predictive capabilities for a total system--and, we understand total system better. So, you know, I'd like to lay it out to be discussed and we have taken a position on that, at least, in front of the National Academy of Sciences.

DR. DOMENICO: And, your position is not necessarily at issue except being itself? It's just--

MR. BROCOUM: Yeah, our position really doesn't add--doesn't truly add to understanding how you--to public health and safety, you know, to that issue whether you talk about releases or doses to the public.

DR. DOMENICO: Does the NRC have some position here?

DR. BELL: Yeah. The answer to your question is given in Part 60, the way it's written, the numerical subsystem performance criteria or in addition to meeting the EPA standard. In other words, the Commission has taken the position that even if you chose to meet the EPA standard, unless you also meet these other subsystem requirements, we don't have reasonable assurance that the EPA standard will be met.

DR. DOMENICO: Is that, Mal, your--I'm sorry.

DR. BELL: And, the Commission further in the rule says that it's not going to rely just on one barrier to do the whole thing. In other words, we reject just out of hand DOE coming in and saying, well, we've got a 10,000 year waste package, and given a 10,000 year EPA standard, we meet it because we're going to say it--you know, no matter what your performance assessment shows, we're human. There could be some mistakes. There's just some process that we don't know about. And, therefore, we want to have these three different mechanisms at the various stages of the isolation process and we want them all to work to some extent, so that even if we completely mischaracterize the ground water flow system, we'll still have engineered barriers that will do.

DR. DOMENICO: I thought part of your statement was "or some other ground water travel time as specified".

DR. BELL: Well, there is some flexibility to approve a number other than 1,000 years for this compelling argument that was mentioned earlier. But, it's not automatic that just because the EPA standard isn't met, we'll approve any other ground water travel time DOE may wish to impose.

DR. DOMENICO: I'm supposed to remind the speakers to speak into the microphones. This is my message here. That's not my response to your response. It's my message here.

MR. MURPHY: No, I agree with that 100% and I may have garbled my earlier answer to you, Pat, and if I did, I apologize. But, that is precisely what the regulations now envision. And, the reason for that is that the Nuclear Regulatory Commission and only the NRC--and let's forget there's such a thing as Congress; nothing else exists. We're in a vacuum and only the NRC exists. And, they and only they can determine whether or not whatever action they take is consistent with their requirement under the Atomic Energy Act that they protect the public health and safety an the environment. But, the EPA just publishes that general standard and only the NRC can determine whether or not--even taking into consideration the EPA standard--if we allow DOE to do this, will the public health and safety be protected? And, I'd put that one page back up in quoting again from--and, that quote comes from the statement of considerations on the proposed rule in 1981. The same kind of considerations were again stated in 1983. But, the containment/controlled release rate in 1,000 year ground water transit time, as they said in 1981, are NRC requirements. But, you can analogize containment and controlled release rate to the EPA standard. That's what the EPA standard is, the controlled release rate. But, the 1,000 year ground water travel time is still an independent criteria of the overall repository performance. And, the reason for that is to allow the Commission that high level of confidence, high degree of confidence, necessary to reach a reasonable assurance that what we're doing now by granting this license will protect the public health and safety which is their obligation under the Atomic Energy Act.

DR. DOMENICO: Steve, speak up?

MR. BROCOUM: It's very hard to see what the relationship of the ground water travel time is to public health and safety. I mean, the whole point of the 1982 Nuclear Waste Policy is to develop a health based standard that's related to public health and safety. Ground water travel time, in and of itself, is an arbitrary--1,000 years is an arbitrary number. To find the edge of a disturbed zone to some degree will be a major debate. It's going to be arbitrary and how that even--whether you do 1,000 years or 10,000 years or 900 years, how that's related to public health to me is something I cannot understand in my own mind. And, that's where we're arguing that it ought to be the performance of the total system which, wherever we go, release dose relates more directly to the health and safety of the public is the way to go.

MR. MURPHY: Well, it's relation to the health and safety to the public is by establishing the level of confidence which the decision makers will feel is necessary before they can take this action. That's how it relates to the public health and safety. The performance of the overall system, the engineered barriers, et cetera, will be fraught with huge amounts of uncertainty even, I would submit, after the 100 year period of confirmatory testing. There's still going to be a whole lot of uncertainty left. And, the idea in 1981 and 1983, and I submit it's still a valid idea today, the idea is to say, okay, we're pretty comfortable, we're fairly satisfied that this thing is going to work the way its intended to work because the EBS is going to work and there's going to be some retardation, there's going to be this, and there's going to be that. But, the thing that really makes us comfortable, comfortable enough to go home and explain to our kids that we just issued a license for Yucca Mountain, is the fact that the ground water is going to travel slowly. That's what the ground water travel time standard is all about. It's adding that final measure of confidence which the public policy demands that the decision makers be able to find before they issue a license.

MR. BROCOUM: We have no problem with the term if the ground water travels slowly. We hope that's the case. The issue is making it an artificial criteria that is not directly related to public health and safety.

I need to also make a comment. When you look at the total system performance, you will look at all components of that system including the waste package, engineered barrier, and the natural site itself. So, doing a TSPA and evaluating using that approach does not mean you will ignore the multiple barriers. So, I think you can handle multiple barriers other ways and by having artificial criteria in the regulation.

DR. DOMENICO: I think I see your point. Are there any other points regarding this particular question?

DR. CHESNUT: I'd like to get this into a specific hypothetical. Take Rally's curves where he shows 10% of the ground water has a travel time of less than 1,000 years. Let's suppose this is correct. Let's also suppose that we can make a strong case that our EBS meets those subsystem requirements and that the total system passes the total system release with flying colors. We have one thing then. We have 10% of the ground water travel which has a travel time of less than 1,000 years. Would that preclude granting a license? Would that keep us from having the degree of confidence that the Commissioners would need? That's the real issue, I think, in this discussion. If you want to separate it from performance, how much can we tolerate on the tale of distribution?

DR. DOMENICO: Anybody wish to address that one?

DR. BELL: Well, and the question is it would not necessarily prevent granting a license, but it would certainly be an issue that would get a lot of consideration before the license was granted.

MR. MURPHY: Well, that's right. It increases the burden. It makes it more difficult. It makes the showing that DOE has to make--you know, it imposes a higher standard on them in order for the NRC Commissioners to be able to reach that high degree of confidence that they've said they need to reach. But, it doesn't make it impossible, no.

DR. DOMENICO: Then, I presume that you're in agreement and possibly you, too, Steve, with the presentation of the method in which ground water travel time will be handled by the last two presenters?

MR. BROCOUM: I don't have too much problems with their methodology. I have a problem with making it a criteria when that criteria is not related to public health and safety. That's the issue here. The issue is not that we shouldn't do studies like this; the issue is should it be a criteria.

DR. DOMENICO: Lester?

MR. BERKOWITZ: What I'd like to say is that the Commission in making whatever determination it makes has said that they will take uncertainty into account and we really shouldn't forget that. DOE will have the burden of doing the best job it can to provide to the Commission the information it needs to make that determination. But, I don't think it was ever contemplated that the Commission would be able to make that determination without taking into consideration the fact that there could be a great deal of uncertainty. I don't think that we're going to know the answer now or in a year or two years or three years what it's going to take to convince NRC. I think that there's going to have to be a lot of discussion back and forth and this is something that we anticipate. I think that it would be unwise to assume that we will ever be able to do all the work to reduce uncertainty to a very, very small amount. The Commission's job is to make determinations in the face of uncertainty and that's what the reasonable assurance standard is all about.

DR. DOMENICO: Are there any other positions regarding this particular issue? Don Langmuir?

DR. LANGMUIR: Not this issue.

DR. DOMENICO: Oh, any other points on this issue? John?

DR. CANTLON: One minor iteration on that and that is have the runs so far looked at some of the paleo-climatological data and used the projected hydrologic conditions of, say, the alluvial period?

DR. RALSTON BARNARD: No, we have not yet. We have only used a very limited set of boundary conditions, but we anticipate needing to broaden our range of boundary conditions which should include what you're concerned with.

DR. DOMENICO: Let me ask a related question and then I'll get to yours because this is the same issue. There's another subsystem performance standard, 10^{-5} or at least, that nobody seems to be worried about. Well, this is not an atomic reactor. Is that a design variable or is that a performance variable and how the hell is anybody going to be assured that that subsystem performance criteria is non-violated, 10^{-5}? How does one guarantee that it's going to be based on various solubilities? Why hasn't that been given the same importance as a subsystem performance standard as ground water travel time? Can someone address that for me?

MR. MURPHY: I don't know that it hasn't.

DR. DOMENICO: You don't know that it has not been--Steve, go ahead?

MR. BROCOUM: Well, the ground water travel time guideline in 960 is a disqualifier. If we don't meet it, we get disqualified. The 10^{-5} subsystem performance is an NRC subsystem performance. It is not in our 960 siting guidelines. So, it's not a disqualifier. So, in that sense, it isn't as high on our agenda, but it is a thing we're very worried about because of the reasons you mentioned of how do you actually demonstrate that rate of release and assure yourself that will happen? You have so many things to worry about; everything from how much the stuff dissolves, to how the waste package corrodes, and it's a real issue. So, that's something we're looking at right now. I mean, the waste package people are thinking of very hard.

MR. MURPHY: But, again, I would suggest the reason we have a ground water travel time disqualifier and DOE wrote the disqualifier. The NRC didn't make it a disqualifying condition, but--I mean, you did that to yourselves, Steve, as Congress required. But, the reason we have that disqualifier is because it's so difficult to assure the Commission and the public that they can meet the 10^{-5} standard.

DR. DOMENICO: Well, you are aware of how much uncertainty goes into a ground water travel time calculation?

MR. MURPHY: Oh, I understand. There's uncertainty piled on uncertainty here.

DR. DOMENICO: Don, you have a point?

DR. LANGMUIR: Just related to this. Dwayne Chesnut pointed out the hypothetical that maybe we've got a 10% arrival time here which is too soon, less than 1,000 years. The big issue comes down to this. How does that tie into releases of radionuclides and their transport? So, that's the big question for DOE ultimately in all of this modeling; is can you get to that one? Can you tie together the source term and transport, sorption, and all the rest of it, and it's suitable if that isn't in that 10%. But, it's not suitable, maybe, if it's in that 10% that gets there first.

MR. MURPHY: Well, and also there's--10% of what? How much?

DR. LANGMUIR: That's it. Yeah, that, too.

DR. DOMENICO: You know, I think everybody realizes in all performance assessment models, the important parameter is the source release. I mean, everything just moves it and spreads it or holds it back. But, you have as much uncertainty in that subsystem performance as you have in ground water travel time and I just wonder that maybe we're overemphasizing the role of the ground water travel time regulation. I just brought that up from things that I've heard here.

Is there any other points regarding this?

MR. MIFFLIN: I think that the intent of the ground water travel time has a purpose that NRC recognized earlier on and that the Yucca Mountain site is a very good example for that purpose. The ground water travel time is difficult to determine, but at the same time, it's a very good measure of the hydrogeologic environment. All of the performance assessment evaluations and many of the other licensing criteria are not based on existing conditions. And, the only thing in the ground water travel time criteria is deciding where the disturbed zone boundary is and we have quite an argument about where that's going to be. So, this shows the uncertainty that comes into this whole site selection or site characterization or evaluation process where to determine, say, the disturbed zone boundary, we're talking about some type of modeling process on the basis of limited or perhaps uncertain databases; whereas, with the ground water travel time, at least you have the opportunity to measure something that's going on right at the present time. And, I think from that perspective it's very, very critical.

The other point I'd like to make is that whether it was purposely structured this way or not or whether it was an accident, look at the effect that the ground water travel time criteria and the disturbed zone boundary requirement does with respect to thermal load and the site. If we put a cold load in, we have the probability of a rather small area of a disturbed zone boundary and we have more of the vadose zone for credit for ground water travel time, perhaps. On the other hand, I noticed in one of the presentations that at least going through the analysis, there would be determined what low thermal loads would do with respect to performance assessment. So, already, this criteria of ground water travel time has very significant importance in the sense that it may eliminate a very high dry out thermal load.

DR. DOMENICO: Any comment to that or something--

DR. LANGMUIR: A related question which ties into--I have similar concerns about the disturbed zone. I guess my question is partly for the NRC folks, as well as maybe DOE. The travel time regulation is based upon a measurement of movement from the outside of the disturbed zone to the accessible environment. Well, in this day and age--this is now 10 years after '84-'85--does that really make sense? Isn't the issue releases from the waste package to the accessible environment? If you put it at the outside of the disturbed zone, you're now saying high thermal loading isn't appropriate because that's going to give you a very large disturbed zone which goes right to the water table. But, that's ignoring the benefits of a high thermal loading strategy, at least if it works the way it's supposed to work which is to completely dry out the system and prevent any releases. It's inconsistent, isn't it? We're saying on the one hand, the high loading will prevent releases. We're saying on the other that the releases from the outside of the disturbed zone are the critical ones. We're going to put that a long way from the waste package if we heat it hot. So, does the definition of disturbed zone as it's being used in the regs make sense any more if we're considering possible high and low thermal loadings as strategies to isolate waste? I guess, I'm interested in Mike Bell's thoughts on that.

DR. BELL: Well, at this point, high thermal loading being an advantage is DOE's proposal. NRC hasn't accepted that. Every other country in the world is going in the other direction as far as I know.

I guess I'd like to go back and comment on something that Dr. Domenico said which was all the uncertainties involved in the calculation of ground water travel time. Well, here, we're talking about essentially something--we're trying to get a handle on pre-emplacement, undisturbed by the construction of the repository, undisturbed by all the so-called unanticipated processes and events. Yet, you want to rely exclusively on an EPA standard in which you have to not only calculate ground water flow, but you have to fold in all the low probability events like faulting, volcanism, human intrusion. To me, that seems like an incredibly more complex analysis, and I guess in the Commission's view you have less chance of having reasonable assurance simply relying on that analysis than also having some of these subsystem requirements.

DR. DOMENICO: Is there a question in there, Michael, someplace? What are you asking me?

DR. BELL: It's really a comment that I think I'd like you to perhaps think about. Which of these is really going to be more difficult to demonstrate that public health and safety is protected? If you can show I've got three independent and somewhat redundant subsystems or if I just have this total thing that everything is flexible and it's going to take into account everything that can happen in the next 10,000 years, you know, maybe more if some of the things we hear from--

DR. DOMENICO: Yeah, I understand, but keep in mind, we have three, four conceptual models of flow. Some will give travel times that are as long as we want them if we want to keep it in the matrix and others will send it through in a few tens of years, perhaps. So, there is a lot of uncertainty in a conceptual model of the saturated and unsaturated zone at Yucca Mountain. There's a lot of uncertainty in the database and there's a lot of uncertainty about the thing people like to call fastest pathway, whatever that is, and however you're going to find it. That becomes part of geologic detail that you just do not discover too readily. It's hidden geologic detail. So, there's uncertainty in all of them, certainly. I'm certainly aware of that.

I don't mean to make light of the other facts that are a part of the investigation, but my question, you know, was related to the following. There's a budget and, you know, how many resources are being expanded to work out something like ground water travel time under a natural state from undisturbed zone that's not there yet and we're not going to know its limit and that will not give any measure of system performance? So, how much money do we allocate to that?

MR. MURPHY: Well, it gives a measure of the geology's performance though, Pat. And, that's the whole point. That's what the NRC said when they adopted these regulations. I think that's probably what Congress said when they told DOE and the NWPA to specify factors which would disqualify and qualify sites including hydrologic factors; be specific. And, I think that's what they were talking about. It does give a measure of the repository's performance. It gives a measure of the ability of this piece of rock in this part of the world, on this part of the globe, to isolate waste.

DR. DOMENICO: It's not my role to argue. I don't want to argue. I'm just trying to find out what the various positions are on this because--

DR. LANGMUIR: Travel time is not a measure of repository performance. A measure of the system in the absence of the repository, in the absence of a disturbed zone which is not very realistic.

DR. DOMENICO: But, again, we're not here to argue. We're here to find positions.

MR. MURPHY: Well, let me add another little bit of confusion to the disturbed zone discussion. This is legal confusion, not scientific confusion. But, both definitions, DOE's and NRC's, both say that the disturbed zone depends on the effect on repository performance. It doesn't say negative effect or positive effect. It just says effect on repository performance. We're all--I mean, everybody in this room is operating on the assumption implicit in our discussions that this does mean negative effect. But, what would happen if someday somebody says, well, there is effect on repository performance out to the accessible environment. It may be good effect. It dried out all the rock and nothing is moving, nothing can touch the waste packages. This stuff is going to stay there for a million years. It's great. But, its effect on repository performance was all the way out to the accessible environment. Your ground water travel time is zero; you flunk. But, we're ignoring that. Everybody is assuming that effect means bad effect.

MR. BROCOUM: By coming up with an artificial criterion, you could, in fact, be driving yourself away from optimizing the system to give you the best overall performance which would give you the lowest releases or the lowest doses to the public. That's the issue here. Should you put your resources into optimizing the system and understanding that system or should you put your resources in evaluating an artificial, arbitrary criteria which might have been good in your early days when you're trying to pick a bunch of different sites and you're trying to get some early indication if the geology is good or bad. But, now, as we're getting more sophisticated and we're trying to understand how the whole--and, you really cannot talk about suitability of the site without understanding about the whole system at work. Is it a relevant thing anymore? And, I think that's the issue on the table and DOE is arguing that it's not relevant.

DR. CORDING: It seems to me at least the definition of the disturbed zone needs to be treated with some sophistication or understanding of what its impact is. Certainly, if you're talking about good effects that are further out, that that should be not used to define the disturbed zone. From what I've seen of thermal effects and underground construction effects, most of these disturbed zones don't extend out very far. It certainly improves the mechanical effects.

MR. MURPHY: Well, I agree with you, but until the 1st Circuit ruled in 1987, nobody thought that taking a system and engineering it and putting a highly designed and highly engineered cask into a--and inserting it into the ground or the wall of the repository constituted underground injection, either.

DR. CORDING: Constituted--I'm sorry?

MR. MURPHY: Underground injection. But, you know, a major part of the reason why the EPA standards failed the judicial test in 1987 was because some Judges in Boston said that burying radioactive wastes in canisters and in a highly engineered repository could constitute underground injection. So, all I'm suggesting, that there's more uncertainty involved and more potential confusion surrounding the definition of disturbed zone than we even discussed in our formal presentations and it's, you know, probably time for the NRC to step up to the bat and start answering some of those questions.

DR. CORDING: It certainly needs to be handled with a technical understanding of--at least, the current technical understanding of what these things are involving at the present time.

DR. DOMENICO: John?

DR. CANTLON: I'd like to hear NRC expand a little bit on the timing issue in the uncertainty or in the disturbed zone issue because that disturbed zone is going to be at different places and different times and the disturbed zone's impact on the site is going to be very different at different times. Highly beneficial if you're dealing with a hot repository very early and, perhaps later, in terms of degradation of retention or sorption, radioactive ions may be negative. Has any thought been given to how NRC is going to pursue that if DOE makes an argument to go, let's say, toward the hot repository?

DR. BELL: I guess all I can say is that we're looking at it and we don't have the final position on that yet.

Let me go back to the earlier question from the gentleman that came up to the microphone and asked about the 10%. I think it's perfectly--say, within the realm of possibility that if we got to the point of license review and DOE had, in fact, done what they were saying they were going to do with the multi-purpose canister, which is now design a canister that's going to last well in excess of 1,000 years, and could also show NRC they meet the 10^{-5} release rate and they meet the EPA standard and that the distribution of the ground water travel times looks something like the curves that we saw and the expected value of ground water travel time is well in excess of 1,000 years, but it was a 10% or so possibility that it might be shorter than 1,000 years, that could be an instance where the Commission could say, yeah, that's what we had in mind in terms of consideration of uncertainty, and even though there is that possibility, because we have all these other things, we still have a reasonable assurance that health and safety is protected and it could be licensable.

DR. DOMENICO: Well, it seems to me like, Steve, you just had your program outlined for you for the next four years. You just got all the requirements we needed for license. Those seem to be priority items. Why I was concerned about--well, maybe it's not important. Let me--I'll ask a related question.

Dwight Hoxie was very anxious to say something about this. Is he still here? Dwight? Did he leave?

UNIDENTIFIED SPEAKER: He's speaking tomorrow.

DR. DOMENICO: He wasn't that anxious. But, Don Langmuir knows something about this, too.

Is there agreement on the definition of ground water now in terms of the problem of gas transport, vapor transport? Hoxie was saying something--well, you know what he was saying.

DR. LANGMUIR: Well, I paraphrased the question, I think, that came out of our discussions. And, bluntly, I guess Mike or anyone else who is willing to comment, is there kind of an NRC regulation that explicitly sets a standard for gaseous radionuclide releases from a repository? Any kind of an NRC reg that identifies that specific potential release and sets a limit on it explicitly or is it all inferential?

Are gases like C^{14} specifically identified in the regs or is something--

DR. BELL: I think the way that would come out is by the standard that EPA eventually adopts. I mean, because there is an explicit value or there was an explicit value in the earlier EPA standard for Carbon-14 release and I anticipate that the revised standard may have a value.

MR. MURPHY: There is no numerical standard. He's correct. The only standard in the regs is the potentially adverse condition. And, remember, a PAC has to--if DOE cannot prove that a PAC is absent, then they've got to go through certain steps and demonstrate that they've characterized it adequately and evaluated, et cetera. But, there is a PAC which says potential for the movement of radionuclides in a gaseous state through air filled core spaces of an unsaturated geologic medium to the accessible environment. So if that potential exists, then DOE has the burden to demonstrate it, that it doesn't--

DR. DOMENICO: But, that doesn't fall within the travel time.

MR. MURPHY: No, no.

DR. DOMENICO: It has just to do with the release--

MR. MURPHY: No, no. It's entirely separate from travel time.

DR. DOMENICO: So that anything going out as a gas, if it goes out in 10 minutes, does not violate the travel time, is that correct? Is that the position? Travel time of ground water, by the way, is that right, because it's not ground water? Just clarification.

DR. LANGMUIR: Same question, related. Are there amounts identified?

MR. MURPHY: No.

DR. LANGMUIR: No numbers are assigned to the permissible releases of radionuclide gases then in any regulations?

DR. BELL: Well, not NRC.

DR. LANGMUIR: Not NRC's, but EPA--

DR. BELL: EPA is just a cumulative release by any and all pathways.

DR. LANGMUIR: It's a cumulative.

DR. DOMENICO: I think the question is on the ground water travel time which is our main focus. If there is gas transport, the gas gets out in 500 years or so, this is not a violation of the ground water travel time regulation. Is that what I'm understanding? It may be a violation due to the EPA standard, but no matter how fast the gas gets out, it's not a violation of ground water travel time. Is that true? In a sense, it's not ground water.

MR. MURPHY: Well, it depends on whether or not you're defining ground water to include vapor.

DR. DOMENICO: That's Hoxie's argument. Do you remember his argument?

DR. LANGMUIR: The regs you read, Mal, indicated that vapors weren't allowed. This was an NRC reg, I believe, vapor releases--but these are not vapors. A vapor, if you're rigorous about it, it's the gas phase of a liquid. So, it could only be water vapor we've been talking about here. It can't transport very much.

MR. MURPHY: I understand that, yeah.

DR. DOMENICO: Well, you speak of technical legal arguments--

MR. MURPHY: No, I'm just saying what the NRC said when they amended their definition of ground water in 1985 to take care of the unsaturated zone problem. The NRC staff in its statement of considerations specifically said vapor is a problem. Vapor can transport contaminants and it's a problem because in an unsaturated geologic media, water travels in both the liquid and the vapor phase, and that, to me, means the NRC meant to include the vapor phase of water in its definition of ground water. If they didn't mean that, it is incumbent upon them to do something officially either to change the regulations or to officially interpret the regulations to take care of that. But, as the record now stands, the language of the regulation itself and its regulatory history, I have to conclude that the definition of ground water in 10 CFR 60.2 includes water in its vapor phase, and that there are some regulatory implications of that with respect to ground water travel time.

MR. BROOKS: Water in its gas phase was not intended to be included in ground water travel time is the current staff's position. We're looking at it. We are still considering other definitions. We're considering the parts of the statement of considerations that have been cited. But, the present staff position, not ratified by the Commission, is that it did not include gaseous release.

DR. DOMENICO: Rally, do you have a point?

DR. RALSTON BARNARD: I'd just like to say this may be a perfect place where the issue of significance comes into effect because if, indeed, it is a fast transit time, but as Don Langmuir points out, there's no significant amount of radionuclides that could be transported by this medium, then it doesn't matter. And, you can come up with what Mal's words were, a strong and well-crafted statement of why it isn't important to have to worry about it.

MR. MURPHY: That's right. That's exactly what I said in my presentation. If, indeed--and, I'm not saying it is or isn't--but if, indeed, that water vapor traveling up to the land surface because of the thermal effects of the repository doesn't have the potential of hurting anybody, then the NRC is going to point to its "or such other" language and say that's not a problem. We're not going to worry about it. But, it's something that they will have to look at, I'm suggesting.

DR. LANGMUIR: Just trying to tie it all together, the Board has heard discussions over the last year or two of source term. That was one of the meetings that I was very much involved in. And, I guess, I'm looking for a systems approach to all of this. I see source term and concerns about releases of radionuclides from waste. I see unsat zone models looking at transport throughout that unsat zone, attempts at Livermore to look at the thermal effects in the disturbed zone, and now we finally get to the beginning of ground water travel time. And, I wonder if all of these other things that I just mentioned are being factored in as the input to the ground water travel time calculation or not. Where do you start when you're concerned about a radionuclide being released from a repository because it certainly starts at the waste package? It's source term, it's near-field, it's far-field, it's in the disturbed zone, and then it goes on out. And, I don't see the system being looked at unless this whole thing is being analyzed.

MR. MURPHY: But, it's pre-waste-emplacement ground water travel time. I don't see how you can look at source term.

DR. LANGMUIR: I know, but should that really matter?

You're saying it's pre-waste-emplacement, but then you're saying you can't start it until outside the disturbed zone. Well, that's post-emplacement.

MR. MURPHY: No, I didn't write those--

DR. DOMENICO: I guess that's the answer then.

Are there any--sure?

MR. LUGO: You just put another confusion or inconsistency in the regulation in that the only reason, like Mike said, why disturbed zone was first invented was just because you didn't want to calculate what was going on within that zone because it was just too complicated. But, when you do the total system performance, that's exactly what you have to do. You have to suffer in the source term, you have to know what's going on in there, and then further out. So, that's something else that even adds to that inconsistency in what does it really mean to calculate ground water travel time.

DR. LANGMUIR: Well, following that up, I guess I would ask if the DOE is consciously trying to persuade the NRC, if you like, and take a position themselves which incorporates all of this in a systems approach?

MR. BROCOUM: We have taken a position in our report to the National Academy. We also saw that that whole evaluation as being a chance to re-look at all the regulations. In other words, the law requires National Academy to have their report, EPA to conform their regulation to that report, and the NRC to conform their regs to the EPA. So, if they go through those steps, we would assume that the NRC would re-look and we would issue a draft which we would comment on. And so, we may look at all that. We're advocating a systems approach here. That doesn't mean when you understand a system that you can't look at each individual barrier to see how it contributes and what the concerns of that barrier are. We're not trying to get away from doing that. We're trying to get ways to rationalize the regulations with respect to public health and safety and not divert our resources to worrying about things which may not truly contribute; in fact, may in the extreme keep us from actually coming up with the best and most optimized system. So, yeah, we look at the 801 activity as a way of revisiting all the regulations and maybe updating them, if you like, based on our current knowledge.

DR. BELL: Well, and when we promulgated the ground water travel time requirement, it was our belief and I think it still is that you're not really diverting resources. Just like we heard from both the M&O and Sandia this afternoon, you're going to have to do most of that analysis and you're going to need that data anyway.

DR. DOMENICO: I don't agree with that. All due respect, James Duguid, all due respect. The performance assessment model that I'm familiar with of little lines of one-dimensional velocity, their velocities are different. They incorporate little dispersion, of course, longitudinal, which you'll never measure. They incorporate retardation which you can handle pretty good. And, they incorporate decay, as well as 7 or 8 daughters. I don't think you need a number of probability distributions for that analysis as you would need in the stochastic analysis. That's number one, make stochastic analysis. You know, it's reasonable. I don't think you would need the detail of the flow patterns that you're doing in that particular analysis because I think by your own admission those are relatively simple, analytical performance assessment models and you've made a strong argument to NRC why you should use them. So, model the data that you're collecting in the ground water travel time study. I feel it is not multi-purpose data, that cannot possibly be incorporated in the simple performance assessment models. It's good data, but it can't be incorporated. That's my point.

DR. DUGUID: I tend to agree with some of that. But, my point is that you need to look at the sensitivity of some of those things on the distribution so you know which distributions you put in the performance assessment models and I think that's what's going to come out of this.

DR. DOMENICO: I tend to agree with that. That's a good statement.

Is there any other--you know, due to my skill and cunning, we should have finished five minutes ago. Is there any pressing important questions?

DR. DUGUID: There was a point that I wanted to make. We now have the Academy looking at the standard and what it should look like and I would guess that the ground water travel time calculation will look somewhat different depending on the type of standard and the time frame of that standard. And, if you have a 10,000 year standard, it would look different than if you had a 100,000 year standard because you'd have to consider some different things. So, I think we're not going to have the whole answer before we see how--or the direction that the new EPA standard might take.

DR. DOMENICO: My understanding is that the Academy is not the one that promulgates the standard.

DR. DUGUID: I understand that. We'll get some indication when they make their recommendation.

DR. DOMENICO: Are there any further points?

(No response.)

DR. DOMENICO: Recess until tomorrow, 8:30 a.m.

(Whereupon, at 6:00 p.m., the meeting was recessed, to reconvene at 8:30 a.m. on Tuesday, September 13, 1994.)

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