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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON NUCLEAR WASTE

January 11, 2006

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE

167TH MEETING

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WEDNESDAY, JANUARY 11, 2006

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The meeting came to order at 9:30 a.m. in room T2B3 of Two White Flint North, Rockville, MD. Michael T. Ryan, Chairman, presiding.

PRESENT:

MICHAEL T. RYAN	CHAIRMAN
ALLEN G. CROFF	VICE CHAIRMAN
JAMES H. CLARKE	MEMBER
WILLIAM J. HINZE	MEMBER
RUTH F. WEINER	MEMBER

ALSO PRESENT:

MICHAEL SCOTT	DESIGNATED FEDERAL OFFICIAL
ASHOK C. THADANI	DEPUTY EXECUTIVE DIRECTOR
LATIF HAMDAN	STAFF

I-N-D-E-X

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

9:32 a.m.

CHAIRMAN RYAN: All right, if I could have your attention. Good morning, the meeting will come to order. This is the second day of the 167th meeting of the Advisory Committee on Nuclear Waste. My name is Michael Ryan, chairman of the committee. The other members of the committee present are Vice Chairman Allen Croff, Ruth Weiner, James Clarke and William Hinze.

During today's meeting the committee will (1) be briefed by the staff on the capabilities of Version 4.1 of the Spatial Analysis and Decision Assistance Bayesian Subsurface Analysis Code. We will hear presentations by and hold discussions with representatives from the Federal Railroad Administration on the use of dedicated trains for transportation of spent nuclear fuel and other high-level radioactive waste to the proposed Yucca Mountain Repository. Three, we will brief the Commission on recent and planned activities. This briefing will take place at a different location in the Commission Briefing Room in 1 White Flint North. That will commence at 2 o'clock, and the schedule is from 2:00 to 4:00, for those that are interested. We will discuss proposed committee letters and reports.

Mike Scott is the designated federal official for today's session. This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. We have received no written comments or requests for time to make oral statements from members of the public regarding today's sessions. Should anyone wish to address the committee please make your wishes known to one of the committee staff. It is requested that speakers use one of the microphones, identify themselves and speak with sufficient clarity and volume so they can be readily heard. It is also requested that if you have cell phones or pagers that you kindly turn them off at this time. Thank you very much.

Without further delay I will turn over. The two next presentations will be led by Dr. Weiner. Dr. Weiner?

MEMBER WEINER: Thank you. I'd like to welcome George Powers from the Office of Research to talk about the Spatial Analysis and Decision Assistance program that is being carried out by NRC along with a number of other federal agencies.

MR. POWERS: Okay, thank you very much. The last time I was here this program was just getting underway.

CHAIRMAN RYAN: Do you have a lapel mic on?

MR. POWERS: Oh, I'm sorry. There, is that? Okay.

CHAIRMAN RYAN: That's great.

MR. POWERS: I can hear myself more than once. And it was started for several reasons, which we'll get to in a few minutes. But anyway, the primary purpose for getting into the involvement of this particular development was to try to pull together a more realistic and dependable estimate of exposure and the parameters leading to determining what that exposure is. And we elected to -- one of the problems we've run into in the past are the number of additional samples. There is an incredible amount of effort out in the field wasted on bad sampling, taken in the wrong place. So what we begin to do is begin to optimize the sampling and the analysis that's going to be involved.

Now, is it new? No. Argonne National Laboratory is kind of where we got our start on this. There's a guy up there by the name of Robert Johnson, and he has used his version of it, which ran on a Unix system, and that system is now just about dead. But the important point is is it's been applied at all of these sites on a piecemeal basis. You can look at your old slides on this one, but the only thing that I think is really of importance here is the savings that have occurred, like 40 - 80 percent sample reductions, 30 percent, 50 percent. Costs going from a $40 million to an $8 million cleanup effort. These are worthy of taking note.

The NRC, we will be talking about one particular little site that we're using as a test site. It's called the Kiski site. It's a very small little sample of data, but it was outstanding. We found out that we could have reduced the number of bore holes by 70 percent on that site, and at the same time reduce the sampling by 85 percent to get the same result. We'll go through that. We've got one we're starting to play with now just a little bit in the SADA framework, and that's Sequoyah Fuels. The interesting thing about Sequoyah Fuels is it's had so many holes poked into the ground that the underground -- the groundwater patterns have changed due to the holes.

We see the potential applications of SADA beyond decommissioning-type activities in the area of early site permits. A lot of sites are going to have to reevaluate where they're going to have to put down wells up close, and there isn't any other code around or any other techniques around that is going to be capable of doing this without an incredible amount of expense. It's going to also assist, I think, in the operating license evaluations that are done, re-licensing, and to some extent partial site release.

The big issue is to, when you get into this, is to understand what the requirements are that you are going to be having to apply. A lot of people will go out and say 'Just bring me some more data and we'll take a look at it.' Know why you're collecting the data and what you're going to do with it. And at the same time be sure that you have a feel for what the uncertainties are, and how much uncertainty you can stand. That led to this sequence that has started here. In August 2000, a document came out by MARSSIM that was a combination of DOE, EPA, NRC, the Air Force, other parts of the Department of Defense, and it began to tie together sampling uncertainties and so forth based upon a two dimensional plane, going out, taking surveys on land down to about 15 centimeters, since that's where most of the dose modeling has been. In that process, one of the things that you got into was having to take a look at the instrumentation. How sensitive were you going to have to be to make measurements, because the more sensitive your instrument the fewer samples you could take. You could go out with a Coke bottle if you wanted to and throw it on the ground, see if it turned brown in the morning. That takes too long if sensitivity isn't there. And MARLAP took care of the instrumentation side of it, and the laboratory side of it. And I think this is probably one of the finest documents that has been put together in a long, long time.

Currently they're working on the materials part of it. They're calling it MARSAME, and they've got it targeted for publication around 2007, sometime in there. Talk to somebody else about that. We have the subsurface one coming along. I am going to just call it MARSSub since it's easy to remember, subsurface. I prefer this one to BINMAR map, but never mind. And then we're using SADA to begin to answer some of these questions. We find that by the time we turn it over to the multi-agencies for review and so forth, if they have not been involved with the development, that a little bit of time is taken. But to review it, if you are familiar with the MARSSIM process, and the EPA, things like data quality objectives, knowing what you're going to do, why you're going to do it, what accuracy you're going to need in like data quality assessment. You start out with the DCGLs. You go through all of the modeling, like you may run into with RESRAD, and you have various components, survey units, release criteria. I think that's probably relatively self-explanatory for you.

An example that MARSSIM had, or came out and had an impact. There was a document out there at one time called 5849, which said go take a survey point every five meters across the site that you are working on. Here's some examples of what might have happened. RESRAD, for an example, will take a 10,000 square foot area and model it. To do that, you would require something like a thousand samples. Football field, everybody can pretty well relate to that. That would be here. And you would need about that many samples to do, let's say, something like a football field here, around a hundred samples to sample an entire football field. What they didn't take into account was the sensitivity of the instrumentation, and how far away from your action guide that you were. The further you were away from the action guide, and the better your instrumentation was, a value called delta over sigma, which is distance from the action point, and the variance of the samples you were taking would get larger. And so you could get exactly the same result. MARSSIM suggests to get around, a delta over sigma of around three. Look, we're only taking around 10 or 12 samples to get the same result with the same confidence that you did when you were taking a hundred. That paid off, and that has paid off on several sites big time. There's -- I just covered about an 8-hour lecture.

Sampling in the subsurface. When you get down below the 15 centimeters, some things begin to happen to you. Bingo, you lose the ability to scan. You can no longer take a meter and walk over in the way that we think about it with radiological things. So we had to find a way to design the survey, make it more efficient, and be sure that we didn't have any hidden assumptions. By the way, through a few of these I'll be just talking to the yellow points. I assume you can read the other stuff.

So the research areas that we're involved with right now is, a lot of it is dealing with optimization. Time and effort, which eventually boils down to cost. Want to improve the survey design. We're using site knowledge now, which is leading us into a Bayesian type of analysis. Take the information that you have now or in the past, and can it be applied to what you are doing. Is there any relationship between it and where the contamination might be. In some cases yes and in some cases no. Improved analysis. We're getting into geostatistics. In the area of geostatistics, most of you are familiar, or may have at least heard the term variogram. What it is is a -- I'll show you one later. We have the same thing occur subsurface. We have, let's say an elevated volume. In MARSSIM we were talking about the area, we had an elevated area. They both kind of have the same relationship and behavioral components. How are we going to get around all this? We're going to start using more and more surrogate data, and professional judgment. One of the things that a lot of the licensees got very upset with when MARSSIM started to come out is that their feet were being held to the fire on a design for a survey, and they didn't want to tie everything up on that one particular survey. They said, well we'd like to go out and look first. Well, the response was that's what's going on during the time you're doing characterization of a site. When you come to the final status survey, we want to be able to go out there and apply our statistics to it. So with taking things like Bayesian and some of this, a little bit of this is going to be able to be relaxed just a little bit, and we're going to be able to probably get better results.

And reducing the number of samples is the big issue. Once you get into subsurface, it really gets out of control. Again, increase the information that we're getting from historical data, other geological data, and make more efficient use of the hard data that you have. That's numerical data that you can take and plug into a code. So I mentioned that.

One thing that is important is not all locations are going to be equally informative. When you go out and you do a random survey, you're not going to be getting the same information from those spots. Even if you have secondary information, you're going to have some areas where there may have been things like oil spills that are going to affect. You may have different geology. And that's where the geostatistics and geophysical information can come in and be used.

Okay, now we're going to run through SADA in rather rapid fashion. It has all of this pretty well built into it. We will touch on each one of these topics briefly, but it might be interesting to note that it has been supported by both the DOE and the EPA, and Version 3, which was about a year and a half, two years ago, had 11,000 downloads worldwide. Since January of 2005, when 4.1 was noticing to come out, we've had around 4,000 downloads. Now, that doesn't mean there's 4,000 people out there using it, but this is people that have actually logged on, I've got their email location, and date and time, and when they downloaded it, so we know who, where, and believe me it's worldwide. Side point: if you go to the website of SADA, which I think most of you can find relatively easily, go to the bottom of the homepage and there's a little number off to the left. Click on that number. It's a counter. It'll bring up such things as where it's been downloaded to, how many hits there have been on a site, from where in the world, and it's really been quite useful and informative.

Okay. Graphics. This has increased quite a bit. We can overlay GIS overlays now. And we're to the point where it really doesn't matter where these come from. They can come from AutoCAD, they can come from any -- Earthvision, what's the other one, Arcview. These are all can be moved back and forth. In any event, your data, you can take a spatial data screen, look at your samples. You can pick out samples with given compounds if you wish, or levels that you're interested in. Survey units, this has been a big thing in MARSSIM. You can draw polygons around what you are going to make as your survey unit, and you, at the time when we talked to you the first time they were just getting started on this. We've gotten to the point now of where polygons can be drawn around all the survey units at once on your site and you can do comparisons.

Visualization. This is what we had when we talked to you the last time, and the camp that -- showing a transparency through a thing. We've now got it to the point of where they can do all the neat slice and dice and cube. One of the important things with SADA is to present the data visually. That's its primary function. Keep the math, the science inside the machine, inside the process as accurate as you possibly can, and present the data graphically. You can get a lot of times much, much more information from a graphic than you can.

Okay, statistics that is available within it is overwhelming. There's univariate statistics that pretty much anything from mean, standard deviation, variances, a whole laundry list, histograms, all sorts of formations of data. You have the ability to identify your analytes that you're working with, detects the means, variances, pretty much all that type of information. And for those of you that have a little twinge into the EPA area, this thing is tied to the CASS database. In fact, that's where we're putting a lot of our stuff.

MARSSIM's in there now full blown. I'm not going to go through this, but what it does is as you go through MARSSIM, you are going to do things like select your DCGL, come up with number of samples, whether there's material and background and so forth, and the key is that as you go through it, it's going to tag whether you have completed all of that particular protocol as needed. Did you pick the right sensitivity of an instrument? If you didn't, it's going to bounce you and you'll have a little red dot out here. And it'll tell you exactly where to go to fix it. The layout of the SADA code is very, very much like your income tax program TurboTax. In fact, if you go on and start to use it you'll see an incredible similarity. The outline will come down in the first block, you'll do it, it'll bring out the information that you need, and keep it as you go on through. If you forget something it'll let you know.

This is just going through some of the detail of MARSSIM. I don't think we really need to do this. This is a sign test. You had 18 samples required. They were using a Level 3. It bounds out the so-called gray region that you're going to be interested in. You're getting into, if you've got stuff in background, where you've got it in your sample and in your background, then you're going to go to a Wilcoxan rank sum test, and in that case you're going to have 18 survey units in your unit and in a background area that you're going to do a comparison on. So all the aspects are in there.

In the spatial analysis side of it, most of you are familiar with things like contouring, where you may have had a point here and a point, and you're going to try and find some position in between that you want to kind of draw an isodose curve. We do this also, but a little more sophisticated, and with a little bit more backup. I wish I could spend more time on what's going on here. Is there anybody that doesn't know what a variogram is? If not, see me. I've got a little quickie thing. I've got a whole presentation on variograms, it's about like that, but what it is, there's a point down here that's called the nugget. This is where your first point is. And immediately around that point there's a lot of variability. So a lot of times this doesn't go through the point. Then you have the range. This is the range of where you have your variance. And then you finally have a sill. That's the end of it. That means that any information here, data that you have here isn't going to influence this over here. Data from here might influence that one from there, and that's what's going on in between. The better correlation you have, the slower the slope of the curve, and the further you can look down. So when you start looking at things like underground water movement, or material running on the ground and moving, you'll see a correlation. Let's say if there had been a flow this way, these all kind of seem to be related, and this'll turn out to be like this. If you go the other way, boom, this thing's going to go up and flatten out. And so we can put that into an estimation of it. And from that we can reprocess and come out and say, okay, where are the areas of uncertainty. We know there's no problem here. We're pretty sure we have material here, quite comfortable, and this is the area that we're uncertain about. So you start getting involved in determining the area. This is kind of like the latest -- one of the later things that we just got into it. It's called a rose diagram. What it is is a color version of a variogram as you lay it down on a -- I don't know if anybody has ever generated a variogram by hand, but it is obnoxious. There is a lot of data that goes -- you have to take every bloody point on that site and process it, and then go to the next point and relate it to all the rest of them. And this goes on and on. And then that's usually in one direction. Here we've just rotated the thing all the way around. Under the -- so you have the processing, so you have a variogram which is equivalent to let's say a line through here. For example, here you have one that went up and dropped off. That would be a point -- okay, I'm sorry. As it goes on up higher, this is a bad fit. You don't want that. You have more of a relationship if the variance stays fairly low over a long distance. Okay.

We've built into SADA since we saw you the last time something over 21 sampling scenarios that are now available. You have the basic ones that everybody's familiar with, judgmentals, random, grids, variations of grids. Depending on who you are, you will select them. We have the MARSSIM design in there obviously. But we get into the situation of when you get ready to re-sample, going back in, taking a look at something. Then we have secondary sampling designs where you may go to the area where there was the highest variance, or you go to someplace like adaptive fill. Hey, we had a random thing, but there's an area in here we could take one more sample. It will calculate the best place for you to do that. The high value, and this goes on. Judgmental sampling. People like to use this on occasion. It has some pros and cons, but along the road is a real good example. A MARSSIM sample across this might not be that informative. Simple random. That's more like your MARSSIM.

Okay. Life is good until you start going down underneath into the ground, and you start wanting to -- how are we going to talk about 3D? What I see here, they call it 3D, I call it 2 1/2D. You've got stuff on the surface that you take. Okay, that'd be like MARSSIM. But now you're starting to go down, and you start placing your point of your result of which you're wanting all this whole area to be equivalent to. This is where people start homogenizing cores. And you can move it, and it'll assign values. I call that 2 1/2D. You can, this is in place now. What we're working on now is being able to take core scans.

And when you start going into the third dimension, go back and think about that variogram, and now start putting it into the third dimension. That is going to really be an effort. But we've got a real, real good start on that. Searching for a hotspot. We have a program out there called Elipgrid, which determines how big of an area you're going to miss when you take samples over a long period of time in a given area. And we can now apply it to subsurface. We can put all sorts of little shapes down there that are standard, and look at what the probability is that you are going to hit or miss it. And this is where things like magnetometry, and some of these other concepts come in, because they can really narrow some of this down for you.

We can customize the criteria. You can get data, bring it in from regions, states, locally, and you can have all that data available to you, and bring it in, and process it, and relating it to what you're working on. There's a human health risk calculation in here, complements of the EPA. See, EPA funded this thing to the tune of, I don't know, several million dollars before we got a hold of it. And they've got all of this type of information in here, and there's a couple of sets of that. There's one slide in cutting the presentation, making it a little shorter. I had to cut one out that had kind of a cute little picture. Okay.

So from that you can develop things like health risk maps. Same thing on the radiological side of it. Where the risk is going to be the highest you can -- you have a site, you have areas where there's contamination on it, you can determine what the risk coefficient is going to be in various components on a particular site. We had points that were identified early on to take a look at.

And to decision analysis. This is the one that I think is probably going to be used quite a bit. You take the data, you have your various sampling strategies laid out. From these you can get spatial screens, and you can come up with risk based on space. Areas of concern. This is going to be areas that you might have to clean up. And we're working on techniques of minimizing this area. We've got some in there now that are quite good, but you can assign what is it going to cost to haul out a cubic yard, or X number of cubic yards of material. And we've got a little risk curve here that will -- risk/benefit that will tell you exactly what it's going to cost you to clean that site up so you can use it in the estimation area.

Geobayesian modeling. Making use of soft knowledge, soft information, and combining it with hard data. And we fall into the area of geobayesian modeling. Ordinary kriging and indicator kriging are generally based on normal or log normal type distributions. Indicator kriging is the one we're finding more useful. We are having more and more luck with the application of non-parametric statistics because from our standpoint we really don't know what the distributions are when you walk into a site, and sometimes you never do. And we've found that through MARSSIM, that any errors that are made by using a non-parametric are usually almost unmeasurable. And people talk about modeling.

Let's talk a little bit about the Kiski site real quickly. This would be a prior knowledge type curve or plot that you would make. In fact, you actually sat down and said, there's X Y, and you drew a line here, and you said okay, everything inside here, we're pretty sure there's something there, and 90 percent sure there's something here, and I'm pretty sure there's nothing out here. This particular range, I really don't know whether there's anything there. Now we're beginning to play some of the Bayesian game.

So, there's where judgmental sampling would come in on something like this. You've got these sampling plans that you can use. But what happens is we're going to go around, we're going to try and take a few samples around this area of concern, some inside and some outside, just for confirmation. This is what the original data set looked like. The guys when they started on this didn't have this information. I asked them what they wanted, and we would provide them the data, and we would pull it out of the data set and give it to them. But, there were 1,261 samples in the shallow sediment, and they took over 90 boreholes was what had been done. And remember I said that we reduced the number of samples by 85 percent, and the number of boreholes by probably 70. And so this is what it all kind of looked like. And this is looking at it that way, and of course through the side. So what we're going to be looking at as we go through here is the analysis that's taking place at various layers. Okay.

From the judgmental sample, what we did is from that we went and said, okay, where is the closest real data point of a real data value they could use. We didn't want to go out and sample again. These red points show above the action guide, the blue points below the action guide. This is on the surface. This is down around six inches. A little bit deeper. The red points are showing, again, above the action guide and those below. There's 130 total samples taken. And these were ran on each layer, and we came up with the variogram prior correlation model that came up and then began to drop off as you moved out at the end. And here's kind of what happened. With zero samples, yes, 0.6, 1.2 and 1.8 it looked like that. Did the sample analysis with 130 samples, and here's what the distribution looked like at the various levels. We doubled the samples. Let's go to 260 samples and see what kind of a change that would make. And a little, but not very much. Probably, depending upon the cost of the sample and where you'd want to do it. And then with all 1,260 samples available. Now, by being a little bit careful on where you took the samples and how you did the analysis, we think we can probably get by in this particular case with an evaluation of probably around 130 samples. When you're looking at the total impact there would be on, let's say material that might be left behind.

These are the areas of concern that came when we did the area of concern by looking at what percent of the areas above a given value. And again, there's not that much change between 130 to 1,260. There's a little larger area maybe, but not enough to spend another couple of million dollars. The metrics on this. This is the area of concern volume versus sample, number of samples, and the volume that you would let's say have to remove, which I was talking about. In 130 samples, Y around 2,000. 260, yes it went down some, and at 1,260 a little bit more. This becomes a weigh, do I want to or don't I. We have a percent change with the number of samples that we were involved with. And finally, the thing that we would be interested in, the percent that we would have missed. And after 130 samples there, the 130 sample things still look pretty good. Okay.

That brought up another interesting thing. This is using a geobayesian analysis. What had happened had you used something like your indicator kriging, the everyday analysis that people use, might use. This is the comparison between the two. The question comes up, now remember, indicator kriging's only going to use the data that's there. Either it's there or it isn't. Bayesian's going to start, and geobayesian's going to start making some assumptions depending upon what you've told it. So it doesn't drop off to a nice clean thing here. In this particular case I would have a tendency to recommend that you might want to kind of compare these two together in reality, just to make sure that things are still pretty close. Let me give you an example. There's a really good concept. You've really got the model right. And then you went out and you took your samples. You got a nice clean variogram, and your model came out looking pretty good. And that when you analyzed this number of samples. Let's say you made a real bad guess. Now you're going to see where Bayesian -- nothing's free. In the case of the Bayesian, here's your estimate, and here's your real data points. Here's somebody let's say trying to -- well, we don't have anything here we're going to sample, and wind up taking a few samples there. And their analysis comes out looking like this initially. Says whoa, whoa, we've got some points up here that are -- look clean, and we've got this area starting to grow here, showing contamination. The impact of this is that you got to this solution let's say with 150 samples. With 150 samples from this one you're going to get something that looks like this. To take enough samples to convince the Bayesian analysis that you're right, you're going to have to take 800 samples. So when people begin to use Bayesian analysis, a lot of care has to be taken in what they are going to use as their priors and their assumptions that they make. Like we're saying we don't want any undefined assumptions. So from our standpoint that's kind of good.

That pretty well covers it. However, I've got some slides you may or may not have. We've got the layering now so we can break it up into solid pieces, individual pieces, and we're starting to work on the third dimension of the kriging. We're getting further and further into the correlation models. That's where you start getting into things like cokriging, covariance, statistics of statistics, if you want to look at it that way. Here's a good example that Pierre Goovaerts pulled out. We do how to study here, or workshop here sometime ago, and this has been a real good example. Here you have rain data. Let's say you go ahead and do indicator kriging on rain fallout, looks like might come down looking something like this. You have another group of data, let's say by elevation. That would be a little mountainous area. And you combine eventually the data from the elevation and the data from the analysis of the rain, and you get a combination of how those two would fit together. And surprise, surprise, your rain is occurring in the higher elevations, but you're not stuck with this big mud ball, or big large area. It begins to define it a little tighter. And this is the effort that we're getting into on this next part of this project, is to be able to do this cokriging analysis, and covariance analysis in three dimension, and using additional data.

Now, I may have some slides you don't have. One of them being informed Elipgrid, getting into the subsurface. And we've mentioned that we've done things like we have lost the ability to scan unless we use something else. So we can't go out with a survey meter again. We're going to go out with a magnetometer. We're going to go out with ground-penetrating radar. We're going to look at the old plans. There's a trench here. Everything.

Another one might be or is geostatistical stimulation. We're bringing some people in from North Carolina on this. And it'll hopefully take -- what it does in short is it takes data that you have, processes it, assumes that's the starting point, and continues on for awhile until you come to some sort of a continued realization. There's not enough information to -- I don't understand it quite enough yet to get into it too far.

Another one that is quite useful is the concept of your ground-penetrating radar, and a few other things. These are the items that we are looking at for big gain, able to set up cokriging, co-analysis, to get a better handle on where the location of contaminants are. We can now -- or are working on getting photos to drape over the analysis area. One of the problems that we've got right now is if you have something with a mountain on it and you start slicing it, it gets extremely difficult to do the kriging and so forth on these sites because you have a little slice up here. But now we're trying to build it in so you can handle the surface geometry, which is going to be really important when you start getting to the underground configurations of the soil and so forth. There are codes out there that can do some of this stuff far better than we, but we've found that we can probably do -- have a much broader variety, and it doesn't cost the licensee anything. Some of the codes out there cost several hundred thousand dollars a year. In fact, SADA's being looked at by some of the oil companies. In fact, it has been used in South America already for a little bit of oil exploration on simple core analysis.

That's -- you've seen the variogram 2D.

We're shooting to go 3D. And we're looking at that one as being really lots of fun because you don't have to go very far to have variability, a lot of variability in a short distance. And especially when you start taking -- well, that's just pretty much it.

This is in case some of you are wondering what Sequoyah looks like. Does anybody remember how many wells there are? All those black dots are a well, or a hole, or a sample point, or something like that that was a core. It's well over a thousand I'm told. And it was sufficient to change the groundwater pattern on the site. And we don't want this to happen, or I don't want it. That didn't seem like a very good approach. There's a lot of historical information and new information now that can be used. At the time, probably not.

And I believe that concludes my presentation. These were the ones that were dumped out. Thanks Ruth. We have a giant help file. We had a big long list of all the detail. Okay. All right. That's it.

MEMBER WEINER: Thank you. Ken?

MEMBER CLARKE: I do have a couple of questions, and maybe you could put that website back up again at some point so we could get it. But I didn't see anything that indicated that this package couldn't be used for both radionuclides and chemicals.

MR. POWERS: Oh, it's used for all of it. If you look at the --

MEMBER CLARKE: You have the EPA databases, IRIS and --

MR. POWERS: Yes. My advice to you is to go to the user's manual on the website. It's unbelievable. It has all the chemicals in the CASS database. It has -- radionuclides are almost a side note in it.

MEMBER CLARKE: Okay. Can you take us to the -- you had two health effects calculation slides. Can you take us to those? I don't know what numbers they are. They were kind of in the middle.

MR. POWERS: Yes.

MEMBER CLARKE: The ones that referenced -- well, let me just ask the question. You would go to the EPA database for the toxicity factors, the slug factors, the reference doses, and then you could select a pathway.

MR. POWERS: Right.

MEMBER CLARKE: And then you would construct and expose your pathway. And then you would construct and expose your scenario. The risk assessment then, can that be done probabilistically as well as deterministically?

MR. POWERS: Yes. It's done in the EPA world. We're taking all of our dose calculations and everything from things like RESRAD. Like one of the features, or one of the things that we need is the thing known as the area factor, you remember? For radionuclides. Well, we can actually take the little spreadsheet that comes out of RESRAD and just pump it into here, and run through it. The EPA has been handling the chemical side of it. I didn't want to, you know, suggest that -- or spend too much time on it.

MEMBER CLARKE: Sure. Just to get to the bottom, I just -- we can construct different exposure scenarios based on different types of land use, and we can do the industrial versus residential versus recreational or whatever. If we were looking at a, you know, a particular future land use given that data. And you could do the risk calculation either deterministically or probabilistically.

MR. POWERS: Again, the human risk assessment part of it has been set aside and is handled in the EPA form, and has been tested and validated for their use. We have not jumped into the risk assessment because there is so much going on in this agency on ICRP, and a lot of it just, you know, we're trying to stay as far away from politics, I'm sorry, as we can, and stay as technical as we can. How they use it, you know, it's something else.

MEMBER CLARKE: Okay. And you'd said there are reports, additional details that are available that would be mentioned on the website?

MR. POWERS: Right. Yes. Let me see if I -- I'll tell you the easiest way to get to the website. Do a Google search on "SADA EPA" and when you see something that says TIEM, which is University of Tennessee, go there, hit their homepage, and you're in.

MEMBER CLARKE: All right.

MR. POWERS: The website is too long. I can't even remember it.

MEMBER CLARKE: Okay, that's good advice. Thank you.

MR. POWERS: Right, yes. And the -- we're getting a lot of information, and the books that we're using, or the information that we're using that's available to everybody. Probably some of you have seen this, but this is a good one to get started on. It's a nice little elementary book on geostatistics.

A lot of the initial code came out of GSLive. So we've tried to keep everything that has a very good pedigree behind it, and a lot of this has gone through a fair amount of modification. And for those that are up to abuse, there's Kressy's book, which is -- probably he and two other people in the world can probably read it and understand the whole thing in detail. But the one that we're focusing pretty much everything on is that by Pierre Goovaerts. He's been here, and he's going to be working on this next phase of it to some extent.

MEMBER CLARKE: Just one more quick question, just to clarify. The cost savings that you referenced where using this approach you could reduce the sampling cost by 40, 60, 80 percent, I assume that was within the same sampling program design as conducted originally. In other words, you didn't reduce the cost by going to a different design.

MR. POWERS: Now, a lot of these were fuse rad sites which had both chemical and there was an initial design as I understand in most cases put together, which was like a 58/49 type, every five meters, something like that. And then they got into the adaptive sampling aspects of it. And Robert Johnson was able to through this process reduce it.

We do have a little bit of a tweeky problem with the process, and it deals with when you're taking the one set of data, and going to put it with the hard set of data, when you go to calculate what the data value points should be at a point where there is a data value, the closer you get to it once in awhile you'll go into a negative correlation which just makes no sense. And so we're futzing around with that a little bit.

MEMBER CLARKE: Okay. Thank you.

MEMBER HINZE: Dr. Powers, you've covered a lot of material here in a very short period of time.

MR. POWERS: About 10 percent of what there is.

MEMBER HINZE: Well, let me ask you a question. It seems to me the SADA is really focused, as I've understood your presentation, on increasing the efficiency of surveying and analysis and to capture and evaluate the uncertainties in the measurements. How, is that approximately correct?

MR. POWERS: That's pretty close, yes. We're trying to optimize sampling where the least amount of information is needed to get the best result. Initial part of it is to visualize the data that you have. I consider that almost in some cases as important as the analysis itself, because a lot of times you can look at something and come up with a solution that you probably wouldn't be able to do mathematically. But the mathematics is there is important.

MEMBER HINZE: That's right. How do you capture the uncertainties in the studies that are being made? For example, you showed us this GPR work. There are multiple interpretations of that.

MR. POWERS: Oh yes.

MR. PALM: Some of them are more credible than others. How do you capture the uncertainty in the interpretation?

MR. POWERS: The linkage between the things that are going to be doing covariance on and cokriging on is our next step. We're fully aware of the -- of how do I know what percent of this data is going to apply to this.

MEMBER HINZE: But there are uncertainties too simply in surface measurements. For example, most of the surface measurements are integrated with GPS for station location, for positional data. And there's uncertainty in those. How is that captured in all of this?

MR. POWERS: As far as location -- no,

that's a good question because we don't. I mean, we're starting out with samples. We're assuming that they've put the samples where they say they are. But I think you -- depending upon the amount of error that you have it's going to have an impact let's say in that particular case on things like shift, or. Hopefully the site that you're working with is going to have data that if you are off a little bit it's going to be irrelevant, or you know, the cliché is close enough for government work.

MEMBER HINZE: Well, you mentioned the use of individual judgment. Do you provide -- does any of this provide guidance on that?

MR. POWERS: That's what we're pulling together during this next part. We're hoping to have available within probably a year or a year and a half a NUREG where we're starting to get some of this stuff together on. In fact, if you're a biologist or a zoologist or somebody like that, you're familiar with binary classification. That's kind of the approach that we're going to take when you walk into a site of where you're going to start making a series of choices. And to determine what the error is that you're going to be required to handle. You're going to have to go in ahead of time knowing how much error can I tolerate, and then you start looking at the systems that you're going to use, and hope that they get in there so you don't get into that situation of bring me another set of data and we'll take a look at it.

MEMBER HINZE: Thank you very much.

MR. POWERS: Yes.

MEMBER WEINER: Are there any burning staff questions? We have a few minutes. I don't want to cut into the next speaker's time too much.

MR. HAMDAN: It can wait.

MEMBER WEINER: Okay. Anyone in the audience? No. Then thank you very much. And I'm sure if people have questions they can come back to you.

The next speaker is here. I understood Michelle Sampson. Oh, there you are. Good to see you. I'll give George a chance to get all his vast data sets together. Our next presentation is by Michelle Sampson from the Federal Railroad Administration on the use of dedicated trains for transportation of high-level radioactive waste and spent nuclear fuel. So welcome, Michelle. It's all yours. Oh, sorry. He walked away with the mic. Do you want to use this?

MS. SAMPSON: I'll just use this. I'm Michelle Sampson, and I do work with the Federal Railroad Administration. We're one of the operating administrations from the Department of Transportation, and I am pleased to be here today to talk with you about our dedicated train study. The title of the study I believe Earl was able to provide a copy of the report to Congress to you. It is Use of Dedicated Trains for Transportation of High-Level Radioactive Waste and Spent Nuclear Fuel.

The first thing that I would like to discuss is a little bit of the history of the report. And I have to apologize to you right now. The expert on the history of this report is Kevin Blackwell with our office. He's been intimately involved with this report since its inception, and could probably answer any question about the many perambulations and changes that the report's gone through off the top of his head. I only joined the Federal Railroad Administration about a year and a half ago, and am not as familiar with the history of this report. As you'll see in a moment it's been ongoing for quite some time. I will do my best to answer questions for you. In the event that I don't have the information with me I certainly will take that information down and make sure that we get back with you to provide an answer.

One of the keys to understanding the report to Congress is to know a little bit about the study methodology, some of the assumptions and decisions that were made at the outset, and how those impacted the study findings. We'll discuss the study findings, and then just briefly I'll talk with you about Federal Railroad Administration's path forward now that we have published the report to Congress.

As I mentioned this has been a process that's been ongoing for quite some time. The study was mandated by HMTUSA 1990. That public law had two specific requirements. It required the Federal Railroad Administration to perform a study that would compare the safety of dedicated trains to other methods of rail transport. That was due to Congress in November of 1991. It also required the Federal Railroad Administration, once the study had been completed, to take those findings into consideration and review FRA's existing regulations for safe rail transportation. We're a little late. Funding for the study was not appropriated until the spring of 1992, and at that time Federal Railroad Administration identified VOLPE National Transportation Systems

Center as a partner to assist us in preparing and conducting this study.

The study really was kicked off with a 2-day workshop in Denver, Colorado in September of 1992. That workshop was attended by representatives of potentially affected stakeholders, states, Native American tribes, the railroad industry, shippers, potential shippers of spent nuclear fuel and high-level radioactive waste. It was also attended by representatives from the Department of Energy and the Nuclear Regulatory Commission.

Utilizing the products of that public meeting, a first draft report was generated in February of 1993. That draft went into a review process within the Department of Transportation. Comments were provided to VOLPE. The VOLPE centers provided a series of revisions and updates to that report. The report has also been coordinated with the Department of Energy and the Nuclear Regulatory Commission. There have been several meetings between the departments to discuss the report, and get input from the experts within Department of Energy and Nuclear Regulatory Commission to assist us at FRA with our report.

In 2001 and 2002, a significant effort was made to update and revise the early 1990s report, and as we began to look at some of the assumptions and some of the findings of the report you will see that it does incorporate data through 2001. So it was significantly updated and revised in the interim. And at FRA we did publish a final report. The report is dated March, 2005. It was actually transmitted to Congress in September of 2005.

I mentioned understanding a little bit about the study methodology. The report to Congress that you may have had an opportunity to look at talks in some general terms about the study methodology, but there are a lot of basis and assumptions that affected that that are not fully discussed in that report to Congress. The study was required to do comparative analysis. We did comparative analysis on three specific types of train service, regular trains, which would be your general freight consist, key trains. That's an industry term for a train that is identified as hauling specific quantities of certain hazardous materials. The key train concept actually is a large part of the 2001 revision. As we begin discussing the key train you'll see it's based on a 2001 Association of American Railroads industry standard. And then of course dedicated trains. There's also a standardized cask prototype, and the details of that cask impact the outcomes of the study finding. And a decision was made that representative routes would be selected and used for comparison.

I mentioned the first type of service that we reviewed was regular train service. Those are general freight trains. They operate at allowable freight track speeds, make numerous classification yard entries for making up the train, and certainly would haul other hazardous material freight along with the cask consist. Those trains are subject to the hazardous material regulations and of course FRA's rail safety regulations, but there were no other limitations or operational controls put on those trains. The study modeled regular train service as a generic 70-car train, and the cask consist was modeled as being directly in the middle of this train. One thing that I would like to note is that's the way it was modeled. In actual regular train service, the weight of the cask car and cask consist, train track dynamics would make that a poor placement for the best operation of the train. The optimal place would be near the front of the train to improve the train track dynamics and fuel efficiency of the locomotives. But it was modeled as being directly in the middle.

Key trains. We incorporated key trains based on a 2001 Association of American Railroads recommended practice circular. I've listed that here. That circular's been updated by the industry since 2001, and has had some minor changes, but the key train that was modeled was based on the 2001 circular. For our study we determined that the only operating restrictions of the AAR circular that would impact our train was the speed restriction. In the operating circulars, trains hauling these specific hazardous materials are restricted to a maximum of 50 miles per hour, regardless of the authorized speed on the track. Other than the speed restriction, the key train was modeled as having the same length and configuration, and going through the exact same operating environment, the same number of yard entries, same passing restrictions. A key train would certainly be expected to have additional hazardous material freight as part of the consist.

And dedicated trains. In the study, dedicated train was modeled as a 6-car consist, two locomotives, two buffer cars, the cask car, and an escort car. In the discussion, all of the results and findings of the study are based on one cask car transportation. The operational limitations for the dedicated trains. Speed was restricted to 50 miles per hour. The dedicated train was assumed to be under a no passing rule which means that on mainline track, either the dedicated train or the other train would be moving only one at a time. The dedicated train would have priority to pass, and we would expect other freight consist trains to be standing still. That impacts the probability that the trains will hit each other in passing, and so the no passing rule is a key operational limitation. Also, because the key train does not have other freight cars, it would limit visits to classification yards. The number of yards that the key train would pass through would be reduced somewhat. The primary reduction is in the amount of time that those cars would spend in the classification yard because they would not need to be switched. They could pass through directly.

The cask description. As the study was envisioned, the number of casks and the availability of information on spent fuel casks that might be available, spent fuel and high-level waste casks that might be available, was more limited than it is now. At the time that the study was developed, the cask that was selected to be used for the study was 125 ton steel, lead steel, prototype cask. One thing that the report to Congress does not really make perfectly clear, both the technical study that supported that report to Congress, the NRC's cask certification criteria was established as an upper bound of the functional strength of the cask. That has certainly been a controversial decision as the report has gone through its reviews, but it is important to understand that that's a decision that was made up front in the way that the study was developed. In addition to those certification criteria, VOLPE and the FRA utilized Sandia's report, the NUREG 6672 which was a study of this cask prototype without impact delimiters, and that was used as input for the rail crash analysis. So those are important factors for how the report itself was developed.

I mentioned that the study is designed to be a comparative analysis. In order to do some type of comparison, the FRA and VOLPE needed to have some shipments to evaluate. A decision was made. Six routes were chosen. The origin points were selected from existing nuclear power plants and high-level waste repositories. The destination point selected for the study was the Yucca Mountain facility in Nevada. The goals of selecting the representative routes were to utilize the major east-west rail links, and to select representative geographic locations and links for the transport itself. Those specific links, exactly how rail traffic would travel from origin to destination were determined using Oak Ridge National Lab's inter-line routing model. And those were just based on a most likely traveled route. There were no additional routing decisions incorporated into that.

This is a little small but not too bad. These are the six routes that were selected. Obviously the origin points are identified there. You can see the length in miles from that origin point to the selected destination facility. The population data for those routes is based on the 2000 census. That was updated in 2001. Just to note, the Routes 1 and 6 are the shorter routes, and Route 5 is the longest route. As we began to look at some of the findings they're listed by route number, not by origin.

Utilizing those inputs. That's the basis for the study. The study itself performs a comparison of the radiation dose risk for each of the six routes under incident-free transportation and under identified accident conditions. In addition to that risk comparison study, the FRA began a preliminary consideration of operational safety. And the report to Congress also incorporates those operational safety considerations that were identified by the FRA.

Our incident-free transportation comparison was calculated using Radtran with the assistance of Sandia National Lab. It took the six representative routes and other inputs that were decided and selected. The cask dose rate was assumed to be 10 mrem/hour at one meter. That does correspond to DOT's non-exclusive use limit. It does not correspond to any data on shipments that have taken place. It was simply selected as the cask dose rate that would be used for the study. The consist description, again I mentioned, 70 cars for a regular key train, and a 6-car consist for the dedicated train. That was input into Radtran along with the service type and speed limitations, the impacted populations from the 2000 census, and shielding factors for the type of area that the train would be traveling through, urban, suburban, or rural.

The results of the Radtran analysis were expressed as population dose and person rem. And those were converted into latent cancer fatalities utilizing the conversions of the NCRP report. We looked at those results and evaluated them by route. They're also evaluated by service and speed for comparison of dedicated train to regular train service to key train service. Also, by population type. Populations were broken down into various rail workers, members of the public. And we looked at the population doses for in-transit dose versus dose during stops.

And looking at the accident-related risk, again the goal is to compare radiological exposure due to the accidents in regular service, key train service and dedicated train service. The accident involvement probability, accident severity probability and expected consequences were identified. For regular train service, the study started with regular train service, and three event trees were constructed. The first was for movement on mainline track, the second was for consist movements within the yard and a separate third event tree was developed for fire events. Fire events of course could be an initiating event, or they could be the outcome at any node in the other trees, so they were handled separately. The Federal Railroad's existing Railroad Accident Information System was used to define and categorize those accident types. And the baseline accident probability was calculated for regular train transport utilizing data from 1988 through 2001. The total number of accidents per year was normalized by dividing it by the reported train miles per year for each year.

The accident types that are contained within the FRA's accident database are derailment accidents, collision accidents, and there's a variety of different collision accidents that are tracked, crossing accidents, miscellaneous other accidents, and then the fire and explosion accidents. The accident severity for the mainline and the yard trees. The impact velocity for the accidents was identified to determine probability and severity, and for the fire event tree the severity as based on fire intensity and duration. The accident consequences were described in terms of the cask damage and the resulting radiation exposure.

For key trains, the baseline normal transportation or incident-free transportation event trees were modified to reflect the speed restriction to 50 miles per hour and the improved braking that would come as a result of that speed restriction. The probability for accident -- or the accident type probabilities were decreased only for the collision and obstruction accidents where speed was a factor in the accident, and for the highway, rail or rail-rail crossing accidents where speed was a factor. Those were very minor decreases in the accident probability.

For dedicated trains, those event trees were modified to reflect the operational restrictions of the dedicated train. And as I mentioned earlier, there were significantly more operational restrictions for dedicated trains. The number of yard entries is decreased as is the amount of time spent in each yard, the consist length is far shorter, only six cars for the dedicated train, passing restrictions, the speed limit of 50 miles per hour, and the fact that no other hazardous material cars can be a part of the train consist. Those operational restrictions resulted in significant reductions in the accident type probability for all types of the accidents except for those accidents who are affected by train frequency. Clearly by utilizing dedicated train with only one cask per train consist, you are increasing train frequency. However, the number of increased trains as compared to the total train miles in the United States was so small there actually was no increase in that accident type probability. It had no change.

MEMBER HINZE: Excuse me, if I might. In terms of the operational restrictions, was the consideration ever given to excluding major urban areas?

MS. SAMPSON: Not in this study. We did not look at that, no.

MEMBER HINZE: Why is that?

MS. SAMPSON: Unfortunately that is one of the questions about how the study was set up originally, and I was not involved in those decisions that were made. You may know more about it.

MEMBER WEINER: I can comment on that when we get through.

MEMBER HINZE: Okay. Thank you.

MS. SAMPSON: But no, it was not. The linkage, the route that the train was transported across from those origin to destination points was simply identified as a most likely traveled. It did not take any other factors into consideration.

The accident rates. After the event trees were developed, it was identified that the overall mainline transport accident rate for all of the accident categories and the yard accident rates were virtually indistinguishable for regular and key service. Again, the only operational restriction for key service was a reduction in speed to 50 miles per hour, and that did not make a significant impact on those accident rates. So as we look at the findings, you'll see that for mainline and yard accident rates, regular and key service were combined.

The overall mainline accident rate for dedicated train service was only reduced by about 3.8 percent less. However, the overall yard accident rate for dedicated train service was reduced by 75 percent less, and intuitively you would expect to see that type of a reduction because of the significant reduction in the amount of time spent in classification yards by the use of a run-through train instead of a train that had to be stopped, cars separated, train broken up and then put back together again.

I mentioned that cask damage and dose rate were utilized to identify the consequences. The FRA and VOLPE identified four accident severity categories. Category 1 was identified, an accident that resulted only in delay. That delay event would not result in any dose increase from the baseline dose of the cask, which as I mentioned earlier was assumed to be 10 mrem/hour at one meter. Accident Type 2's were those accidents that could result in a dose increase to 1,000 mrem/hour at one meter but no release of radioactive material. The third accident category were accidents that would result in loss of shielding or internal damage, and the dose rate was anticipated -- or dose rate was assumed to increase to 4.3 rem/hour at one meter. The fourth category of accident would have been an accident resulting in release of the radioactive contents. That category of accident was analyzed to be equally unlikely for all of the shipping -- or was identified to be equally unlikely for all of the shipping options and was not further analyzed.

Dose accident consequences were calculated again using Radtran 5. Doses to the general population, rail workers and emergency response personnel were identified. The findings we'll look at in a moment. A Category 1 accident was determined to result in a 10 hour delay. The Category 2 and Category 3 accidents were looked at over a range of delays lasting between three and 72 hours. The accident comparison is between regular and key service combined with dedicated train service, because again the accident probabilities for -- or accident probabilities for regular and key service were indistinguishable once we finished the event trees.

After the determination of the person, rem and latent cancer fatality findings was completed, the FRA determined that there were operational safety considerations that should be taken into consideration in looking at these different types of service that weren't fully addressed by just looking at the radiation risk of transportation.

CHAIRMAN RYAN: Can I just pick up a little follow-up question.

MS. SAMPSON: Sure.

CHAIRMAN RYAN: I'm troubled by the use of fatal cancer risks. The reason is is it's absolutely incorrect to apply a fatal cancer risk expectation value to an individual dose or to a dose to a small group. The idea of person rem here is meaningless. It's very conservative and just flat out wrong to use a cancer risk indicator for these small groups. So can you maybe give me some insight as to why you did that, or why didn't you just stick with dose? It's so much simpler and more accurate.

MS. SAMPSON: Unfortunately again I cannot, and I apologize.

CHAIRMAN RYAN: Okay.

MS. SAMPSON: You would have benefited by having someone who was more --

CHAIRMAN RYAN: And I don't mean to put you on the spot. I appreciate that, but I just wanted to, for everybody's benefit, point out that these risks of fatal cancers are just flat out wrong. I mean, it's a misuse of an expectation value of a distribution. Thank you.

MS. SAMPSON: Yes. The study looks at a relatively small dose over a very large population, and then does use that to.

CHAIRMAN RYAN: We're on record on several occasions as a committee of pointing out that's just wrong.

MS. SAMPSON: However, there are several assumptions and decisions that were made at the onset of the study that resulted in the findings being what they are, and it is important to understand what those assumptions were because they do affect how the findings of the study came out.

MR. THADANI: Mike, also impact limiters were not considered.

MS. SAMPSON: They were not.

MR. THADANI: So that's significant.

CHAIRMAN RYAN: Sure. And I appreciate that additional point, but it's -- I think it's very important to recognize that, you know, a dose calculation doesn't automatically translate into a cancer risk calculation. It has to be done with great care, and even with -- well, I mean let's leave it at that. Thanks.

MS. SAMPSON: Taking into consideration comments that we had received on this study, and also FRA's review of the study, at FRA we felt that there were operational safety considerations that should be identified in looking at the differences between regular, key and dedicated train service, and that looking strictly at the radiation risk did not fully identify those operational safety improvements that could be realized. Obviously reduced time in transit and switching operations does reduce your radiation risk. However, avoidance of switching and the classification yard is a significant operational safety consideration. In looking at the accident data, a significant portion of accidents do happen in switching operations, and being able to completely avoid switching operations is a significant improvement to the operational safety for the train itself.

You have a reduced derailment and collision potential if you utilize some of the newer technology that's available. The electronically controlled pneumatic brakes that are available could be used on a dedicated fleet of rail cars, and the uniform consist significantly improved the train track dynamics, and braking capabilities of that train, which of course make it far more safe operationally.

Other potential operational enhancements. If you're using dedicated equipment operated in smaller consist you have less wear and tear on the equipment. There would be fewer mechanical malfunctions anticipated for the equipment utilized in dedicated train service. You have a reduced risk from interaction of other hazardous materials in the event of a derailment or collision. The risk analysis -- or the radiation risk analysis took that into consideration in reducing the time that it took to respond to a dedicated train accident versus regular key service. However, the operational consideration there is the increased or improved ease of response to the emergency responders when they're only dealing with one hazard, the reduced amount of time that it takes to clean up a derailment if you have six cars in the consist versus 70 cars or more.

And in addition to the ECP brake technology that I discussed just a moment ago, there are additional potential engineering enhancements that could be utilized. ECP brakes require a communications backbone that links the cars, and various types of onboard defect detectors are being tested, and some are in utilization, and with a dedicated fleet and a small consist those could be utilized quite effectively to improve the operation of the train.

If you have had a chance to look at the report to Congress you will see that the findings in the report to Congress were that the VOLPE study indicated that risk to the employees and the public from transportation of spent nuclear fuel high-level radioactive waste is low, but on a comparative basis dedicated trains appear to offer advantages over general consist. And if you have not had an opportunity to look at the report to Congress it is available online from FRA's website, which I have listed here. Our website is not the easiest to navigate, but the report's available under our safety publications links.

The report concludes that on a comparative basis that dedicated trains are safer. One thing I would like to provide is some of the numbers that back up that comparative basis. And one of the things that's important to recognize when you look at these numbers is dedicated train service is comparatively safer based on this, but the numbers are very, very close, and the numbers are very, very small. I mentioned the routes. Routes 1 and 6 were your shortest routes under normal conditions of transportation those have the lowest total person rem, which of course results in the lowest latent cancer fatalities. That's merely a function of the reduced time in transit. Less time exposed to the shipment results in lower dose rates. Route 5 I think was the longest.

CHAIRMAN RYAN: Just another follow-up question. I have to point out, I can't accept four significant digits. I see 0.1 or 2 as your total person rem, and I see something like, oh I don't know, pick a rounded off number, 4 times 10^{-5}, and I would challenge anybody to prove to me that any of these are different, or any doses are different.

MS. SAMPSON: Yes.

CHAIRMAN RYAN: So I see one number.

MS. SAMPSON: And we'll get to that in a moment.

CHAIRMAN RYAN: Okay.

MS. SAMPSON: No, I do think it's important to realize they are very, very small numbers.

CHAIRMAN RYAN: Well, and it probably misrepresents your level of certainty to use four significant digits. It's just not right.

MS. SAMPSON: The accident findings are very similar. As I mentioned, the regular and key train services were combined in looking at the accident findings. Where you see the R/K that's regular and key service, and D of course is the dedicated train service. For the accident events for Category 1 accidents the duration of the delay event was assumed to be 10 hours. There is some comparative reduction in the numbers for dedicated train service, but again, the numbers are very, very close. For accident categories or event Categories 2 and 3, there is more of a difference, but the overall numbers are still very small.

The issue you just alluded to is really when you look at these study findings, what the study identified is that non-incident risk from the entire shipping campaign. And we based our definition of the shipping campaign on the number of rail shipments identified in the Department of Energy's EIS. It's appreciably less than one latent cancer fatality, regardless of the type of service. That's the baseline finding of the study.

And that is -- oh, our path forward. Thought I was done. That is the finding of the study.

FRA of course had a part two from the 1990 HMTUSA, and that was to determine if rulemaking is warranted. FRA is in the process of developing cost-benefit data associated with the dedicated train study. We're also reviewing the industry operating and maintenance standards that have been published post-study. Quite a bit of work has been done by the industry. AAR has updated the key train circular, which was mentioned as the basis for the 2001 incorporation of key trains, and also have developed a standard S2043 for equipment use for high-level waste or spent nuclear fuel shipments. FRA is reviewing those. And we also are actively interested in and reviewing Department of Energy and industry shipment planning documents. A determination of whether rulemaking is warranted or not should be made within the next 18 months by the FRA. We're also in the process of reviewing and updating our internal safety compliance oversight plan for shipments of high-level waste and spent nuclear fuel to ensure that FRA's internal inspection resources are focused where they can be most effective. And now I'm done. So any question?

MEMBER WEINER: Thank you very much. We'll go around the table. Dr. Hinze?

MEMBER HINZE: I'll pass.

VICE CHAIRMAN CROFF: Yes, I had one question. In reading the report that you're summarizing, if I understood it correctly near the end it basically said that most spent fuel or high-level -- I guess spent fuel mostly right now shipments are occurring by dedicated train right now anyway. Is that -- do I remember that correctly?

MS. SAMPSON: That is the information that FRA has been provided on shipments of spent fuel that have been made is that the majority of them do take place by dedicated train at this time, yes.

VICE CHAIRMAN CROFF: Okay. All right, thank you.

MEMBER WEINER: Further comments? Jim?

MEMBER CLARKE: Just one. Could you back up a couple slides? You had a couple of tables I think. Very, very close to the end.

MS. SAMPSON: Just a moment. Be glad to. Were you interested in the accident table or the non-incident?

MEMBER CLARKE: The final comparisons.

MS. SAMPSON: Okay. This is the comparison of total dose.

MEMBER CLARKE: Yes, that'll work. Actually the next one's probably better.

MS. SAMPSON: Okay. Yes.

MEMBER CLARKE: Okay. As Dr. Ryan said, we have problems with collective dose, and you know that so I won't go into that anymore. But if you look at the methodology that you used in the results, actually I want the slide, the one you had. It was one up. Previous.

MS. SAMPSON: Oh, okay. Certainly.

MEMBER CLARKE: Again, apart from the -- as a chemist in a former life I don't like to see that many significant figures either, but it's not a unique problem. Those numbers look all pretty much the same. I mean, the regular and key were -- even though the key train had operational limitations compared to the regular it looks like the results were indistinguishable.

MS. SAMPSON: The operational limitation of 50 mile an hour speed restriction was indistinguishable by the time you transported it over several thousand miles.

MEMBER CLARKE: And even if you factor in reasonable uncertainties there doesn't appear to be much difference between the regular and key.

MS. SAMPSON: I think that's a valid conclusion.

MEMBER CLARKE: Is that a valid conclusion?

MS. SAMPSON: The study was of course conducted by VOLPE with FRA, and a decision was made early on that this was the method that would be used for comparison. At the conclusion of the study, as you can see, the comparison is that you have less than one. What FRA does believe is that there are operational considerations which do impact the safety of transportation. Clearly the technological enhancements that are available with the smaller consist. And it would not have to be a one cask car consist. You could have a number of cask cars in a dedicated train and still benefit by use of dedicated fleet of cars, and the communications backbone that would be available with the ECP braking, and additional onboard sensors for bearing defect and failures that really do enhance the safety of this. Clearly, limiting the number of cars in a derailment, and limiting the interaction of other hazardous materials during a derailment are significant operational enhancements, independent of the comparative radiation risk analysis that was done.

MEMBER CLARKE: That's really not risk, but you know, the comparison that you did. Okay, thank you.

MEMBER HINZE: While you have this up there if I may, my recollection is that Number 6 was Hanford as a source, and Number 1 was Humboldt, if I recall correctly.

MS. SAMPSON: Yes.

MEMBER HINZE: And there was quite a difference between the population density per line mile in 1 and 6, but the distances were relatively the same if I recall. And yet these numbers come up quite close. Does this mean that the population density along the line mile is really not a very significant factor?

MS. SAMPSON: I think I would defer maybe to Dr. Weiner, her familiarity with the Radtran program. And that's really a function of the Radtran program. She probably can speak to that better than I can. If that's?

MEMBER WEINER: That's fine. As long as you've point out, I'll make two points. The routing code that was used for this was INTERLINE, and it is really -- it's really more a function of the routing code than of Radtran itself. The INTERLINE uses existing railroad tracks and population densities within a half mile of the route. The existing railroad, the use of existing railroad tracks answers the question you asked awhile ago, which is tracks go from city center to city center. So if you try to avoid urban areas, you have a very, very long route. The second thing is that the longer the route, what almost any routing code will tell you is the longer the route, the more the results that you get look alike. And because you're integrating, you're spreading the population over a very long route, and on the average these become very close to the national average, rural, suburban and urban populations. And by the way, when you divide into rural and urban populations, the population divisions are also a function of the routing code itself. These were developed by Oak Ridge as part of the routing code, so that's why these things look alike.

I have to add my objection to four significant figures, and I already have transmitted this to the FRA people.

CHAIRMAN RYAN: Could you back up to the accident slide.

MS. SAMPSON: The one showing the numbers?

CHAIRMAN RYAN: Yes. Next slide I guess it is. In your accident cases, did you do a deterministic, you know, here's what happens, here's the dose, or did you do a sampling, or a probabilistic analysis, or how did you arrive at 70.90 person rem?

MS. SAMPSON: The FRA's rail accident database was utilized. And utilizing FRA's historical rail accident database from 1988 through 2001, actual accident numbers were utilized to determine probabilities. Those numbers were normalized --

CHAIRMAN RYAN: That's the accident happening part. I'm talking about the consequence. How is that assessed?

MS. SAMPSON: The consequences are based on the cask performance dependent upon the information that we gain. What type of accident we identify that it would be, and then the cask response to that accident type. And Earl would like to speak up about that.

CHAIRMAN RYAN: It's deterministic is my question.

MR. EASTON: I think these accident doses are really based on emergency --

CHAIRMAN RYAN: And tell us who you are please.

MR. EASTON: Back again. Earl Easton with the staff. I think these accident doses were really based on the emergency response, and how long it would take, and how complicated --

CHAIRMAN RYAN: I'm asking a real simple question, Earl. I don't want to go through the scenario. Is it deterministic or probabilistic?

MR. EASTON: I think it's deterministic.

CHAIRMAN RYAN: Okay, that's what I wanted to know. Because I think that's something where there's an opportunity to gain insight. If you're just assuming one set of accident parameters, that is the cask gets whacked, there's a fractional release, the fractional release exposes X people in a certain way, and we come up with 70.9 rem when we add that all up, that's one realization. What are the other realizations that you could come up with to gain insight?

MR. EASTON: This is based on loss-of-shielding accident as opposed to a release, I believe.

CHAIRMAN RYAN: Whichever. My point is it's a deterministic one-off set of assumptions, correct? That's what I need to know. Again, I think that's an area where if you wanted to look at an improvement, it would be to try and identify some critical group and then do a number of realizations, and a number of scenarios to see what impacts might be. It's a way to think about it in a little bit more of a probabilistic sense.

MS. SAMPSON: And again, the cask prototype here was a steel-lead-steel cask, which is important in the loss-of-shielding issue.

CHAIRMAN RYAN: Sure. Absolutely. Thank you.

MEMBER WEINER: Just to respond to that last, the raw analytical results from the analyses were not available in the final report, and they were not -- I haven't looked at them. However, if indeed Radtran was used to calculate the accident dose risks, this was done probabilistically and not deterministically.

CHAIRMAN RYAN: Well, this is deterministic --

MEMBER WEINER: Well, yes but he didn't --

CHAIRMAN RYAN: -- you don't know, but maybe --

MEMBER WEINER: That's correct.

MS. SAMPSON: The input into Radtran -- and let me back up. Maybe I can help with this a little bit. The accidents were based -- the historical FRA accident data was analyzed, and then was grouped into predefined accident categories to determine the probability that you would have an accident in one of those categories. And then those dose rates of the accident categories were the inputs that were put into Radtran, along with the anticipated delay time, to come up with the dose rate. So.

CHAIRMAN RYAN: It's this information that led me to conclude it's deterministic.

MS. SAMPSON: So the delay event was assumed to be an additional 10 hours on top of the regular transport time with the cask remaining at 10 mrem/hour for that entire duration. Radtran was used to evaluate all six of the transportation routes. The same was true for accident Category 2 and accident Category 3, and the delay time for regular and key train service was determined to be slightly longer than the delay time for dedicated train service, which is really what results in your increased dose rate for those evaluations.

MEMBER WEINER: Yes, which indicates that in fact Earl is correct because the probabilistic aspect of Radtran accident analysis was not used. These were --

MS. SAMPSON: This is the way --

MEMBER WEINER: That was --

MS. SAMPSON: I'm sorry if I was a little slow getting all that put together, but.

CHAIRMAN RYAN: No, I appreciate the fact that you're following up on where it preceded in your text, and we appreciate that.

MEMBER WEINER: I have a couple of questions. One is why was there any reason for using 6672 rather than the modal study, for example.

MS. SAMPSON: I don't believe the modal study was completed when they started doing this. I may be wrong about that.

MEMBER WEINER: Well --

MS. SAMPSON: It was completed during the time --

MEMBER WEINER: It may be a question you can't answer. How did your results compare with the Yucca Mountain EIS? Did you do any -- did FRA do any comparison?

MS. SAMPSON: We have not done any comparison to date, no.

MEMBER WEINER: Finally, is there an accident that in this suite of accidents, is there something that would correspond to the Baltimore Tunnel Fire?

MS. SAMPSON: Jump in. Feel free. Please.

MEMBER WEINER: Yes, Earl?

MR. EASTON: And the reason I'm jumping in is the original law said the FRA DOT in consultation with the NRC should do this study. So we did review the underlying technical stuff. What the VOLPE center conclusions were, that accidents involving fully engulfing fires at greater than the NRC cask certification's duration and intensity would be reduced by 89 percent. But the numbers again are very small. They'd be reduced from 1 in $4.2x10^{-15}$ to $4.6x10^{-16}$. It's an 89 percent reduction, but when you work out in terms of years, that's once in every 250 million years versus once in every billion years for this campaign. So the numbers are very, very small reduction in that type of event.

CHAIRMAN RYAN: And that's one side of the story. The probability of an event is one thing to consider. But the consequences is the second part, and I think it's risky to rely on saying, well the probabilities are very low, to then just hang your hat on a strictly single deterministic assessment of impact.

MR. EASTON: We do do a consequence analysis in 6672 for long duration fires where you get fuel breach cladding and all, and it shows that the release tends to be very low also. So if you linked the two together.

CHAIRMAN RYAN: And that's what I'm asking.

MEMBER WEINER: Any staff?

MR. SCOTT: Ruth, I've got one.

MEMBER WEINER: Mike.

MR. SCOTT: Mike Scott, ACNW staff. In one of my previous lives I had the good fortune of working for a nuclear utility that probably has shipped more spent fuel than any other, and we typically would ship it about 100 miles between one place and another, and if I recall correctly and my memory doesn't fail me we would ship two cars at a time. Your assumption was one car, correct?

MS. SAMPSON: The -- all of the assumptions for the study are based on a single cask car in the consist, yes.

MR. SCOTT: I'm wondering, especially on a cross-country route, it would seem that economics would strongly dictate several more than one at a time. Did that enter into the considerations at all, and what do you think the effects would be on your conclusions?

MS. SAMPSON: I believe, and I apologize. In -- let me -- I will answer your question, but let me -- there is a technical study that supports the report to Congress. The technical study was completed by the VOLPE center and has been submitted to the FRA. However, I do have to apologize. We hoped that it would be available by now. The technical study is still in review process with the FRA. It's not a contents review. Because the study has been worked on for so many years and has been transmitted electronically between Cambridge and Washington, and between various agencies here in Washington, there are several significant editorial problems with the technical study right now. Figure numbers don't match up correctly anymore with the actual figures that they're supposed to correspond to, data has been dropped out of tables, headings are missing. FRA is trying to utilize their resources that have worked with the study over the number of years to do that review of the document and try to get it into a format where it won't have a lot of technical problems with the technical study. And we do hope to have the study available in February of this year, and as soon as it is available we will place it on our website. It does provide a great deal more of the background information. It provides examples of the event trees, and in the actual analysis of each of the six routes that were reviewed. So it does provide better information.

One of the things that was looked at in the technical study, and I don't have it tapped, but there was some consideration given to a two-cask consist, and how that might impact some of the results. It's a much less detailed review, because it was kind of tacked on as we came to the end of the study. The utilization of two casks has some impact, but it's a very minor impact on the results. It really didn't significantly change the findings in any way. There is a little bit of an address of that, and I think your point is very significant. It does not make economic sense to take cask cars across the country one car at a time. It's not an efficient use of resources. Doesn't seem to be, from my opinion.

MR. THADANI: I don't really have a question, but a couple of comments probably. The first one, I think that if you do more realistic analysis, at least technically you might conclude that there's essentially no difference in the outcomes. And so one would be then forced to make what I would think would be a policy decision based on perhaps some engineering considerations that you talked about. And then that would make sense.

The second comment that concerns me is when we talk about probabilities that are so low, 10^{-10}, 10^{-15}, whatever it is, then I think one needs to think about the uncertainties. That's what's going to drive whatever decision you're going to make. Because quite honestly those numerical values are not very useful. I'm reminded that perhaps likelihood of a meteorite striking certain parts of the United States is probably higher than some of these estimates. So I just urge caution in the use of these probabilistic estimates. All it tells me is then I have to look for what else can get me in trouble, rather than this particular model I'm looking at. That's it, thank you.

MEMBER WEINER: Are there any questions or comments from members of the audience? Come up, then and identify yourself.

MR. MALSCH: Yes, I'm Marty Malsch. I'm a lawyer with the State of Nevada. I just had two questions. One is what did you assume by way of the rail corridor between the existing lines and Yucca Mountain?

MS. SAMPSON: I do not know what the INTERLINE utilized to get to Yucca Mountain since there is not a rail line to there. I don't know the answer to that.

MR. MALSCH: Okay. And then my second question was in doing the comparison you eliminated Category 4 accidents purely on the basis of probability rather than risk. Yet in other categories you're comparing risk across the transportation modes. Why is that?

MS. SAMPSON: Again, I apologize. That's a decision that was made at the outset of the study. There was analysis done of rail accidents that had happened utilizing FRA's rail database, and the accident that would result in forces that were equivalent to those identified in the 6672 were not identified in the existing rail database. So it was eliminated. But it was a decision made at the outset of the study.

MR. MALSCH: Okay, thank you.

MEMBER WEINER: Bob, would you?

MR. HALSTEAD: Oh there it is. It's a clamp. Okay, got it. Thank you. Bob Halstead, State of Nevada. I just want to make a comment that we do endorse the conclusion of the report favorable to dedicated trains. I would add to Marty's comment, we were involved in that 1992 workshop. Most of the stakeholders wanted to see the Category 4 rolled in.

I don't want to repeat, although I agree with much of the discussion about the probabilistic analysis, but there's a point here where quantitative analysis doesn't always give you a good handle on whether as a matter of policy giving added assurance that you eliminate the potential for accidents like the Baltimore Tunnel Fire involving spent fuel, there just isn't any really good way to quantify that even though Earl as always has a number to throw on the table for it. I think there are some security advantages that are also very hard to put any kind of a cost-benefit number on.

The State of Nevada has a petition for rulemaking, PRM73-10 that has been before the NRC for now going on seven years arguing that use of dedicated trains would be a good idea for security reasons. Congress ordered the GAO to do an assessment of that in 2003. They concluded that that was a good idea. I realize back when you were directed to do this study that wasn't one of the concerns, but since then security issues are involved.

And while Nevada has consistently advocated use of dedicated trains, I do want to say we're sensitive to this issue of the train crew dose, and while again I agree with the discussion here that it's probably pretty low and not a good discriminator between different classes of service, nonetheless it probably would be a good idea, given the concerns on the part of the railroad unions that with the exclusive use dose rate assumed, which would be a higher routine dose rate, it probably would be a good idea to recalculate the train crew doses not to come up with an LCF calculation, but to come up with some number on -- given the expected crew rotations, what are the maximum annual doses to a particular crew, or a particular worker. And I think that goes in line with Dr. Ryan's concern that those collective dose numbers not be misused. Thank you.

MS. SAMPSON: I do want to say, the FRA is very aware of concerns raised by the rail unions, the Brotherhood of Locomotive Engineers and Trainmen, and also the United Transportation Union. And we have met with them on several occasions. FRA is currently undertaking a process to try to identify some baseline dose rate information for our rail inspector employees, and we hope to be able to utilize some of that information to assist the railroads in developing their own radiation dosimetry programs if they determine that that would be beneficial to them. It is a concern of the rail workers, and something that does need to be addressed with them for all modes of, you know, for all routine patrols transportation.

MEMBER WEINER: Any further questions? Hearing none I'll turn it back to the chairman.

CHAIRMAN RYAN: Thank you, Ruth, and thank you very much again for your presentation and our other fine presentation this morning. Let's see. We are adjourned for lunch until 1 o'clock, and I think after lunch we have just a brief preparation for the Commission briefing. The Commission briefing and then letter-writing. So I believe this will close our formal record for the day. So we'll close the record here, but we will come back to prepare for our Commission briefing at 1 o'clock. Our Commission briefing is scheduled from 2:00 to 4:00 p.m. We'll be in again White Flint 1, the large public meeting room over in the other building. And then we'll reconvene here after the conclusion of the briefing to follow up on this discussion of letters, on what we're going to write. And then I think we're scheduled for first thing Thursday morning to take up the details of the Part 63 letter, and anything else that we decide late in the afternoon. And Ruth's transportation, we'll take that up this afternoon, or afterward. Thursday morning?

MEMBER WEINER: Thursday morning because I want to get it printed.

CHAIRMAN RYAN: All right, Thursday morning it is. All right, very good. Thank you all and see you at 1 o'clock.

(Whereupon, the foregoing matter went off the record at 11:39 a.m.)

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Nuclear Waste 167th Meeting

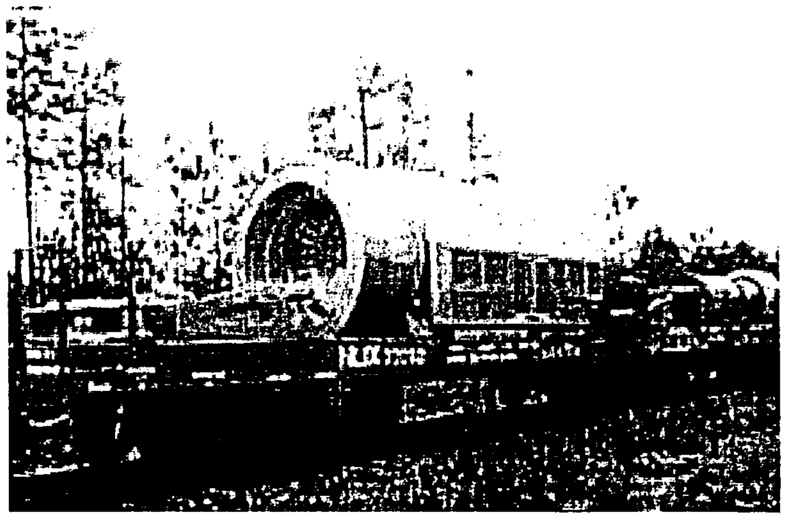
Docket Number: n/a

Location: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Eric Hendrixson
Official Reporter
Neal R. Gross & Co., Inc.

Use of Dedicated Trains for Transportation of High-Level Radioactive Waste and Spent Nuclear Fuel



Michele Sampson

January 11, 2006

Federal Railroad Administration

Introduction

- History
- Study Methodology
- Findings
- Path Forward

History

- Study mandated by Section 15 of the Hazardous Materials Transportation Uniform Safety Act of 1990
  - Railroad Transportation Study -- comparing the safety of "dedicated trains" to other methods of rail transportation [November 1991]
  - Safe Rail Transport of Certain Radioactive Materials -- taking the findings into consideration when reviewing existing regulations for safe rail transportation [~ December 1992]

History

- Funding appropriated Spring 1992
- FRA requested VOLPE National Transportation Systems Center to conduct the study

History

- VOLPE and FRA held a 2-day workshop in Denver, Colorado September 28 & 29, 1992
  - Representatives of potentially affected States and Native American tribes
  - Railroad industry
  - Potential SNF/HLRW shippers
  - DOE and NRC

History

- 1st Draft dated February 1993
- Review within DOT
- VOLPE revision and updates
- Coordination with DOE and NRC
- Final Report to Congress March '05
- Transmittal to Congress September '05

Study Methodology

Comparative Analysis Inputs

- 3 Types of train service
  - Regular trains
  - Key trains
  - Dedicated trains
- Standardized cask prototype
- Representative routes

Study Methodology

- Regular Train Service
  - Operate at allowable freight track speed
  - Numerous classification yard entries
  - Other hazardous material freight
- Study model
  - Generic 70 car train with the cask consist in the middle of the train

Study Methodology

- Key Trains
  - Based on 2001 AAR Recommended Practice Circular OT-55-D "Recommended Railroad Operating Practices for Transportation of Hazardous Materials"
- Study model
  - Same length/configuration as Regular Train Service
  - Same operational environment (yards, passing, HM) as Regular Train Service
  - Speed restricted to 50 mph (also analyzed 35 mph)

Study Methodology

- Dedicated Trains
- Study model
  - 6 car length consist, 2 locomotive, 2 buffer cars, cask car and escort car
  - Speed restricted to 50 mph (also analyzed at 35 mph restriction)
  - No passing rule
  - Limited visits to classification yards

Study Methodology

- Cask description
  - 125-ton steel/lead/steel prototype
  - NRC cask certification criteria established the functional strength of the cask
  - NUREG/CR-6672 "Reexamination of Spent Fuel Shipment Risk Estimates" study of the cask without impact limiters used as input for the rail crash analysis

Study Methodology

- Representative Routes
  - 6 routes were chosen by VOLPE/FRA
  - Origin points include nuclear power plants and existing waste repositories (SNF or HLRW)
  - Destination point DOE's Yucca Mountain facility
  - Utilize major east-west rail links
  - Representative of geographic location and length
  - Links determined by ORNL's Interline routing model, "most likely traveled"

Study Methodology

Route Number	Origin	Length	Average Population Density Persons/sq mile (2000 Census)		
		Miles	Urban	Suburban	Rural
1	Humbolt Nuclear Power Plant, CA	1090	6237	1164	26
2	Crystal River Nuclear Power Plant, FL	2988	5641	976	38
3	Dresden Nuclear Power Plant, IL	1920	5169	1006	26
4	River Bend Nuclear Power Plant, LA	2471	4964	919	30
5	Seabrook Nuclear Power Plant, NH	3086	6109	1028	28
6	Hanford Repository, WA	1226	4744	1307	17

Study Methodology

Utilizing the inputs

- Comparison of radiation dose risk
  - Incident-free (normal) transportation
  - Accident conditions
- Operational safety consideration

Study Methodology

Incident-free Transportation

- Calculated using Radtran 5
  - Six representative routes
  - Cask dose rate 10 mrem/hr @ 1M (DOT non-exclusive use limit)
  - Consist description (# cars & position)
  - Service/speed
  - Impacted population
  - Shielding factors

Study Methodology

- Results expressed as population doses (person-rem) and converted into LCF
- Evaluated by
  - Route
  - Service/speed
  - Population type
  - In-transit vs. stops

Study Methodology

Accident-related Risk

- Compared radiological exposure due to accidents
  - Accident involvement probability
  - Accident severity probability
  - Expected consequences

Study Methodology

Regular Train Transportation

- 3 event trees were constructed
  - Movements on mainline track
  - In yards
  - Fire events
- FRA's Railroad Accident Information Reporting System (RAIRS) was used to define and categorize the accident types
- Baseline accident probability calculated for regular train transport 1988-2001 (total # accidents/yr normalized by reported train miles/yr)

Study Methodology

Accident Types:

- Derailment
- Collision (Head-on; Rear-end; Side; Raking; Broken Train; Obstruction)
- Crossing (Highway-Rail; Rail-Rail)
- Other (i.e., Acts of God)
- Fire/Explosive

Accident Severity:

- Mainline & Yard Trees

  Impact velocities identified
- Fire Event Tree

  Fire intensity & duration

Accident consequences:

- Described in terms of cask damage and resulting radiation exposure

Study Methodology

Key Trains

- Modified event tree to reflect speed restriction and improved braking
- Decreased accident type probability
  - Collision/Obstruction w/speed as a factor
  - Highway-Rail or Rail-Rail Crossing w/speed as a factor

Study Methodology

Dedicated Trains

- Modified event tree to reflect operational restrictions
  - Yard entries; consist length; passing restrictions; speed limits; no HM
- Reductions in accident type probability for all types except those affected by train frequency (No change)

Study Methodology

- Accident rates
  - Overall mainline rate for all accident categories and yard accident rates are the same for Regular and Key service
  - Overall mainline accident rate for Dedicated service is ~ 3.8% less
  - Overall yard accident rate for Dedicated service is ~ 75% less

Study Methodology

Accident Severity Categories

- I – Delay event, no dose rate increase from baseline 10 mrem/hr @ 1M
- II – Accident results in dose rate increase to 1 rem/hr @ 1M, no release
- III– Accident results in loss of shielding/internal damage, dose rate increase to 4.3 rem/hr @ 1M
- IV – Accident results in release of radioactive material. This category was equally unlikely for all shipping options and was not analyzed.

Study Methodology

Accident Consequences

- Calculated using Radtran 5
- Doses to general population, rail workers, and emergency response personnel
  - Category I – a 10 hour delay
  - Category II and III – delays lasting between 3 and 72 hours
- Comparison between Regular/Key and Dedicated Train service

Study Methodology

Operational Safety Considerations

- Reduced time-in-transit and switching operations by avoiding yards
- Reduced derailment/collision potential by use of ECP brakes and uniform consist

Study Methodology

- Fewer mechanical malfunctions by use of dedicated equipment operated in small consists
- Reduced risk from interaction of other hazardous material in the event of derailment/collision
- Potential engineering enhancements to dedicated equipment (on-board defect sensors; utilization of the ECP communication backbone linking cars)

Findings

"The Volpe Study indicates that risk to employees and the public from the transportation of SNF/HLRW is low, but on a comparative basis dedicated trains appear to offer advantages over general consists."

Available online www.fra.dot.gov under Safety – Publications
"Use of Dedicated Trains for Transportation of High-Level Radioactive Waste and Spent Nuclear Fuel"

Findings – Normal

Route	Service	Total Dose (person-rem)	Latent Cancer Fatalities
1	Regular/Key Dedicated	0.1316 0.0720	$5.57x10^{-05}$ $3.10x10^{-05}$
2	Regular/Key Dedicated	0.1949 0.1188	$8.15x10^{-05}$ $5.03x10^{-05}$
3	Regular/Key Dedicated	0.1528 0.0838	$6.36x10^{-05}$ $3.54x10^{-05}$
4	Regular/Key Dedicated	0.1684 0.0980	$7.00x10^{-05}$ $4.13x10^{-05}$
5	Regular/Key Dedicated	0.2094 0.1258	$8.81x10^{-05}$ $5.40x10^{-05}$
6	Regular/Key Dedicated	0.1223 0.0700	$5.13x10^{-05}$ $2.98x10^{-05}$

Findings - Accident

Event		Regular/Key Service		Dedicated Service	
	Duration (hrs)	Total Dose (person-rem)	Predicted LCF	Total Dose (person-rem)	Predicted LCF
I	10	$6.3x10^{-03}$	$2.62x10^{-06}$	$6.56x10^{-03}$	$2.73x10^{-06}$
II	10 (D) 16 (R/K)	16.36	$6.56x10^{-03}$	4.91	$1.98x10^{-03}$
III	10 (D) 16 (R/K)	70.90	$2.81x10^{-02}$	21.17	$8.52x10^{-03}$
IV	Not evaluated				

Finding

- Non-incident risk from the entire shipping campaign, based on the number of rail shipments in DOE's Environmental Impact Statement on Yucca Mountain, is appreciably less than one LCF regardless of type of service.

Path Forward

- Determine if rulemaking is warranted
  - Evaluate cost/benefit data associated with dedicated service
  - Review AAR operating and maintenance standards published post-study
  - Review DOE and industry shipment planning documents
- Review and update FRA's SCOP

USE OF DEDICATED TRAINS FOR TRANSPORTATION OF HIGH-LEVEL RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL

Report to the Congress
March 2005

The Mandate

Section 15 of the Hazardous Materials Transportation Uniform Safety Act of 1990 (Pub. L. No. 101-615), amended section 116 of the Hazardous Materials Transportation Act (49 U.S.C. App. 1813) to read in part as follows:

(a) RAILROAD TRANSPORTATION STUDY - The Secretary, in consultation with the Department of Energy, the Nuclear Regulatory Commission, potentially affected States and Indian tribes, representatives of the railroad transportation industry and shippers of high-level radioactive waste and spent nuclear fuel, shall undertake a study comparing the safety of using trains operated exclusively for transporting high level radioactive waste and spent nuclear fuel (hereinafter in this section referred to as 'dedicated trains') with the safety of using other methods of rail transportation for such purposes. The Secretary shall report the results of the study to Congress not later than one year after the date of enactment of this section.

(b) SAFE RAIL TRANSPORT OF CERTAIN RADIOACTIVE MATERIALS. -Within 24 months after the date of enactment of this section, taking into consideration the findings of the study conducted pursuant to subsection (a), the Secretary shall amend existing regulations as the Secretary deems appropriate to provide for the safe transportation by rail of high-level radioactive waste and spent nuclear fuel by various methods of rail transportation, including by dedicated train.

Executive Summary

This report compares the relative safety of rail shipment alternatives for the transport of spent nuclear fuel (SNF) and high-level radioactive waste (HLRW). These alternatives involve the use of: (1) regular trains: operating without restrictions with the exception of current hazardous materials and rail safety regulations; (2) key trains: similar to regular trains but operating with a maximum speed limit of 50 miles per hour (mph) or 80.4 kilometers per hour (km/hr) and other handling restrictions; and (3) dedicated trains: operating with a maximum speed limit of 50 mph (80.4 km/hr) and additional operating restrictions.

In preparation for this report, the U.S. Department of Transportation's (DOT) Volpe National Transportation Systems Center (Volpe), a part of the DOT Research and Innovative Technologies Administration (RITA), under contract to the DOT Federal Railroad Administration (FRA), performed a study to provide a safety analysis on whether the FRA should require carriers to use dedicated trains for shipment of SNF and HLRW (Volpe Study). In preparation for this report, FRA preliminarily considered the relative cost implications of using dedicated trains and the additional opportunities for risk reduction associated with use of dedicated rolling stock.

The study was initiated once funding was appropriated for it in the Spring of 1992. Representatives from the Department of Energy (DOE), the Nuclear Regulatory Commission (NRC), potentially affected States and Native American tribes, the railroad industry, and SNF/HLRW shippers were invited to attend and consult with the FRA and the study contractor at a 2-day Dedicated Train Workshop held in Denver, Colorado, in September 1992.

In preparing this report, FRA coordinated closely with the DOT Pipeline and Hazardous Materials Safety Administration (PHMSA), which also issues regulations governing transportation of hazardous materials in all modes,[1] and with the DOT Office of the Secretary. In addition, FRA consulted with DOE and NRC. Although comments from other governmental agencies were incorporated, this report is ultimately the responsibility of the DOT.

As more fully explained later in this report, the transportation of SNF/HLRW is thoroughly regulated, and several agencies of government play active, highly coordinated roles in endeavoring to ensure its safety. Over the past 45 years, approximately 600 train movements of these materials have occurred by rail without any incidents occurring that

[1] FRA, in concert with PHMSA, develops hazardous materials regulations specifically applicable to the rail mode for issuance by PHMSA. FRA enforces hazardous materials regulations applicable to transportation by rail. Both agencies act by delegation from the Secretary of Transportation. Actions referred to in this report where PHMSA is referenced were taken by the Research and Special Programs Administration (RSPA). The PHMSA, created by P.L. 108-427, is the successor organization to RSPA for DOT's hazardous materials transportation and pipeline safety responsibilities and did not yet exist for purposes of this report.

have affected the integrity of the shipping package. At the discretion of the shipper/carrier parties involved, the majority of these shipments were made using "special" or dedicated trains.[2] The responsible agencies work to continually verify the safety of packaging, rolling stock, and procedures, and the training of personnel involved in transportation. The railroad industry also issued its own standard for movement of these commodities, that seeks to establish performance guidelines for a cask/car/train system transporting high-level radioactive material. These guidelines are designed to ensure safe transportation, minimize time in transit, and incorporate best available technology to minimize the potential for a rail accident.[3] This report addresses one additional means by which a greater level of safety might be achieved, the use of dedicated trains.

The Volpe Study analyzed both non-incident risk from radiation emitted from the cask during transportation and accident risk. Non-incident risk from the entire future shipping campaign is estimated to be on the order of approximately one (1) latent cancer fatality (LCF) for every 40,000 shipments in non-dedicated trains and approximately one (1) LCF for every 50,000 shipments in dedicated trains. Using the number of rail shipments expected over the life of the shipping campaign, as stated in DOE's Environmental Impact Statement on Yucca Mountain as a measure, the potential expected LCF's would be appreciably less than one. Therefore, regardless of the type of train, the potential exposures are essentially benign when compared to a lifetime of normal background radiation exposure from the sun or heightened radiation exposure from flying in a commercial airliner at 30,000 feet. The potential exposures are also benign when compared to radiation risks associated with smoking tobacco. However, given public interest in the subject matter, the basis for these estimates is set forth below. As the results show, if there is a discernable difference in risk for affected populations, the risk is less using a dedicated train.

With respect to accident risk, safeguards are already in place — principally NRC package certification requirements, railroad industry key train requirements, and FRA's focused inspection program — that have reduced the potential, to an extremely low probability, that a cask could be damaged in rail transportation to the extent it might release radioactive material into the environment. However, further reducing the possibility of a train accident involving a SNF/HLRW cask is highly desirable, despite the very low probability that the cask might be compromised. It is also recognized that any train accident involving a cask shipment would degrade public confidence in the ability to safely transport this material, and the presence of a cask would greatly complicate emergency response and wreck clearance operations, thus compounding costs to responders and the railroad.

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[2] As used in this report a special or dedicated train is a train that consists only of equipment and lading associated with the transportation of SNF/HLRW. That is, the train consists only of necessary motive power, buffer cars and cask car or cars, together with a car for escort personnel. Such a train does not transport other rail rolling stock or other revenue or company freight.

[3] Association of American Railroads (AAR) Standard S-2043: Performance Standard for Trains Used to Haul High Level Radioactive Material; AAR Circular Letter C-9619 dated April 29, 2003.

Importantly, the study results support the conclusion that use of dedicated trains would reduce both the probability of a SNF/HLRW cask being involved in a train accident and the possibility that other hazardous materials might be involved that could subject a cask to a fire environment with possible loss of shielding. Although the study intentionally uses worst-case assumptions (e.g., minimum compliance with NRC fire exposure criteria) and should not be taken as an absolute measure of risk, on a comparative basis, it is apparent that a dedicated train strategy should have a favorable impact on any residual risk.

As the Volpe Center was finalizing the study effort underlying this report, FRA's Office of Safety, in concert with the Office of Railroad Development, was reviewing informally the economic and other practical issues associated with this public policy decision. Appropriate train make-up and the value of rolling stock that incorporates the latest lessons in derailment prevention and most advanced technology are clearly important. FRA also recognizes the improvements in quality and efficiency of inspection by the railroad and FRA that can be realized through use of dedicated consists. FRA further recognizes the utility of enhanced operating procedures and training that could further reduce the potential for collision or derailment. The risk of an accident that seriously compromises a cask is extremely small under current conditions. Avoiding any accident that gives rise to a concern over cask integrity should heighten public confidence in the ability to safely transport SNF and HLRW and hold down the cost of emergency response related to any events where the circumstances suggest the need for caution.

FRA preliminarily explored whether use of dedicated trains would result in higher costs to shippers or railroads, and found that use of special trains is, de facto, the current reality. Railroads cannot afford the disruption associated with any event involving apparent or possible compromise of an SNF/HLRW shipment. Shippers seek to use escort personnel efficiently, and having their cars switched en route degrades this efficiency, particularly given terminal dwell times for normal freight that often exceed 24 hours. FRA's own safety program for these shipments is greatly simplified by use of special trains and would be further simplified to the extent particular rolling stock is dedicated to this purpose. Accordingly, preliminary analysis suggests that overall costs to society by using dedicated trains is not materially in excess of those costs for general revenue trains or key trains. In concert with RSPA, FRA will further extend and refine this analysis in the coming months and will make a final determination regarding the need for further rulemaking regarding conditions of transportation for these materials.

FRA is aware that post-9/11, security looms large as a concern for all forms of transportation. Although this report does not address security issues in detail, FRA is aware that NRC and DOE are considering the security ramifications of this issue. At the same time, DOT is working with the Department of Homeland Security (DHS) on the wider scope of security for the transportation of all regulated hazardous materials, of which SNF/HLRW is but one area. Based upon FRA's general knowledge of the rail environment and information available to the agency as a result of its efforts with industry and other agencies of government, use of dedicated trains should enhance security for transportation of the SNF/HLRW. Dedicated trains will be provided priority on the railroad and will be routed more directly to a destination with a minimum of interruptions to the journey. Security arrangements along the route can be executed with greater precision because the routing and scheduling will be more certain. Accordingly, while this report does not make final judgments regarding the role of dedicated trains in the security of the these shipments, neither does FRA discern any reason why security concerns should be in conflict with the use of dedicated trains; and there may be significant synergy.

Background

SNF is fuel that has been withdrawn from a nuclear reactor following irradiation and has undergone at least one year's decay since being used as a source of energy in a power reactor. Further, reprocessing has not separated the constituent elements of SNF. This fuel includes: (1) intact, non-defective fuel assemblies; (2) failed fuel assemblies in canisters; (3) fuel assemblies in canisters; (4) consolidated fuel rods in canisters; (5) non-fuel components inserted in pressurized water reactor fuel assemblies; (6) fuel channels attached to boiling water reactor fuel assemblies; and (7) non-fuel components and structural parts of assemblies in canisters [42 U.S.C. § 10101(23), 40 CFR 191.02 and DOE Order 5820.2A].

HLRW results from the reprocessing of SNF in a commercial or defense facility. It includes liquid waste produced directly in reprocessing and any solid waste derived from the liquid that contains a combination of transuranic waste and fission products in concentrations requiring permanent isolation [42 U.S.C. § 10101(12), 10 CFR Part 72.3 and DOE Order 5820.2A]. HLRW meeting this definition has been shipped by modes other than rail.

SNF and HLRW are required to be transported in casks constructed to NRC requirements. Casks are secured to specially constructed rail cars capable of transporting the heavy load.[4] This study assumes that the cask car(s) will be surrounded by two buffer cars and accompanied by an escort car. This complement of cars is referred to as the cask consist. A dedicated train is comprised of the cask consist and multiple locomotives. A regular or key train will include the cask consist, locomotive(s), along with any number of additional cars potentially containing other regulated hazardous materials, various other general cargo and/or empty rail cars.

Regular trains typically operate at allowable freight track speed, make numerous classification yard entries, and adhere to hazardous materials transportation regulations when transporting any regulated hazardous material, including SNF and HLRW. Since it was not possible to analyze all possible consist and operational arrangements of regular

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[4] A typical cask assembly weighs about 250,000 pounds, and a loaded cask car weighs about 394,500 pounds, in contrast to a typical rail load of 286,000 pounds. Like other cars constructed to carry heavy loads, cask cars use additional axles and span bolsters to distribute the weight over a larger portion of the track structure. Other special loads transported on the railroad include large transformers and specialized industrial equipment.

trains within the confines of this study, the model consisted of a generic regular train of 70 cars, with the cask consist in the middle of the train.[5]

In 2001, the Association of American Railroads (AAR) issued a Recommended Practice Circular defining any consist containing SNF or HLRW as a Key Train and routes with specified levels of hazardous materials including SNF and HLRW as Key Routes.[6] Key trains are similar to regular trains in length and general operating rules except for the following:

- No consist restriction in excess of current regulatory requirements
- Cask is placed on a flatcar between two buffer cars
- Train has a railcar with escort personnel aboard who monitor/guard the shipment
- A 50 mph (80.4 km/hr) speed restriction
- Passing not restricted unless on lower than Class 2 Track
- All cars in the consist are equipped with roller bearings with rules about alarms
- Key Routes have hot bearing detection equipment at minimum intervals and the track must be inspected twice annually for internal flaws and geometry irregularities.

In the Volpe Study, by contrast, dedicated trains were assumed to operate according to the following:

- Consist is restricted - no freight other than SNF and/or HLRW is carried
- Cask is placed on a specially designed and equipped flatcar between two buffer cars
- Multiple locomotives
- Train has a railcar with escort personnel aboard who monitor/guard the shipment
- A 50-mph (80.4 km/hr) speed restriction. For completeness a 35 mph (56.3 km/hr) speed restriction was also analyzed although this restriction no longer applies since the publication of AAR circular OT-55-D
- Passing is restricted on all track classes-when a dedicated train is passed by another train, one of the trains remains still while the other train passes at a speed less than or equal to 50 mph (80.4 km/hr). Again, for completeness a 35-mph (56.3 km/hr) speed was also analyzed.

Between 1979 and 1997, there were over 1,300 shipments of commercial SNF and HLRW totaling over 1,102 tons (1,000 metric tons). Although only about 11 percent of the shipments were by rail, these accounted for over 75 percent of the tonnage [NRC,

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[5] FRA does not mandate specific placement of loaded and empty cars in trains except in the case of placarded cars carrying regulated hazardous materials in accordance with 49 CFR 174.85. However, industry guidelines and carrier rules exist to address train make-up in light of joint industry-government research. From the point of view of train-track dynamics, a heavy vehicle such as a cask car would typically require placement in the first third of the train.

[6] AAR Recommended Practice Circular OT-55D, Recommended Railroad Operating Practices for Transportation of Hazardous Materials, 2001.

1998].[7] To date, there have also been approximately 800 shipments of naval SNF and HLRW safely made in both regular trains and dedicated trains. In the future, DOE estimates that a total of between 11,000 and 17,000 casks of SNF and HLRW will need to be shipped by rail [DOE, 2002b].[8] A shipment by rail can consist of a single movement of a single cask or a single movement of multiple casks with escort and buffer cars, as needed.

Safety Compliance Oversight

Regulations addressing hazard communication, training, security plans, packaging and modal operational requirements for transporting regulated hazardous materials, which includes SNF and HLRW, exist in 49 CFR Parts 100-185 (Hazardous Materials Regulations). Rail safety regulations in 49 CFR Parts 200-244 address safety requirements for railroad operations, including, for example: rail equipment, track, signal systems, communications, train crews, and grade crossings. These rail safety regulations apply regardless of whether there is any hazardous material being transported in a train.

The nation's rail carriers conduct their own inspections in their efforts to ensure compliance with all applicable regulations. The FRA and participating State agencies that have FRA Certified State inspectors continually use the resources available to them to the extent possible to conduct inspections of the nations rail carriers and to ensure that regulatory compliance is being achieved.

In addition to these efforts, the FRA developed and implemented the Safety Compliance Oversight Plan (SCOP),[9] a coordination and inspection plan specific to all known rail shipments of SNF and HLRW. Implementation of the SCOP focuses available resources in order to ensure the safe and secure transportation of SNF and HLRW. The SCOP addresses what tasks the FRA and its FRA certified State inspection partners will perform for shipments of SNF and HLRW. The tasks cover all operational aspects of the rail transportation environment, as well as planning and coordination tasks with entities and agencies involved in the transportation of this material.

To date FRA has implemented the SCOP for each movement due to the infrequency of these shipments. However, FRA recognizes that as shipments "ramp up," which could be as early as 2007, it will be become increasingly difficult to implement the SCOP tasks in their entirety as they currently exist for every shipment. Congress has recognized the

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[7] U.S. Nuclear Regulatory Commission. "Public Information Circular for Shipments of Irradiated Reactor Fuel." Washington, D.C.: NUREG-0725 Rev 13. October 1998.

[8] U.S. Department of Energy. "Final Environmental Impact Statement for a Geological Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada." Washington, D.C.: Office of Civilian Radioactive Waste Management, DOE/EIS-0250 Vol. I and II. February 2002.

[9] FRA's Safety Compliance Oversight Plan (SCOP), can be viewed and downloaded from FRA's web site at www.fra.gov/downloads/safety/scopfnl.pdf

importance of ensuring that shipments of SNF and HLRW move safely and securely and provided FRA with the ability to add inspection personnel via the budget process. Regardless of the type of train used for this function, FRA and participating State agencies will continue to facilitate the safest possible transportation of SNF/HLRW by enforcing the railroad safety laws and regulations, and the Hazardous Materials Regulations. However, it is evident that FRA's task in this regard is greatly simplified and the likelihood of success is enhanced, where dedicated equipment is employed and the route is as direct and well suited to the mission as possible. Concentrating on the safety of a discrete subset of locomotives and cars, and surveying a route that avoids congested yards, will increase the likelihood that safety concerns are reliably identified and remedied before the shipment is accepted by the railroad.

Comparative Risk Assessment

The Volpe Study assumed two basic types of risks involved with transporting SNF and HLRW: (1) incident-free risks and (2) accident-related risks. The incident-free risks associated with normal emissions of very low radiation doses from the cask involved absolute risks of appreciably less than one LCF for the entire exposed population for the highest risk case-the regular train-over an entire shipping campaign. Primarily because of the reduced time in transportation, incident-free risk was lowest for dedicated trains (again appreciably less than one LCF for the shipping campaign). These estimates are higher than would be realized in actuality, as they assume the maximum allowed emissions from the casks in non-exclusive use transportation, rather than the generally lower emissions from actual shipments.[10]

Incident-free risks result from continuous emissions of low doses of radiation, which the cask shielding cannot totally contain. However, the emissions can and are limited to acceptable safe levels (a maximum of 10 millirems per hour (mrem/hr) at 3.3 feet (1 meter) from the surface of the package [49 CFR 173.441]). All individuals exposed to the radiation being emitted from the cask during transport, handling, loading and unloading are exposed to very low doses of incident-free radiation.

Accident-related risks result from the potential of exposure to radiation after an accident occurs. Radiological consequences were calculated for accidents where consequences vary with the use of a regular, key, or dedicated train service. For each accident type, incident durations from 3 to 72 hours were analyzed to account for a range of severities, and three locations types, urban, suburban, and rural, were analyzed. For the purposes of this study, accidents were broken down into four severity categories:

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[10] Prior to proffering a cask for shipment, the shipper must demonstrate compliance of the cask design with 10 CFR Part 71, as promulgated by the NRC. Experience has shown that radiation levels emitted by the package are generally below the maximum allowed by regulation for non-exclusive use shipments due to the shielding built into the packages and the efforts of the shipper to reduce the external radiation levels to be as low as possible. In addition, radiation levels are checked by State and Federal Government agencies prior to being offered into transportation and can also be monitored while in transportation. FRA recently secured additional staff to support this function.

Category I Delay event - accident well within the Hypothetical Accident Conditions (HAC) modeled by the cask packaging test criteria of 10 CFR Part 71; dose rate assumed equivalent to the allowed non-exclusive use transport rate of 10 mrem/hr at 3.3 feet (1 m) from the cask surface. Accidents in Category I could result in an increased duration of exposure to certain individuals (such as crew and nearby population) due to the extended time required to clear the wreck scene and resume transport.

Category II Serious accident - an accident close to the HAC, which could result in a hundredfold increase in radiation levels but no release of radioactive material occurs. The dose rate is assumed equal to 1 rem/hr (1,000 mrem/hr) at 3.3 feet (1 m) from the cask surface. Accidents in Category II could expose populations to higher doses of radiation for extended time periods.

Category III Major accident - an accident that generates forces or temperatures that exceed the HAC. A greater loss of shielding or internal damage occurs but there is no release of radioactive material. The dose rate is assumed to be equal to 4.3 rem/hr (4,300 mrem/hr) at 3.3 feet (1 m) from the cask surface. Accidents in Category III could expose populations to higher doses of radiation for extended time periods.

Category IV Severe accident - an accident resulting in forces or temperatures well in excess of the HAC. A significant loss of shielding or cask damage resulting in the release of some radioactive material. This category was not analyzed as it was considered equally unlikely for any of the shipping options and the consequences would not be substantially different.

The consequences of any of these four types of accidents are determined by: the environment in which the accident occurred; the potential for a second "event" such as a fire following the initial impact, puncture, or fall; and the time required to respond to the accident.

Incident-free and accident-related risks are analyzed for entire populations, and results are expressed as population doses (person-rem). These population doses are also converted into an estimate of health effects, i.e., LCFs. Doses for individuals (where applicable and possible) are expressed in units of millirem (mrem).

The use of LCF as a metric of deleterious health effect is based upon the assumption that any amount of radiation exposure may pose some risk. This is the linear, no-threshold (LNT) model, in which any increase in dose has an incremental increase in the risk of occurrence of cancer. LNT is the accepted model used in the U.S. as well as by international radiation protection bodies. The LCF rate for worker population is 0.0004, while that for the general population is 0.0005 [NCRP 1993].[11] When the rates are applied to an individual, the units are for a lifetime probability of LCFs per rem (or 1,000 mrem) of radiation dose. When the rates are applied towards a population of individuals, the units are excess number of cancers per person-rem of radiation dose. The difference between the worker dose and the general public risk is attributable to the fact that the general population includes more individuals in sensitive age groups (that is, less than 18 years of age and over 65 years of age).

Calculating Risk

The total risk associated with transporting SNF and HLRW is the result of both incident-free risk and accident-related risk. The amount of the low-level exposure associated with Incident-free transport depends on the details of the number of shipments, specific routes and operating variations. Accident risks are associated with relatively low probability events. The accident probabilities are based on historical accident data independent of a specific route or location. Incident-free and accident-related risks of radiological exposure are calculated independently for regular, key, or dedicated train service. The results from these calculations are then compared against commonly accepted radiological exposures to put the calculated risk into perspective.

Incident-Free Risk

"Incident-free risk" involves calculating the total expected radiation dose to the public and other impacted populations for specific routes, assuming no accidents, and comparing that calculation to the incident-free risk for regular, key, and dedicated trains. A radiation level of 10 mrem/hr measured at 3.3 feet (1 m) from the package surface was used to calculate population exposures; this is the maximum level for radioactive material packages in non-exclusive use service. The results are also compared to the radiation received by a passenger on a four-hour airline flight. Regulations in 49 CFR 173.441 for exclusive-use shipments do allow for higher radiation levels to exist both at the package surface and at one meter from the package, and yet still allow the package to be transported, but only if additional safety measures are implemented. Experience with shipments of SNF and HLRW to date have shown the radiation levels are well within the prescribed lower regulatory limits for non-exclusive use shipments, and therefore are the norm.

Though SNF/HLRW casks are very well shielded by design, they continuously emit low levels of radiation throughout all phases of transportation. Hence, radiation exposure to crew, handlers, yard personnel, and the wayside population occurs even in the event that an accident does not occur. Therefore the probability of exposure is equal to one. The exposure of all affected populations during regular transport is defined as the incident-free risk. The radiological consequences of SNF/HLRW shipments are a function of the selected route, the cask design and material being transported, the size of the impacted

[11] National Council on Radiation Protection and Measurement (NCRP). "Limitation of Exposure to Ionizing Radiation." Bethesda, MD: NCRP Report No. 116, 1993.

populations, the population distance from the cask, the total exposure time, and the amount of shielding between the cask and the impacted populations.

RADTRAN 5, a set of computer models for the analysis of the consequences and risks of radioactive material transport, was used to calculate the incident-free risk. The package dose rate and the package-specific characteristics are used to model the transport cask as a point source for extended distances. For shorter distances, within two characteristic lengths of the cask, the package is treated as a line source. The transportation system characteristics are incorporated into a rail-specific model, with input parameters for population along the route and at stops, vehicle velocity and stop duration. The population density is defined by the user along each route segment. Inputs include the specific characteristics of sub-populations like the number of passengers, crews, and rail workers. The general population is broken into three sub-groups: urban, suburban, and rural.

The calculations were conducted for in-transit exposures (off-link and on-link) and exposures at stops. Off-link doses are defined as those received by persons on the ground within 875 yards (800 m) of a passing train. On-link doses are defined as doses received by persons on passing trains as well as by the escorts and crews onboard the cask-carrying train. Stop doses were calculated as doses received by persons on the ground as well as crew and escorts within 875 yards (800 m) of the train during a stop.

Six routes were chosen for analysis. These routes were chosen to cover a representative number of origination locations across the country with currently operating nuclear power plants or waste repositories that handle SNF or HLRW. The presumed destination point for all routes is Yucca Mountain in Nevada. Table 1 provides a breakdown of the length of each route as well as the associated average population densities along each route broken down into urban, suburban, and rural sub-groups. The selected routes are likely candidates and are representative in terms of their geographic location and length.

There are many designs and sizes of casks for transporting SNF and HLRW. For purposes of this study, it is assumed that the cask will be a large 125-ton (113-metric ton) multi-purpose rail cask [DOE, 1993].[12] The incident-free dose rate was taken as 10 mrem/hr at 3.3 feet (1 m). As described above the transport cask emission rate was modeled as either a point source or a line source depending on the distance of the exposed population from the transport cask.

[12] U.S. Department of Energy. MPS Conceptual Design. Draft 1993.

Table 1. Routes Used in the Analysis

Route Number	Origin	Length	Average Population Density Persons/sq mile (persons/sq km)		
		miles (km)	Urban	Suburban	Rural
1	Humboldt Nuclear Power Plant, CA	1,090 (1,754)	6,237 (2,408)	1,164 (449)	26 (10)
2	Crystal River Nuclear Power Plant, FL	2,988 (4,809)	5,641 (2,178)	976 (377)	38 (15)
3	Dresden Nuclear Power Plant Dock, IL	1,920 (3,090)	5,169 (1,996)	1,006 (389)	26 (10)
4	River Bend Nuclear Power Plant, LA	2,471 (3,977)	4,964 (1,917)	919 (355)	30 (12)
5	Seabrook Nuclear Power Plant, NH	3,086 (4,966)	6,109 (2,359)	1,028 (397)	28 (11)
6	Hanford Repository, WA	1,226 (1,973)	4,744 (1,832)	1,307 (505)	17 (7)

Source: 2000 U.S. Census

The exposed populations were broken down into the following categories:

- General population - individuals residing and working near rail lines (waysides) over which the cask passes as well as people who live near yards and sidings where the cask consist may stop temporarily
- Persons on trains sharing the route of the shipment
- Vehicle occupants at grade crossings along the shipment route
- Train crew located in the lead locomotive on the train transporting the SNF/HLRW
- Escorts on the train transporting the SNF/HLRW
- Railroad personnel who work in close proximity to the cask in classification yards and inspect the train at various points
- Other rail yard workers not in close proximity of the shipment.

Each of the different groups experience different exposure levels and durations. Wayside populations and passengers on passing trains will be exposed as the shipment passes. High-resolution population data was used from the 2000 U.S. Census to allocate population density along the length of each route in a one-mile wide corridor. Greater exposure will be calculated for longer routes that are highly populated. This is because exposure time is the determining factor in the amount of radiation members of a population group receive. Time spent near both moving and standing shipments affect exposure. Train operational restrictions such as train speed and run through operations impact exposure time both at stops and in transit.

The train density and train occupancy data derived from the Rail Garrison[13] network studies were used to assign the number of persons likely to be sharing the railway with the shipment. The average passenger train density was used for the three general population sub-groups: urban at 0.4 trains/hr, suburban at 0.2 trains/hr, and rural at 0.14 trains/hr. The weighted average train speed for each type of train is the determining parameter for exposure. The faster the trains are allowed to travel, the shorter the exposure time.

Vehicle occupants at grade crossings on each side of the railroad can be exposed to emissions from passing shipments. The exposure to this sub-population was split into two different calculations: one for the general sub-population and the second for cars within a prescribed distance to the passing shipment. For the purposes of this study it was assumed that five vehicles would be occupying either side of the track during the passing of a shipment.

Members of the train crew and escorts are exposed for the full duration of the shipment and therefore experience the highest exposure levels of any sub-population. The exposures for these sub-populations are governed by distance from the source, length of route, and stops. Crew members on regular or key trains have the advantage of being further away from the cask consist than those on dedicated trains. However, the position of the escorts on any train type is the same.

During stops at yards or sidings, other railroad personnel will be exposed for the duration of the stop. Since train stops usually occur at rail yards, the population in and near a rail yard is modeled as a uniformly distributed population and the dose is integrated over this population. For rail stops, the public dose was calculated using the suburban population density. Greater exposure occurs for longer stop times and along routes that have more stops.

Exposure time for incident-free risk is determined by train speed, whether run-through operations are allowed, and the number of stops required at yards or sidings. The speed restrictions on the key and dedicated trains increase in-transit exposure time when compared to regular trains. However, the difference is greatly affected by such factors as the class of track over which the shipment traverses. Higher track classes allow for greater train speeds.

The last critical factor associated with exposure is the type of shielding factor that is applied to the various sub-populations to determine gamma radiation attenuation (absorption by physical structures). For the general wayside population different shielding factors were applied depending on the population density. Rural populations were assigned a shielding value of 1.0, which corresponds to no shielding. Suburban

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[13] Peacekeeper Rail Garrison Program, Rail Network Database developed by Earth Technology Corporation for the Department of the Air Force. Network not publicly available but similar network data available from National *1:100,000 scale* Rail Network, distributed on the National Transportation Atlas Database produced by the Bureau of Transportation Statistics (BTS)

populations were assigned a shielding factor of 0.87 because of the presence of closely spaced structures generally constructed from wood and cinderblocks. The urban population had the highest shielding factor of 0.018 due to the concentration of buildings constructed from concrete and steel. Occupants at grade crossings, train passengers, escorts, and inspectors/handlers were assigned a shielding factor of 1.0 (no shielding). Crewmembers were assigned a shielding factor of 0.5 assuming that the intermediate locomotive(s) provides gamma radiation attenuation. General yard workers were assigned a shielding factor of 0.1 due to the mitigating effects of gamma radiation attenuation by rail cars and structures in the rail yard. The suburban shielding factor was used for the general population for all stops.

Risk to all population groups is strictly a function of the period of exposure, distance from the cask and the assumed level of shielding provided by intervening equipment or buildings. Transit time and time in yards becomes a major determinant when comparing service options.

Accident-Related Risk

"Accident-related risk" involves comparing the radiological exposure due to accidents with that for regular, key, and dedicated train service by using three components: accident involvement probability, accident severity probability, and expected consequences.

Accident-related risk is the second form of risk associated with the transport of SNF and HLRW along the national rail corridors between originations and final destination. Aggregate accident-related exposure is not calculated; aggregate accident probabilities, not specific to routes, are calculated. Potential accident related exposure is examined by predicting the accident likelihood for the three rail transport methods, and then assigning radiological consequences, broken down into four severity categories. The baseline accident probability is calculated for regular train transport using historical accident data from 1988 to 2001. Dividing the total number of accidents by reported train miles for each year normalized these historical accident rates. The rates were then adjusted to reflect the special constraints associated with key and dedicated trains.

Event schematic "trees" based on these probabilities were then constructed that show the probability of any mainline or yard accident for regular train service. During this 1988-2001 period the number of train miles varied from year to year but generally has risen. A long period was chosen to help determine the probability of extremely rare events such as major fires or high-speed collisions. The variation in accident probability in terms of train miles is not expected to noticeably change with the addition of dedicated trains in the future. Changes in operating practices and improvements in equipment and infrastructure maintenance should reduce these rates. For this analysis, the accident probability is assumed to be constant, as reflected by the event trees. These trees were then modified to reflect the effect of key and dedicated trains on accident probabilities. Aside from speed limits, the dedicated train modifications included operational restrictions, consist limits, and reduced visits to yards.

Radiological-related risks from accidents are based upon the following factors: the design of the cask and its ability to withstand mechanical, thermal, and combined mechanical and thermal accident loads, the likely level of loss-of-shielding (LOS) resulting from accident loads, and the effect of that radiation on crews, escorts, emergency response personnel and the general population surrounding an accident site.

A key assumption in the analysis was the response of the generic cask design. Analysis results were taken from a Sandia National Laboratories study performed on a bare cask with no impact limiters, impacting surfaces with varying hardness, at a range of impact speeds and in different orientations. Force-crush characteristics were taken from that study for the hypothetical 125-ton (113-metric ton) steel-lead-steel cask. These characteristics were then used as inputs into a simplified collision dynamics model to investigate residual cask impact speeds for secondary impacts. The conservative assumption was made that any impacts in the rail environment would be considered as impacts into a hard but not unyielding surface. The speed equivalent of the NRC required package certification HAC drop test criteria in 10 CFR Part 71 onto an essentially unyielding planar surface has been determined to be 30 mph.

There is substantial kinetic energy associated with a train in the event of a collision or derailment. This energy must be dissipated through various mechanisms prior to the train coming to a complete stop. Energy consumption through plastic deformations of colliding objects, plowing of rails and ballast, and emergency braking are only a few ways that the collision energy is absorbed. Of concern for this analysis is the consumption of energy through plastic deformations of rail equipment and the cask. Two collision types were studied: a primary impact against a heavy freight locomotive, and a subsequent secondary impact against the surrounding infrastructure or environment.

A transport cask impact with a heavy freight locomotive was chosen as a representative example of a worst case primary impact in the rail environment. Two impact load paths were assumed for crush of a generic freight locomotive. Using each crush trajectory, force-crush characteristics were developed based upon previous crashworthiness work. The force-crush characteristics of both the transport cask and the freight locomotive were used to establish LOS from a direct impact of the cask with a locomotive. LOS ddresses the extent or degree that a SNF/HLRW cask may experience alteration of the radiation shielding component of the cask package, potentially resulting in increased radiation fields outside the cask package envelope. It was determined that cask damage could not occur for primary impacts with a heavy freight locomotive.

The second collision type studied was secondary impact of bare transport casks, without force limiters with the surrounding rail environment. The cask residual speed after a primary impact at various cask orientations and speeds was calculated for the following classes of collisions: head-on, rear-end, rail-rail crossings, and raking/corner impacts. Calculations were performed to determine scenarios where residual cask speeds exceeded the required NRC package certification drop test speed equivalent. This information was then used to estimate the accident consequences for the four severity categories.

Three event trees were constructed for regular train service: one for mainline incidents, one for yard incidents, and one for fires. Fires are treated independently, because they can be initiating events or a secondary event following one of the other accident scenarios. The distinction between mainline and yard accidents is made to account for the significant difference in the number of yard entries made by a regular/key train versus a dedicated train. There is a significant decrease in accident probability that results from this operational distinction. This information is used when modifying the accident rates for dedicated trains.

Each event tree begins with the overall train accident rate per train mile based upon the historical accident review. Accidents are further sub-divided into the following categories: collision, derailment, highway-rail grade crossing, fires/explosions, and miscellaneous. The probabilities for these sub-accident distinctions are reflected in the second level nodes on the event tree. These sub-accidents can result in a derailment, so the probability of a subsequent derailment is also calculated. Accident severity is calculated using the range of speeds that the derailment occurs at and is broken down into the four severity categories. The severity category is based upon the comparison of the final derailment speed to the required NRC package certification drop test speed equivalent.

Study Results

Incident-Free Risk

The total exposure during incident-free transport of SNF and HLRW is extremely low for all train service types (regular, key, and dedicated). In all of the examined representative routes, the expected number of LCFs incurred by any type of train service is less than one (1) for the total estimated number of shipments over the entire projected DOE shipping campaign.

The magnitude of radiation dosage to any population in incident-free shipping of SNF and HLRW is dependent on the total exposure time and the distance from the shipping cask. Exposure time, therefore, is heavily influenced by the amount of stop time (mostly in rail yards) and the amount of time the shipment is in transit.

Although all train service types have extremely low dose levels, there are measurable differences in radiological exposure due to the service type. Regular and key train service would result in higher potential doses to the general public, with estimates of 0.0235 person-rem to 0.0495 person-rem per single cask shipment. This translates into LCF estimates of 1.17×10^{-5} to 2.48×10^{-5} per single cask shipment; in the worst case, this is roughly one LCF for every 40,000 shipments. The DOE estimates that there are approximately 11,000 to 17,000 waste packages to be shipped by rail over the entire campaign [DOE 2002b]. Dedicated trains reduce this exposure range to 0.0177 person-rem to 0.0364 person-rem per shipment, or 8.85×10^{-6} to 1.82×10^{-5} LCF. The highest range of this estimate corresponds to approximately one LCF per 50,000 shipments. This reduction is primarily due to the fact that dedicated trains do not stop in yards for classification, reducing the total exposure time.

The total radiation dose to a person standing 98.5 feet (30 m) from a train carrying a single SNF/HLRW car as it passes at 15 mph (24 km/hr) is calculated to be approximately 0.0004 mrem (this value is independent of train type). For comparison, the average dose received by a passenger on a four-hour jet flight is roughly 3 mrem, or four orders of magnitude greater than a cask shipment.

Rail worker doses are lower for dedicated trains than for key and regular trains. The total radiation dose to all rail workers through regular or key trains for the examined routes ranges from 0.0988 person-rem to 0.1755 person-rem per shipment, or 3.95×10^{-5} to 7.02×10^{-5} LCF. The highest range of this estimate corresponds to approximately one LCF per 14,000 shipments. Dedicated train single shipment doses ranged from 0.0496 person-rem to 0.0987 person-rem, which translates into 1.98×10^{-5} to 3.95×10^{-5} LCF. This small decrease in absolute dose value is primarily due to the reduced yard visits of dedicated trains.

Train crew doses are actually higher for dedicated trains than for the other service types due to the proximity of the cask car to the locomotive in a dedicated train consist; however, in all cases the radiation exposure of the train crew from a single cask shipment is multiple orders of magnitude less than the annual limits prescribed by Federal regulations (10 CFR 20). The highest exposure estimate of a dedicated train crewmember is 0.808 mrem per single cask shipment. For comparison, the regulatory maximum annual dose for non-radiation workers is 100 mrem, or over 100 single cask shipments in a year by the same crewperson for this worst-case dose estimate. The highest crewperson dose per single cask shipment for regular or key trains is less, approximately 0.016 mrem.

Accident-Related Risk

The assumptions used to analyze the accident consequences and probabilities make regular and key trains nearly identical in terms of risk.

The historical accident probabilities were sorted by the resulting radiological severity category. The consequences of category I, II, and III accidents are slight in terms of resulting LCF for all train service types. Analysis indicates that category II and III accidents are very unlikely events, regardless of service type.

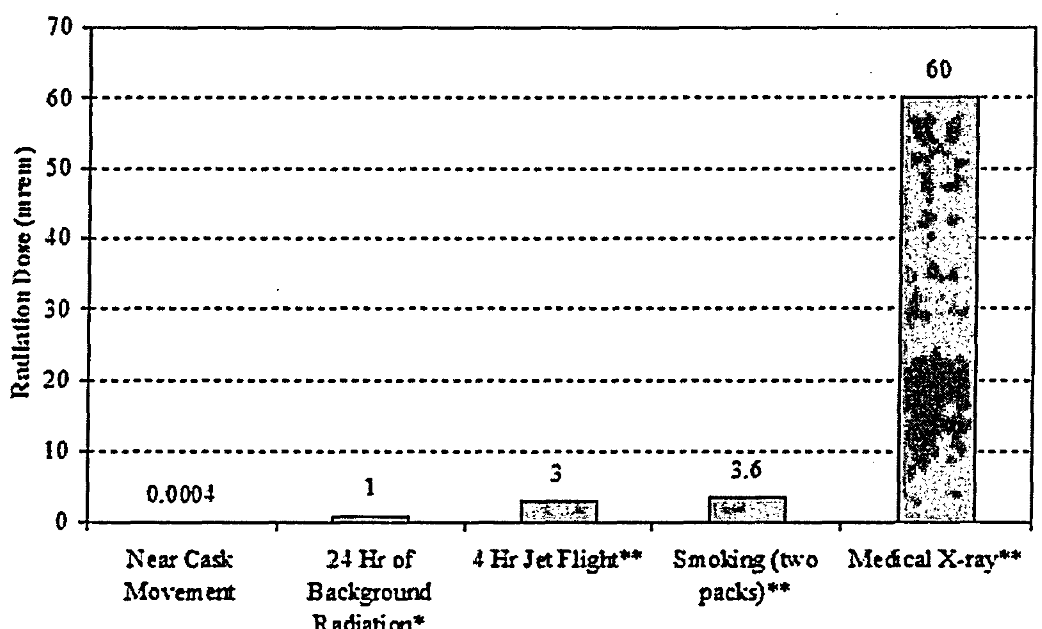
The event trees constructed from historical accident data indicate that the most likely sources of category II accidents are derailment accidents and yard accidents. The probability of an accident that is more severe than the NRC HAC package certification regulatory test requirements (category III) is extremely low for all service types. Dedicated trains have the lowest accident probability due to the decreased stopping distance of the shorter consist, the fewer number of cars to derail, and fewer yard visits (decreasing yard accident probabilities). The probability of a fire engulfing the cask car is lower for dedicated trains because cars carrying hazardous materials are restricted from the consist.

The predicted LCF consequences of category I, II, and III accidents are multiple orders of magnitude less than one per incident, regardless of service type. As with incident-free transport, differences in service are delineated in the results of this study. Regular or key trains involved in a category III accident are estimated to result in less than 0.03 LCF. The LCF prediction for dedicated trains involved in a category III accident is considerably lower: less than 0.009 LCF. The differential is due to the fact that the greater number of cars in regular and key trains requires more rerailing time. The accident consequences of category I and II accidents are substantially less severe, resulting in several orders of magnitude less than one LCF per incident.

Significance of Findings

The study concluded that the maximum individual radiological exposure resulting from an incident-free shipment of SNF or HLRW by regular, key, and dedicated trains is approximately equal to the exposure received in the first two seconds of a typical 4-hour airline journey. Figure 1 compares incident-free exposure rate with other common exposures.

Figure 1
Comparison of Incident-Free Exposure Rate vs. Other Common Exposures



Source:
* www.ocrwm.doe.gov
** National Council on Radiation Protection (NCRP)

The dominant feature that differentiates the three types of service in the incident-free analysis is transit time. Although both key and dedicated trains have a 50 mph operating speed limit, dedicated trains will have the shortest transit times because they would spend less time in yards.

Dedicated trains would be expected to have lower collective population exposures because of the shorter transit times. Dedicated train crew exposures would be higher due to the cask being closer to the crew. The study did not take into account potential As Low As Reasonably Achievable (ALARA) radiation controls that could be used by train crews to further limit their potential exposure.

When considering the accident-related radiological risks there are three relevant issues: the likelihood of an accident, the severity of the accident, and the recovery time from the accident. When considering the accident risk, the likelihood of a category III accident, where cask damage exceeds regulatory limits but does not involve radioactive material release, dominates the analysis. For all types of service studied, the category III events are very rare. The resulting exposure would still result in a small fraction of one LCF.

Dedicated trains, compared to regular and key trains, reduce the potential radiation exposure in any accident, as accident clearing can be expedited with shorter trains. In addition, since there are no other hazardous materials in the consist, there would be little chance of a fire which would prolong the response and accident clearing duration.

Key trains, similar to dedicated trains, provide an increase in safety resulting from speed restrictions, but are more similar to regular trains in terms of overall risk. Key trains have a risk of high-speed impacts equal to or slightly greater than that of dedicated trains, which could result in cask damage that could potentially exceed the criteria to which it was certified. A severe fire involvement and yard accident probability of a key train is equal to the risk for regular trains. Given a derailment, the length of regular and key trains and the likely number of derailing cars will extend the time necessary to address an accident and increase the radiation dose to surrounding populations.

Analysis of the location and pattern of accident occurrences indicates that route specific factors, such as the number of yards encountered, can have a significant impact on risks. The use of dedicated trains will expedite shipments and will reduce the hazards associated with frequent yard visits, especially on long routes where multiple stops in yards are required. Use of dedicated trains also allows more flexibility to avoid higher-risk locations and to impose restrictions such as lower operating speeds.

In this study a consist of only one cask was assumed to be present in any of the transport options. Operating consists of multiple casks could be included in any of the trains changing the cumulative exposures to crewmembers and the general public. Multiple cask consists would in general reduce the cumulative radiation exposure for the incident-free case, but might slightly increase the probability of severe accidents due to a cask-to-cask collision.

Note on Total System Risk

Some analyses of the merits of dedicated trains suggest that their use would increase train miles and thus, overall, increase risk in rail transportation. FRA appreciates this perspective but believes this consideration is not dispositive for the following reasons:

- Any additional net increase in exposure is significantly less than that associated with the dedicated train. A conventional train would need to switch the shipping point, incurring risk similar to that incurred by the dedicated train. Depending upon the configuration of the rail facilities, including the industry track, additional risk might be introduced related to cars left on the main line (collision potential, roll-away potential) in the conventional train configuration. The same issues apply at destination
- As reflected in the Volpe Study, the more direct route taken by the dedicated train reduces both non-incident and accident-related risk associated with this type of shipment
- Under the new AAR Standard, the likelihood of derailment associated with transportation of the overweight cask car will be further mitigated through use of a state-of-the-art consist (Although defined in terms of key trains, this is actually a dedicated train concept and is wholly incompatible with a general manifest train)
- Use of Electronically Controlled Pneumatic (ECP) brakes by dedicated trains will reduce or greatly mitigate collision events, including highway-rail crossing collisions
- The principal element of exposure for all types of trains are highway-rail grade crossing accidents. This exposure, and it is the same for dedicated, key, and regular trains, is in decline due to improvements in engineering, education, and enforcement (when compared with the incident rate during earlier studies).[14]

It should also be noted that, as a society, some risks are tolerated more readily than others. Normal risks associated with rail transportation are more readily tolerated than the risk of a significant event involving a SNF/HLRW movement, in part because of limited public understanding regarding the safeguards provided. Where public tolerance is low, there is value (in the form of reduced anxiety and increased acceptance) in further reducing the already-low risk that a serious event will occur.

Summary and Conclusion

The Volpe Study indicates that risk to employees and the public from transportation of SNF/HLRW is low, but on a comparative basis dedicated trains appear to offer advantages over general consists. Several of these inherent advantages—avoiding yards, reducing derailment potential, and reducing the risk of involvement of other hazardous materials in an accident scenario—could be further exploited with careful attention to

[14] Exposure related to trespassers on railroad property is a material issue, but it is by no means clear that the number of casualties varies by number of trains operated or by train miles.

conditions of transportation.

For instance, the recent AAR Standard S-2043,[15] which was issued too late for formal consideration in the Volpe Study, calls for use of ECP brakes on trains carrying SNF/HLRW. ECP brakes have the capability of reducing stopping distances by 40-60 percent. Coupled with uniform composition of the consist, ECP brakes should significantly enhance the ability of the locomotive engineer to control in-train forces and mitigate the severity of collision with other trains and obstructions on the right of way, including vehicles at highway-rail crossings. In some cases, collisions may be avoided entirely. Use of the communications backbone provided by ECP brakes may also make possible the use of on-board sensors that can identify safety problems such as overheated bearings before they progress to failure. These kinds of engineering enhancements should be possible with equipment dedicated to these special trains. By contrast, such enhancements will not be implemented for some time on the general interchange fleet.

FRA's SCOP efforts are also much more likely to be successful if dedicated equipment and special trains are employed. While inspection processes are a proven, essential element of quality control, they work best as part of a total system approach. Being able to examine dedicated equipment at regularly-established shop locations and following the service history of the equipment to identify any propensities for wear or malfunction will increase the reliability of the inspection process both for the railroad and FRA.

Historically, the principal objection to use of dedicated trains was cost to the shipper. However, FRA's preliminary analysis indicates that use of dedicated trains should not result in significantly higher costs for these movements. Bypassing switching yards dramatically shortens transit times and lowers the cost of dedicated train operations. Dedicated trains comprised of state-of-the-art equipment maintained for this service and operated in small consists should incur many fewer mechanical malfunctions (e.g., broken coupler knuckles, unintended emergency brake applications) that could delay transportation and result in unexpected costs to shippers and the railroad.

A cost comparison of the six routes used in the study indicates that the operational and escort labor costs of dedicated train shipments of at least three casks or more are approximately equal to or less than if shipped by a train which would require yard switching. Thus the inherent cost of a dedicated locomotive and crew can be offset by the shorter transit time. Public costs should also be lower, since SCOP inspections can focus on a smaller number of route miles and fewer units of rolling stock.

Over the next 18 months, FRA will further explore in detail the costs associated with the use of dedicated trains and other special conditions of transportation that may further reduce the already low risks associated with transportation of SNF/HLRW, and determine whether further regulations governing transportation of these materials are required.

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[15] Association of American Railroads (AAR). " Performance Standard for Trains Used to Haul High Level Radioactive Material." Washington, D.C.: AAR Circular Letter C-9619 /AAR Standard S-2043, April 2003.

Spatial Analysis and Decision Assistance (SADA) Version 4.1

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Presented at

Advisory Committee on Nuclear Waste (ACNW) Meeting 167

January 11, 2006

Research Objective Dealing with Subsurface Radionuclides

Pursue more realistic and defensible estimates of exposure of the public to radiation from radionuclides released from contaminated sites through optimization of sampling and analysis

2

Successful Adaptive Sampling Applications and Projected New Uses

FEDERAL SITE IMPLEMENTATIONS

Sandia National Laboratories
- Estimation of contaminated soil volumes;
- Number of bores reduced by 40%, samples by 80%.

Kirtland Air Force Base
- Estimation of contaminated soil volumes;
- Number of bores reduced by 30%, samples by 50%.

Argonne National Laboratory
- Estimation of extent;
- Number of samples reduced by 60%.

Brookhaven National Laboratory
- Estimation of contaminated soil volumes;
- Cost estimates for removal action reduced from $40M to $8M.

Fernald Site
- Radionuclide soil contamination;
- Support excavation design and execution;
- Expected to reduce $80M sampling to less than $40M.

Joliet Army Ammunition Plant
- Estimation of contaminated soil volumes;
- Per sample costs reduced by 80%.

FUSRAP Painesville Site
- Mixed waste soil contamination;
- Overall project savings estimated at $10M.

FUSRAP Ashland
- Radionuclide soil contamination;
- Precise excavation support;
- Overall project savings estimated at $10M.

NRC

NRC Specific Testing and Application
- Kiski – Could have reduced number of bores 70%, sampling by 85%
- Molycorp
- Sequoyah Fuels - TBD

NRC Projected Applications
- Reactor early site permit (ESP)
- Combined construction operating license (COL)
- Re-licensing
- Partial site release

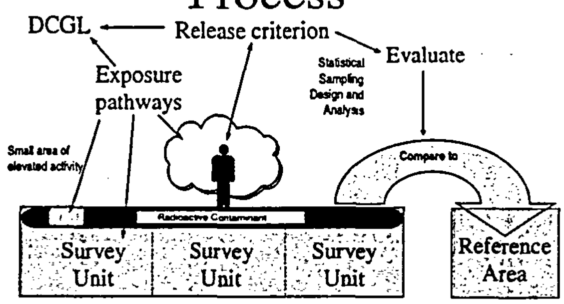
3

Planning (Multi Agency)

- Understand requirements of pending decisions
- Explicitly identify and manage uncertainties that could lead to decision errors
  - Sampling uncertainties - MARSSIM (Aug 2000)
  - Analytical uncertainties - MARLAP (Dec 2003)
  - Materials specific – MARSAME (Target 2007)
  - *Subsurface specific* – MARSSub (TBD)
- Implementing the intent of "performance based" (surface/subsurface sampling & analysis) – **SADA**

4

MARSSIM *DQO/DQA* Process



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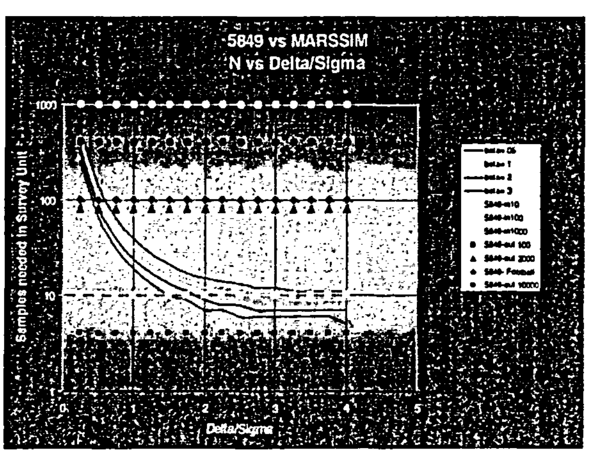


Sampling the Subsurface

- How is designing a sampling survey for subsurface materials different from designing a sampling survey for surface materials within the first 15 cm of soil?
- At issue is how to design the survey more efficiently, because the sampling effort is considerably higher for subsurface sampling than it is for surface soil sampling.
- The approach needs to be better than what we are doing now, with a justifiable technical basis and no hidden assumptions.

Active Research Areas

- Doing more with less
- *Optimizing sampling costs and analytical costs*
- Better survey design using site knowledge as a guide (Bayesian)
- Better data analysis using sophisticated statistics (geostatistics)
- Dispersed plume versus discrete sources
  - "Elevated volume" analogue to "elevated area"
- Cannot scan 100% in Class 1 – How do we keep confidence High and uncertainty Low?
- Incorporating surrogate data and professional judgment data into the decision process (e.g., geophysical, hydrological data)

HOW DO YOU MAKE IT USABLE?????

Design More Efficient Surveys

Reduce required number of samples by increasing the information available by other means than simply taking more direct measurements. This can be done in two ways:

- 1) increase the information available from professional knowledge of site processes, historical data, pollutant transport etc.
- 2) make more efficient use of the hard data that is already available by the use of more advanced statistical methods.

Develop further design efficiency

- Incorporate prior information quantitatively as "soft data" that can be combined with hard concentration data from samples- **Bayesian Statistics**
- Sampling design based on maximizing the information that will be added - **not all locations are equally informative**
- **Geostatistical** data analysis that incorporates known spatial relationships among data locations
- **Geophysical** data may be used for scanning - Bayesian extensions to ELIPGRID

10

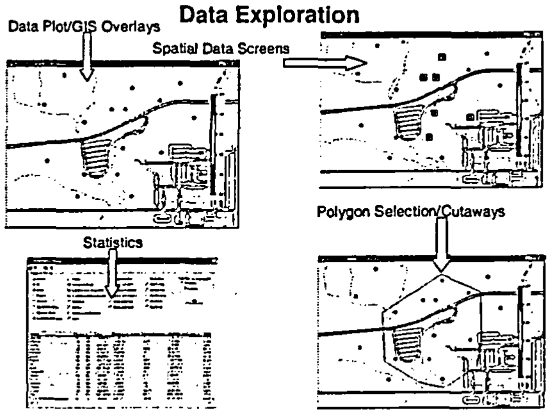
SADA Overview

Windows–based freeware designed to integrate scientific models with decision and cost analysis frameworks in a seamless, easy to use environment.

- Visualization/GIS
- Statistical Analysis
- MARSSIM Module
- Geospatial Uncertainty Analysis
- Sampling Designs
- Custom Analysis
- Geospatial Interpolation
- Area of Concern Frameworks
- *Human Health Risk Assessment*
- Ecological Risk Assessment
- Cost Benefit Analysis
- Export to Arcview/Earthvision

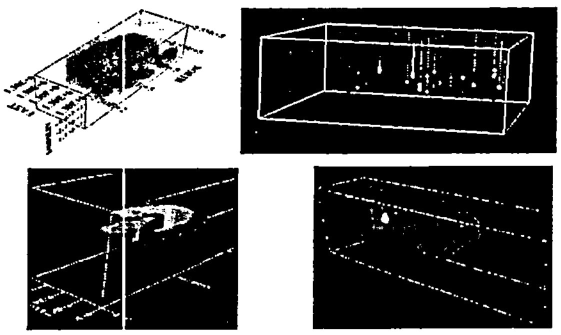
SADA has been supported by both the DOE, EPA, and the NRC. SADA Version 3.0 had about 11000 downloads. Version 4.0/4.1 has had about 4000 since January, 2005.

Data Exploration



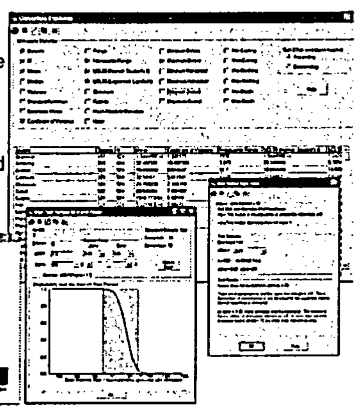
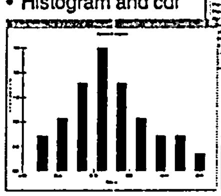
3D Visualization

True 3d Views: Points, Blocks, and Isosurfaces



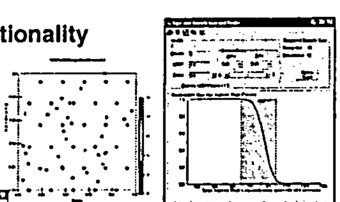
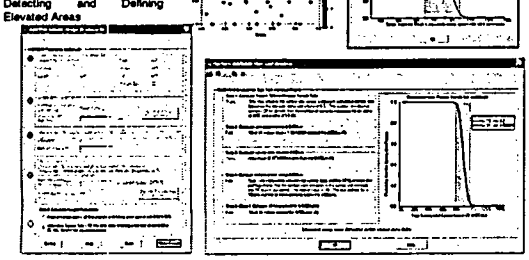
Statistics

- Numerous univariate statistics
- Non-parametric hypothesis testing
- Power curve based sample sizes
- Histogram and cdf

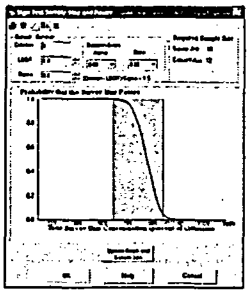
MARSSIM Functionality

- Calculate sample size based on Sign Test or WRS Test
- Develop initial sample design incorporating DCGLS, Area Factors, Instrument sensitivity
- Post sampling analysis (A site passes or fails)
- Detecting and Defining Elevated Areas

Determining Number of Samples - Sign Test

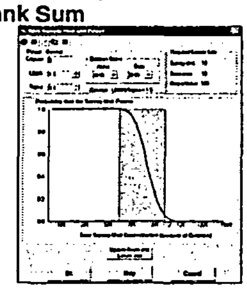
- User inputs a decision criterion, a lower bound of a gray region, and acceptable Type I and II error rates
- Appropriate for grid designs and simple random sampling
- Used when no background is available



SADA

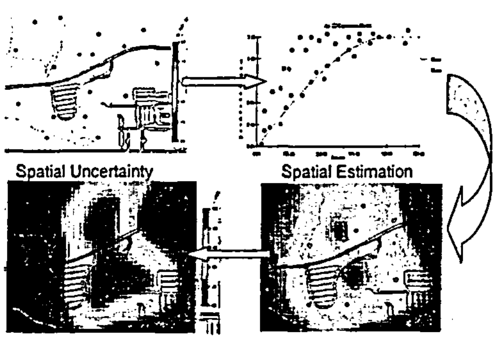
Determining Number of Samples – Wilcoxon Rank Sum

- User inputs a decision criterion, a lower bound of a gray region, and acceptable Type I and II error rates
- Appropriate for grid designs and simple random sampling
- Used when contaminant is in background and a reference area is available

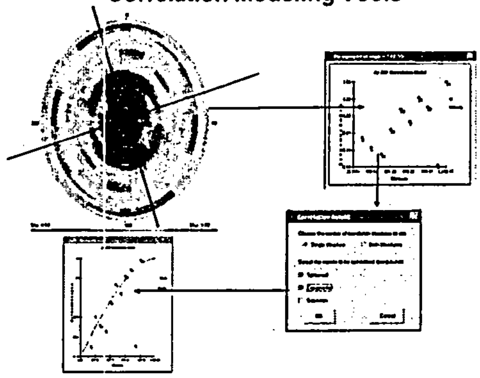


SADA

Spatial Analysis



Correlation Modeling Tools



Sample Designs

SADA has a number of sample design strategies in Version 4.0. These strategies include initial and secondary designs. Some are based on data alone while others are based on modeling results. With the exception of a couple of exclusively 2d designs all are available in 3d dimensions.

Initial Sample Designs
- Judgmental
- Simple Random
- Simple Grid
- Simple Unaligned Grid
- Standard Grid
- Standard Unaligned Grid
- MARSSIM Design
- 2d and 3d Hot Spot search designs

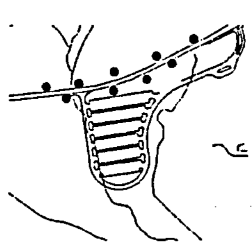
Secondary Sample Designs
- Threshold Radial
- Adaptive Fill
- High Value
  - (soft, simulated & unsimulated)
- High Variance
  - (soft, simulated & unsimulated)
- Extreme Value
  - (soft, simulated & unsimulated)
- Area of Concern Boundary Design
  - (soft, simulated & unsimulated)
- Minimize/Maximize Area of Concern
- LISA Designs
  - (Ripley's K,Moran's I,Geary's C)

Judgmental Sampling

Description
- Selection of sample locations based on expert knowledge or professional judgment

Pros
- Easy to implement
- more efficient (when correct)

Cons
- Introduces bias
- Cannot reliably estimate precision of estimates nor use statistical analyses to draw conclusions



Simple Random

Description

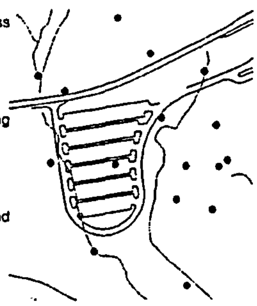
- Samples are distributed randomly across the site.

Pros

- Random sample designs are underlying assumption in most statistical tests.

Cons

- Samples may miss areas of interest and can occassionaly be clustered.



3 Types of Sample Designs: 2d, 3d, and 3d Core

With all designs, SADA first identifies the location of the sample. Then, based on whether there are multiple layers and whether the user wishes to core, the following broad scenarios are possible for a single sample.

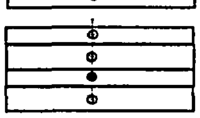
2d

In a 2d application, the sample is placed on a single layer.

3d

In a 3d application, the sample is placed on a single layer at the depth required.

Core



In a core application, the sample is placed on a single layer at the depth required. Then all layers above and below are also sampled subject to polygon definitions.

Three Dimensional Hot Spot Searches

Description

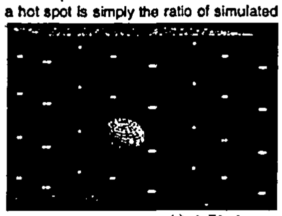
- The concept of hot spot searches in two dimensions can easily be extended into the third dimension through the use of simulation. A grid is specified in three dimensions, and the location of ellipsoids are simulated across the site. The likelihood of hitting such a hot spot is simply the ratio of simulated hits to total simulations.

Pros

- Provides an estimate of how effective a sampling grid will be at finding hot spots in subsurface.

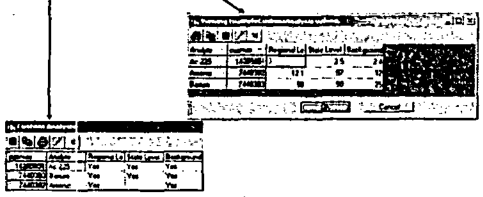
Cons

- As with two dimensional hot spot searches, the grids can be too dense for practical sampling budgets.



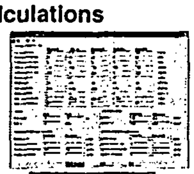
Custom Criteria

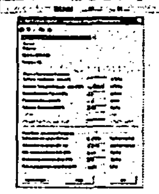
- View or Edit Criteria
- Data Screens

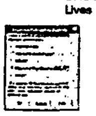


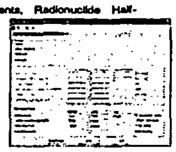
Human Health Risk Calculations

- For each media
  - Soil, Sediment, Surface Water, Groundwater
- Exposure Scenarios
  - Residential, Industrial, Recreational, Agricultural, Excavation
- Exposure Pathways
  - Ingestion, Inhalation, Dermal Contact, Food Chain (Beef, Milk, and Vegetable Ingestion)
- IRIS and HEAST Toxicity Databases for Carcinogenic and Noncarcinogenic Effects
- Physical Parameters for Modeling
  - Bioaccumulation Factors
  - Volatilization, Particulate Emission Factors
  - Permeability Constants, Absorption Factors
  - Saturation Coefficients, Radionuclide Half-Lives



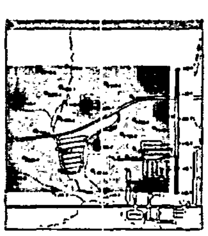


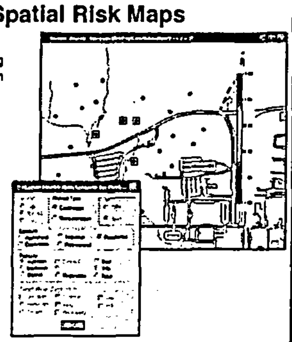


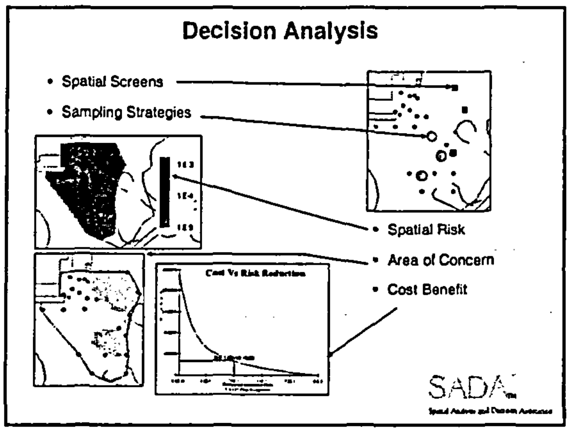


Human Health Spatial Risk Maps

- SADA calculates risk for each sampling point or spatial estimate based on contaminant and exposure scenario
- Legend scale changes to risk







Overview of Geobayesian Modeling

- Integrates bayesian update methods with standard geostatistical approaches
- Makes use of prior knowledge ("soft information")
- Integrates soft information with hard sample data to produce a combined or collective characterization result.

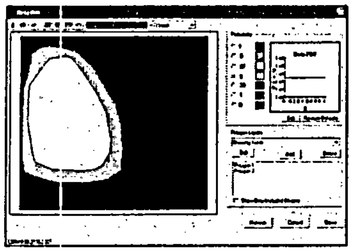
Geobayesian modeling joins SADA's suite of other spatial modeling tools

- Natural Neighbor
- Nearest Neighbor
- 3d Inverse Distance
- Ordinary Kriging
- Indicator Kriging
- **Geobayesian Modeling**

Furthermore, the Geobayesian model is connected other existing models such as remedial design, sample design, and cost analysis.

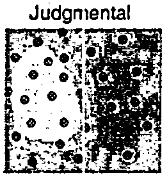
Denoting high probability, low probability, and unknown contaminated areas.

User creates a "site conceptual model" denoting areas of high, low, and unknown probabilities of contamination.



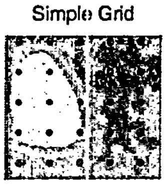
Example Sample Designs

Judgmental

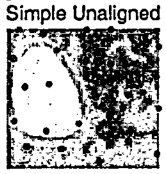


Random

Simple Grid



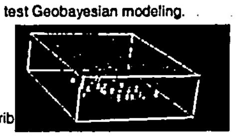
Simple Unaligned Grid

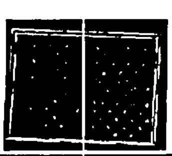


Case Study: Site Description

The KISKI Data Set

- Received by NRC as an example data set to test Geobayesian modeling.
- 1261 samples in shallow sediment.
- ~90 boreholes.
- Values range from near zero to 900 pCi/g.
- Large number of data, but typical spatial distrib
- Good starting point for evaluating the new Geobayesian approach.

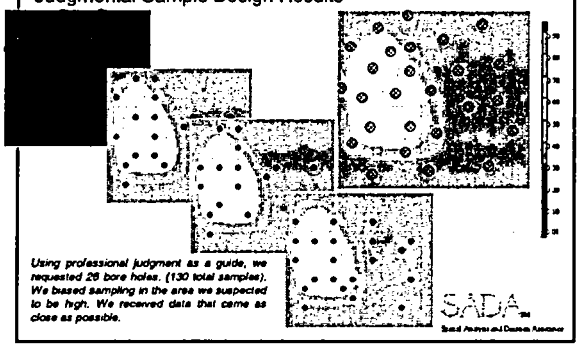




SADA

Geobayesian Case Study 1

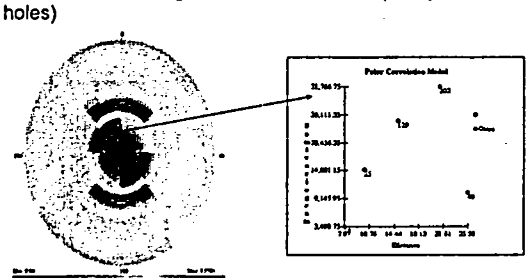
Judgmental Sample Design Results



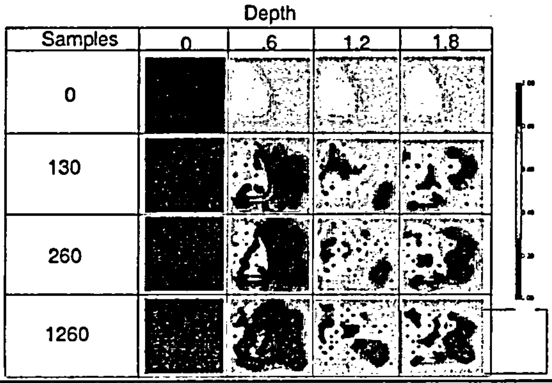
Using professional judgment as a guide, we requested 26 bore holes. (130 total samples). We based sampling in the area we suspected to be high. We received data that came as close as possible.

Geobayesian Case Study 1

Correlation Modeling Results After 130 samples (~26 core holes)

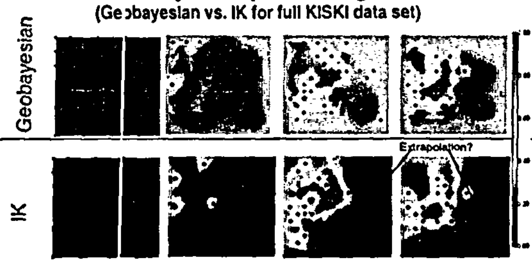


Case Study: Iterative Sampling



Case Study: Comparison Against IK

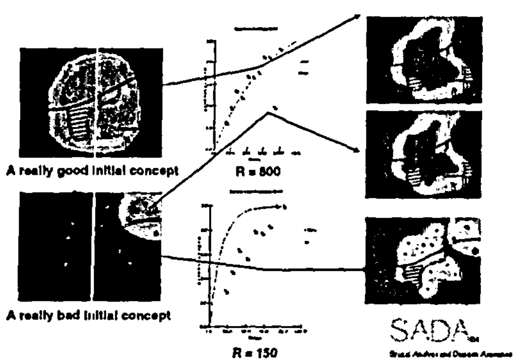
(Geobayesian vs. IK for full KISKI data set)



IK modeling presents a fairly tight and confident picture of contamination that adheres well to the existing data patterns. *Of particular interest is the IK result of high contamination to the north in the 3rd & 4th layers.* Even with a very large data set, the geobayesian model presents a less certain *picture of the likelihood of contamination, primarily due to the affect of the prior* information. The areas near low values are beginning to reduce in likelihood, but the range of these data's influence is not large enough to reduce probability values for the far site extents. This may be a very reasonable result, as little or no data are found there. The geobayesian model responds to this extrapolation by maintaining near prior probabilities.

SADA

Case Study: Impact of Correlation Range



Markov Bayes II

- Explicitly incorporates soft information such as core hole scans, ground penetrating radar, etc into the model
- Can produce more realistic heterogeneous results
- *Can support investigations that have sparse data sets*
- Source code is available for implemenation in SADA