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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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REGULATORY POLICIES AND PRACTICES SUBCOMMITTEE

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TUESDAY

JULY 10, 2012

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 1:30 p.m., John Stetkar, Acting Chairman, presiding.

COMMITTEE MEMBERS PRESENT:

JOHN W. STETKAR, Acting Chairman

CHARLES H. BROWN, JR.

HAROLD B. RAY

NRC STAFF PRESENT:

DEREK WIDMAYER, Designated Federal Official

WILLIAM OTT

JOSEPH KANNEY

NILESH CHOKSHI

HOSUNG AHN

JILL CAVERLY

THOMAS NICHOLSON

ALSO PRESENT:

RAJIV PRASAD, Pacific Northwestern National*

JOHN ENGLAND, U.S. Bureau of Reclamation*

DON RESIO, University of Florida*

VICTORIA SANKOVICH, U.S. Bureau of Reclamation*

TY WAMSLEY, U.S. Army Corps of Engineers*

*Present via telephone

C-O-N-T-E-N-TS

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

1:37 p.m.

CHAIR STETKAR: The meeting will now come to order. This is a meeting of the Advisory Committee on Reactor Safeguards, Subcommittee on Regulatory Policies and Practices. I'm John Stetkar, filling in for Dr. Dana Powers, who was originally scheduled to chair this meeting.

ACRS members in attendance are Charlie Brown, Harold Ray and we may be joined by Mike Ryan and Dana Powers. I'm not quite sure whether they are going to make it.

The purpose of this meeting is to discuss Draft Regulatory Guide DG 1290, Design-Basis Floods for Nuclear Power Plants. The subcommittee will hear presentations and hold discussions with representatives of the NRC Staff and other interested persons regarding this matter.

The subcommittee will gather information, analyze relevant issues and facts and formulate proposed positions and actions as appropriate. The subcommittee will report its findings at an upcoming meeting of the full committee but at this time we have not yet decided whether to issue a letter report on this matter.

This meeting is open to members of the public. The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the *Federal Register*. We have received no written comments or requests for time to make oral statements from members of the public regarding today's meeting.

Derek Widmayer is the Designated Federal Official for this meeting.

A transcript of this meeting is being kept and will be made available on the web. I understand that some of the participants in today's meeting are on the bridge line. It is requested that speakers first identify themselves and speak with sufficient clarity and volume so they can be readily heard.

And also I will ask you folks who are on the bridge line if you could either mute your phones when you are not speaking or put them under a pillow or do something so that we don't get background noise. It tends to come through pretty strongly here.

We will now proceed with the meeting and I call upon Bill Ott of the Office of Research to open the proceedings. Bill?

MR. OTT: Thank you. I am Bill Ott. I am the Chief of the Environmental Transport Branch in the

Office of Nuclear Regulatory Research. RES and in particular my branch has the lead responsibility for revising Reg Guide 1.59 as part of the General Regulatory Guide Update Program which started seven or eight years ago.

In August of 2008, NRO gave us a User Need, which requested development of a technical basis for revising and applying Reg Guide 1.59, Design-Basis Floods for Nuclear Power Plants. The last update of that particular Reg Guide was Revision 2 and that was back in 1977. They asked us to update the flooding information from the federal agencies responsible for inland and coastal flooding, flood monitoring and predictions, namely the National Weather Service. They have Bureau of Reclamation and the U.S. Army Corps of Engineers and the U.S. Geological Survey. We are also to provide state of the art -- state of the practice methods for determining design-basis floods.

Again just to let you know that this is not a relatively new effort. This is an effort that has been going on since 2008. So we have put a lot of effort into this.

We have under considerations the results of the work undertaken to satisfy the user need, namely, Draft Regulatory Guide 1290.

To get to this point, we placed contracts with Pacific Northwest National Laboratory with Rajiv Prasad as the principle investigator for technical basis development. We placed a contract with Bureau of Reclamation for research to develop guidance on maximum precipitation estimates for the eastern U.S. with Dr. John England as principle investigator of that work. And the work on South Coastal flood surges with the U.S. Army Corps of Engineers with Dr. Don Resio and Ty Wamsley as the principle investigators in that project. Dr. Resio has since left the Corps of Engineers and is now with the University of North Florida. All of these, the principle investigators are on the phone and have presentations prepared for later in the afternoon.

During the execution of this work, we met frequently with cognizant office staff in the user offices. We used the Technical Advisory Group on Flooding, which is comprised of those people in various offices that are knowledgeable about the subject and also included PRA staff. So this whole process we have been communicating with both the flooding people and the PRA people in the user offices.

We directly involved contractors in these discussions through conference calls and technology transfer seminars here at headquarters.

I'm going to make two observations. One, the March 11th reactor accident in Japan focused attention on flooding but was not the motivation for this work. We started this long before the activities in Japan.

We are also aware of domestic --

MEMBER RAY: Let me just -- it seems like a good point to say did it have any effect on the work?

MR. OTT: Not directly. You can't ignore it. I mean it is there and the people that are involved are the same people. But we did not -- it will have more effect on future work than it had on this particular work.

MEMBER RAY: Obviously, it didn't invalidate the conclusions of the work that you are going to present today.

MR. OTT: We don't think so, no. That would be better asked of the investigators but since the primary weakness was the tsunami and that is not the mean thrust of what we have done. It is just one of many mechanisms that will have affected that part of --

CHAIR STETKAR: Well since you brought it up and Harold followed up, how does the staff view this update of the Reg Guide interfacing with the activities under Near-Term Task Force Recommendation 2.1 to essentially reconfirming or reevaluating the design-basis floods for all sites in the U.S.?

MR. OTT: It would be better to get into that in the context of some of the slides that come later on.

CHAIR STETKAR: Okay, thanks.

MR. OTT: And we also have Chris Cook here who is intimately involved in that so we might get a perspective from his office.

CHAIR STETKAR: Okay, thanks.

MR. OTT: I would also like to point out a couple of other instances that have emphasized the importance of flooding. One, the situation at Fort Calhoun and, for those of who may not be aware, both the 1999 episode of Blayais in France, where we had significant flooding of a nuclear reactor, a French nuclear reactor.

It is clear to me that this evidence and from the March 11th accident that flooding can be a significant safety concern and that our guidance on its treatment needs updating.

Now I'm going to turn it over to Joseph Kanney. He is the leader in my Branch for development of Reg Guide 1.59. He has a Ph.D. in environmental engineering from the University of North Carolina with a concentration in surface and groundwater flow and in atmospheric dynamics.

And Joe, take it away.

MR. KANNEY: Okay, thank you. Thanks for inviting us here to talk about DG 1290 today.

A quick outline. I will give just a little bit of the background. And actually if I am going through the background and it is the same as that you guys are intimately acquainted with, just stop and tell me to shut up and move on. And I will talk -- I'll give you a brief overview of the technical scope and I will split it up into topics that are common to most, if not all flooding mechanisms, and then talk more about the guidance related to individual flooding mechanisms. And I will follow up with a short discussion on combined events and the status of the concurrent reviews on the guide. The guide is in concurrence review among several offices right now.

As probably most of you are well aware, the regulatory basis for the guidance on design-basis flood comes from 10 CFR Part 50 and 10 CFR Part 52, Part 50 of Appendix A, the General Design Criteria, specifically GDC-2 on Design Bases for Protection Against Natural Phenomena.

And in addition, there are sections of 10 CFR 100 relating to siting of nuclear power reactors which address flooding in some aspects.

There are related NRC guides in this area. There are two standard format and content guides, Reg Guide 1.70 basically which parallels 10 CFR Part 50 and then for the 10 CFR Part 52 Reg Guide 1.206 adds to the material in Reg Guide 1.70.

And then in addition, there is the Standard Review Plan, NUREG-0800 Section 2.4 and that NUREG deals with the staff reviews of design-basis flood estimation that licensees provide in their applications.

In addition, there is a separate Reg Guide 1.102 on Flood Protection for Nuclear Power Plants. One of the things that you may have noticed in going through DG 1290 is that the old guide, Rev. 2 of 1.59 sort of blended in a little bit of things of guidance regarding flood protection. And since Reg Guide 1.102 is being updated right now, we thought it would be better to move the things which are flood protection guidance into the new 1.102 and have Reg Guide 1.59 deal just with the hazard estimation. We think it is a cleaner way to divide it.

MR. WIDMAYER: So Joe, excuse me.

MR. KANNEY: Yes.

MR. WIDMAYER: What is the schedule for revision of 1.102?

MR. KANNEY: Bill, do you have a good feed on the schedule?

MR. OTT: I don't have a good handle on it right now but the technical basis contract is supposed to be completed sometime this fall. And we are looking for a draft revision of the guide sometime in early winter. So we are talking January/February, something like that.

MR. WIDMAYER: Okay, thanks.

MR. OTT: The contract there also has been placed with the Corps of Engineers.

MR. KANNEY: And in addition, I'm going to skip over the next to the last bullet and go to the last bullet. Reg Guide 4.7, General Site Suitability, which is also under revision right now, actually the revised version is out for public comment right now. And just as the title implies, it does address the flooding issues but from a general site suitability standpoint, not in detailed guidance on methodologies for estimation and things like that.

And then there is one other Reg Guide, which deals with technical adequacy of PRA results for risk assessment. There is some guidance in that guide regarding external events and some of the criteria for external events. It is at a fairly high level. It is not very detailed guidance but it does speak to the issue of external hazard evaluations.

Okay, and then in the international community there are a suite of IAEA guides that touch on external hazards and flooding in particular. Many of these guidance documents are generally consistent with what we do at the NRC. Typically they are less detailed than our guidance. Our guidance speaks specifically to our regulations. And of course, IAEA guidance are more generic. But there are a number of IAEA guides that do touch on the content in this Reg Guide.

Why update the guide? I think Bill and others talked a little bit about it in a little bit more detail reasons to update this guide. We have new data. Bill mentioned the age of the previous revision in the intervening almost 40 years we have new data on storms, on precipitation, on floods. And as you will see as you have gone through the guide and some of the background material, the estimation process is, in some cases, very much sort of a data-driven process so that the estimate you are going to come up with for a particular flooding phenomenon may depend a lot upon the historical record that you are starting with. And we have a longer historical record than we had before.

In addition --

CHAIR STETKAR: Joe?

MR. KANNEY: Yes.

CHAIR STETKAR: Are you going to talk a little bit more about the use of that data in any of your presentations?

MR. KANNEY: Yes.

CHAIR STETKAR: Okay.

MR. KANNEY: Yes, I will talk about it sort of at a higher level. I think Don Resio and Ty Wamsley from the Corps will talk specifically about some of the older methods and how it relates to newer methods. And I think John England can also touch on the hydrometeorological reports. What is in the older reports versus what they have done.

CHAIR STETKAR: Thanks.

MR. KANNEY: Okay. There is a lot of higher resolution topographical data that is now generally available to someone doing this sort of work in the form of Digital Elevation Maps which have been standardized for much of the U.S. and that are very high-resolution compared to what was available even 20 years ago and even higher resolution for smaller areas. One can do a LIDAR survey in some cases if LIDAR surveys are available from state or government bodies. So there is a lot more data that can be put into a flooding analysis.

In addition, analytical methods and tools have evolved. You know, we can now quite easily on a desktop P.C. to 2D and distributed hydrological models. With a little bit more computational power we can do coupled wind-wave surge models. This is in contrast to essentially a quasi-1D approach that was used say for a storm surge model circa the Rev 2 of this guide.

And in addition with all of the data and the new analytical methods and tools, you can put all of these together in geographical information systems which just makes the process of doing the analysis much more tractable. And an analysis which would be extremely time consuming even 15 years ago can be done much more quickly now because of the way that one can process the information much more quickly, using GIS.

And I think I touched on this briefly before. Our computational resources have increased dramatically in terms of the capability of the resources and the costs. They are much more affordable in terms of how much data you can store, how much data you can process and how fast you can process this.

Okay, so let's move on to sort of the topics common to most of the flooding mechanisms. There is in the guide there is actually one entire appendix devoted to site hydrologic description and what I tried to do there is outline the data sources which are wildly available and the types of things that we are looking for. Obviously, the site-related elevation structures and any other equipment that is pertinent or safety-related with regard to flooding need to be described but described from the hydrologic perspective, which may be different if you are looking it at only say from a structural perspective, for example. The topography of the site needs to be described, taking into account any changes that are envisioned when the site is actually going to be constructed and then operated.

Of course water bodies that may influence flooding at the sites; streams, lakes, estuaries, man-made channels or natural channels, these things have to be described in an adequate way that you can do an engineering analysis. So that means location, size, and various hydrologic characteristics.

And in addition, if there are any water-control structures, either on the water bodies that communicate with the plant or on the plant site itself. And this could be a variety of structures. You know people think of dams and levees quite readily but also there may be intakes. There may be man-made channels. And the structures need to be considered, whether they are either upstream or downstream. Downstream structure can have an effect on the plant through backwater effects, for example. So it is not just upstream structures that are important.

And then another important part of the hydrologic description is the flooding history of the region and of the specific site. If there are any major historical floods that have happened in the region, these historical floods need to be examined. They are very good sources for, for example, validating a model which you may have, parameterizing a model that you might have. You can try to match the water levels, durations of those floods in your modelings. And we will check on the models that you are using.

And where it is available, paleoflood studies, information from paleoflood studies can be very valuable in terms of I mentioned the length of the record. In certain locations where it is available, paleoflood information could dramatically extend the record of available flooding, both in terms of what may have happened and putting a bracket on what hasn't happened. Using the paleoflood information many people think of you are looking for specific floods but look if that information tells you that you have not seen a flood that exceeded a certain level in X number of years, that is also very pertinent information.

CHAIR STETKAR: Before you get to that --

MR. KANNEY: Yes.

CHAIR STETKAR: -- and I am going to come back to this probably two or three times during the afternoon but one topic that intrigues me is this notion of using historical flooding data, historical meteorologic data to support this assessment, recognizing the fact that the whole list of criteria are that we are trying to estimate the severity of floods that have a return period, if you want to think of it that way, of once in a million years. Not once in a hundred years or a thousand years, once in a million years. There is ten to the minus six numbers there. These are floods that we have never seen because if we had seen them, for example, they would have a return period much, much more frequent than once in a million years.

So I am really interested to understand on a deterministic basis how you use an available flooding history in the United States that may go back maybe 200 years and why you don't, for example, more strongly emphasize the need to do the paleoflood studies, not where available but they shall be available? Because they at least might go back through a few millennia, which are still much less than once in a million years.

MEMBER RAY: That is the point I would make.

CHAIR STETKAR: So from a deterministic -- let me just finish my thought.

MEMBER RAY: Go ahead.

CHAIR STETKAR: There is this notion that probabilistic analyses are uncertain because there is not enough data. I maintain that deterministic analyses are even more uncertain because they rely on data that don't even exist and they rely on it as if it is fact. So I would like to kind of address you and perhaps some of the contractors out there who have thought about this more strongly that notion. Because indeed, according to the guidance, we are trying to predict floods of a severity such that they occur only once in a million years or less frequently. And that is a real challenge.

MR. KANNEY: Yes. Yes, it is.

CHAIR STETKAR: I'm sorry.

MEMBER RAY: No, I just wanted to underscore the point you are making, which is even under the best of circumstances, it seems like there is a big discrepancy between what we think is an acceptable exceedance level for a seismic event and what we could demonstrate to be an exceedance interval for a flooding event.

CHAIR STETKAR: And you brought it up. So I will follow-up on that. Thanks, you are a good straight man.

One of the questions that I have and I didn't look through the slides that perhaps will address it but let me just lay it on the table, is this notion. In the Agency's regulatory guidance there are not written requirements, to my knowledge unless Harold knows that they are written down somewhere, but in a sense we define a design-basis seismic event as an event that has an expected frequency on the order of roughly once in 10,000 to roughly once in a 100,000 years. Ten to the minus four to kind of ten to the minus five range. Typically, ten to the minus four is used. That says that that is the level of seismic acceleration at which we design our plants, once in 10,000 years.

In this regulatory guide, it says you have to design your plant to accept a flood that happens once in a million years. Well I have to design my plant to a seismic event that happens once in 10,000 years. Why do I have to design my plant to a flood that happens once in a million years? And for that matter, why do I have to design my plant to a hurricane or tornado that happens once in ten million years? Why do I get a factor of ten relaxation in flooding compared to hurricane and tornado wind-loading? Which I can point to the Reg Guide that says it is ten to the minus seven per year.

So I am interested in the rationale of why are we designing the plants to ten to the minus six events? And given the fact that we have to design them to ten to the minus six events, what kind of confidence do we have in our estimation of design-basis floods at that frequency?

Something out on the table. I hope somebody can answer that because I will come back to that at the end.

MR. KANNEY: Okay. Well, the 1E to the minus six number in this guide was actually inherited from the ANS-2.8 was adopted as Appendix B. It replaced Appendix B of this guide. When was that? Was it 1977? Okay.

And in ANS-2.8, when they went through their analysis of combined events, when they chose their combined events, what things they wanted to put together, they used 1E to the minus six annual exceedance probability as their target.

Yes, I think Nilesh wants to add something.

CHAIR STETKAR: Hi, Nilesh.

MR. CHOKSHI: This is not a definitive answer, I think as Joe said. But looking back and if I look at seismic and we have ten to the minus four, ten to the minus five, but my design has a margin. And then the way we do a design flood protection it is generally, my feeling is that margins are not equal to the seismic margin. So you may be looking at the initiating event frequency ten to the minus six but if you tried to compute maybe the total risk, it may be --

Now on the wind side, and again I could go back and look at my data but if I remember right, those are very steep hazard curves that covers those wind speed scale. And again, I think we are --

CHAIR STETKAR: They are not that steep if you look at the delta --

MR. CHOKSHI: I remember one time looking at the difference between ten to the minus seven and ten to the minus six wind speed. You know, and it might be a practical decision I can design for ten to the minus seven, so I am going to design it.

CHAIR STETKAR: I understand that. And I don't want to direct talk because there is a lot of material to cover here this afternoon. I want to make sure that we get to all of it.

MR. CHOKSHI: But that is a good question.

CHAIR STETKAR: There is pragmatism in terms of if we think we can design a structure to a ten to the minus four earthquake load and we think we can design it to a ten to the minus seven wind-loading, that is fine. That is the designers. We are in the business of trying to protect public health and safety and we ought to have criteria based on hazard frequencies that are consistent.

What the designers tell us, you know, if they can't design a structure to a ten to the minus seven wind, they had better put it in some place where they don't get ten to the minus seven winds.

MR. CHOKSHI: No, I agree. It is in all the different time frame and it has been inconsistent.

CHAIR STETKAR: Well that is part of the problem. Having grown up in the risk business, over the last 30 years, I will tell you that back in the 1970s was the first time people started to throw these numbers around but they didn't understand those numbers.

Ten to the minus seven to a lot of people in those days was the same as ten to the minus four. It was a really small number. I will start to use the technical terms teeny tiny, and itsy-bitsy. You know, teeny tiny might have been ten to the minus four and ten to the minus five is not that much lower because four versus five is not that much difference. So really teeny tiny might have been ten to the minus five but there isn't all that much difference.

There was not an appreciation of what these frequencies really mean when you start to look at the types of events that we are actually talking about here. You know, the tsunami event, for example, in Japan was not a ten to the minus six tsunami. A ten to the minus six tsunami in Japan is a heck of a lot bigger. It's not much but it is a check of a lot bigger than what hit Fukushima. And yet, we are saying we need to design a plant to that event deterministically.

That's enough.

MR. KANNEY: Okay, moving on. Another, I think sort of common thread that runs through the guide is that we have these existing design guides is what I like to call them that have been produced over the years with regard to certain natural hazards that impact flooding. There are theories of so-called hydrometeorological reports that were developed by the National Weather Service in conjunction with other federal agencies, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, the NRC funded some of this work as well. And then that is with regard to precipitation.

In regard to the hurricane, maximum hurricane wind fields, there is sort of an analogous technical report, NOAA Technical Report NWS-23. And in all of these cases, there is a great deal of data and hydrometeorological knowledge and judgment that went into these reports. These reports were technically the best available at the time.

In their intervening years, two things have happened. One, as I mentioned before, we have a longer storm record. And in some cases, some of the concepts specifically I want to calling out the Probable Maximum Hurricane concept has been superseded. It doesn't mean that these documents are totally useless. There is a great deal of valuable information in them that someone can use when looking at hazard analysis but what I tried to put into the guide is that you cannot -- maybe at one time a designer would just go to a certain page of one of these reports, pick out the parameters relevant, storm parameters relevant to their site and go with it. But one needs to do a great deal more due diligence now to look at whether the assumptions or the data for that particular area you are interested in has been superseded by a longer record or a change in concepts for your area.

CHAIR STETKAR: One of the things that has bothered me, quite honestly, as I started to read more of the regulatory guidance in the entire area of external events, is the fact that I believe the Agency, this is my own personal belief. It is a subcommittee meeting. So it is me. It is not ACRS, nor is it the subcommittee.

It has become very, very compartmentalized in terms of the way it looks at these events. Seismic people look at seismic things, flood people look at flood things, wind people look at wind things, tsunami people look at tsunami things, dam people look at dam things.

The reason I am bringing this up, this kind of rambling, is that you reference maximum hurricane wind fields and some pretty outdated reports. In July of last year, I am looking at Regulatory Guide 1.221, Design-Basis for Hurricane and Hurricane Missiles that is really updated information about hurricane wind speeds. I couldn't find a reference to that anywhere in your regulatory guide or in any of the background documents. Why is that?

MR. KANNEY: That guide only looks at the wind speeds themselves. In order to generate the surge, there are a lot of other factors in play. That is one --

CHAIR STETKAR: Okay.

MR. KANNEY: I mean, the hurricane wind fields that were produced in the Reg Guide you are talking about, the purpose of that was for structural design.

CHAIR STETKAR: Does the hurricane know that? Did Katrina know that it was supposed to have different wind speeds for structures and different other wind speeds for storm surges on Lake Pontchartrain, for example?

MR. KANNEY: Well but the way that you use the hurricane wind fields, the way that would flow into a surge analysis is different than if you were just merely doing a structural analysis. If you are doing a structural analysis for a building, you are only really worried about certain sustained gust speed. For a surge, there are basically about five different parameters with regard to the storm that you are going to need to worry about. You know, there is obviously going to be like the central pressure or central pressure deficit, the radius to maximum winds. Because you know the surge is going to be created by a wind field over a very large area. And so the angle that the storm makes as it comes into the coast, whether it is coming along the coast or straight in, and then the actual distribution of pressure within the storm is also going to be important for the surge.

And then you have the bathymetry and the topography. So you know, in my -- I'm not a wind engineer. Let me put that out there. But in the way I look at it, the structural design input that you need from the storm is a heck of a lot simpler than what you would use for the surge.

CHAIR STETKAR: You are right. You are looking at different elements of the storm. On the other hand, the folks who did the work to support this particular regulatory guide, one result of this regulatory guide that that estimated frequency of a three-second peak gust wind speed of X miles per hour did a heck of a lot of modeling of hurricanes using data, using simulation techniques, looking at things like wind fields and pressure differentials and things like that. And it is surprising that it is not even referenced. I mean, that is my whole point is we ought to at least try to tie some of these issues together, especially in areas where there is some degree of overlap. It means wind-loading on buildings, winds for storm surges and hurricanes, for example.

MR. KANNEY: Right. Well it is true that is not referenced but if you dig a little bit deeper, what we will see is that both of those guys referenced some of the same material with regard to the processes as it affects the different phenomena.

For example, in the storm surge one of the key aspects is the planetary boundary layer model that you are using. I believe that the work that Peter Vickery and his coworkers did, their planetary boundary layer model is almost exactly the same as --

CHAIR STETKAR: At some point I am sure there is common information, obviously.

MR. KANNEY: Yes. And --

MR. AHN: Can I make one comment? I am highly interested in your work. I think we are talking about same hurricane but we use two different wind speed. For the storm surge, you used a ten-minute, ten meter-high wind speed. However, the wind from the structural design, I think they used the three-second -- cost, cost, cost.

CHAIR STETKAR: Absolutely.

MR. AHN: So that is the difference.

CHAIR STETKAR: Absolutely. My only point is that information that is point that information that is published by this agency in 2011 that derives from current thoughts about how to model the behavior of hurricanes, and there is a lot of good stuff in the background of this Reg Guide, it strikes me that that same information ought to at least be referenced or acknowledged when we are talking about hurricane-driven storm surges, recognizing that we are talking about different dynamics of the particular wind field, if you want to call it that, gusts versus more sustained. But if we have learned stuff about modeling hurricanes and we are using that information to inform one of our regulatory guides for structural wind-loading, there just might be something in there that we could use to inform these efforts also, rather than relying on things that are 1974 or 1979-related.

Physics is physics. I will grant you that. Fundamental physics probably hasn't changed but our understanding of it might have changed a bit.

MR. KANNEY: I'll let Don Resio or Ty Wamsley speak a little bit more in their section but I guess the point I want to make is that in the work that the Corps did, it could be the model for the hurricane, the key thing here is how you are modeling the planetary boundary layer. And those things are very similar in the two approaches. Okay.

Okay, the other topic is broad topics of what I call non-stationarity. And I sort of identify two flavors. Some other folks I think could probably come up with other flavors but for coastal sites we do have sea-level rise. Actually in some cases you have sea-level decline. But in most cases we are worried about the sea-level rise and there are historical trends due to rebound from the glaciers. And what we point out in the guidance is basically where you can go to get this information. You know, this sort of information, the NOAA's National Ocean Service, one of their key responsibilities is tracking this sort of information and so they there is very good information about historical trends that one can use as input to your analysis.

And then for another flavor is how some of these things may change due to climate change. And here the message gets muddied, quite frankly. In terms of the potential for accelerated sea-level rise rates, there is a fairly well understood methodology recommended in reports by the U.S. Global Climate Research Program. Essentially their approach is to look at what the range of sea-level rise projections are from climates, scientists, sources for that information would be like the IPCC reports and use that to modify the historical rates that have been observed. And in the guide, there is actually ranges and numbers that have been recommended.

When it comes to other factors that one might worry about, such as increases in storm intensity, here I actually just call it ambiguous.

And the ambiguity here is that if you look at the model, the climate models and their impact analysis, they predict that there will be changes based upon a certain change in global temperatures. But if you look at the temperature rise we have seen, then go out and look at the observation for the last 20 or so years and folks at the National Hurricane Center have done this, they don't really see the trends. The trends are extremely weak and kind of in the noise.

CHAIR STETKAR: You can see decade cyclic behavior and we are probably in something like that. I mean you can actually, if you go back 100 years, 50 to 100 years, you can see cycles in severe storms depending on regions but I have done similar things.

MR. KANNEY: And then for increases in precipitation, here there is ambiguity. It is a slightly different flavor. Here if you look at say the global models are really not going to be very useful for this sort of a prediction. there are finer scale regional climate models but if you take different regional climate models, there is quite a bit of difference in the models. For one specific region, one model may say precipitation is increasing. The next model may say it is decreasing. So there is differences in just what the models say.

Then in terms of if you want to take precipitation and then transfer that into a stream discharge, again you have there are ambiguities. There are models which predict some changes. The observations on the USGS recently did a very detailed study looking at they have reference basins around the country that are relatively pristine. They are relatively undeveloped. They are gauged and so they can look for trends in these basins, which shouldn't be polluted by human activity. And they really don't see much in the way of trends.

So I put this information in the guide. It is something that one would have to watch as things move forward. But right now the only real non-stationarity that you can get your arms around and actually model is the sea-level rise aspect of it. The others you should be aware of it and I give some references in the guide to systems that people, frameworks that people have put together for doing it but we don't actually tell people you must do that.

Okay, deterministic versus probabilistic analyses. As you are well-aware, the Staff has relied mainly on deterministic approaches to the design-basis flood estimation. And in NUREG/CR-7046 that our contractor at PNNL put together, they put a nice package around this and sort of made a nice systematic description of it, the phrase they use is a hierarchical hazard assessment. Other people look at it and they say it is a progressive step-wise screening approach. But the key is when doing an analysis, start out with the most conservative, plausible assumptions consistent with the data that is available. And then if you can live with the flood that that sort of analysis gives you, then you are pretty much done with the analysis.

The idea here is to streamline the analysis by using conservative and simplified analysis in place of something which would take you a lot more effort to do is basically the idea.

MEMBER RAY: Well but what does it realize? What does it achieve in terms of exceedance interval do we think?

MR. KANNEY: That is the problem.

MEMBER RAY: Everybody wants it to be easy and simple. But you know, seismic research isn't easy, particularly in the West. It is a lot of work. People spend a lot of time and effort to identify what the seismic structures are and yet we don't seem to require much at all when it comes to flooding. I'm talking about recurrence interval. I'm not talking about competence.

CHAIR STETKAR: The way I look at this, and by the way I was going to bring this up when PNNL comes up but we are going to run short on time so I might as well get it on the table. It is relevant to what you just said, Harold. This HHA concept is not novel. It is not new and it doesn't at all address the recurrence interval of the hazard, regardless of what people say. It is directly analogous to the process that is followed in NUREG/CR-6850, write it down, look it up, for the valuation of internal fires. You start with a fire whose frequency you derive from data. In the case of fires we do have data. You presume that that fire burns everything in this room the worst way possible and see what the risk is from that fire. Then, if you cannot survive that level of risk, you start to apply refinements to the analysis. In many cases, those refinements deal with modeling the physics of a fire, which is the same level of refinement in terms of modeling the local hydrology modeling, perhaps. If it is a seismically-induced dam failure, the fragility of that dam, it doesn't necessarily address the initial frequency of the fire, it refines your understanding of the consequences of that fire. This HHA process is exactly analogous to that. Now, within the construct of CR-6850 we have a framework to systematically examine the consequences of events for which in fire analysis we have guidance to develop frequency. We also have guidance about how to evaluate uncertainties in the models for physics of fires, which we could evaluate, for example, in the models for hydrology, they are directly analogous from a modeling perspective.

So that this framework is nothing new. I'm glad to see that it sort of parallels that higher assessment process or the process that is used in a probabilistic analysis of many, many hazards. It doesn't address the initial hazard frequency. It doesn't address the frequency of a tsunami. It doesn't address the exceedance frequency of a rainfall of X number of feet in Y number of hours.

MEMBER RAY: The word that comes to my mind in seismic area is source characterization.

CHAIR STETKAR: That's right. This process doesn't --

MEMBER RAY: You have got to spend 16 to 100 million dollars doing a seismic source characterization. You know, you spend $250,000 doing this. The two things just don't seem to make -- they don't line up for whatever reason I don't understand.

CHAIR STETKAR: So take that as it is. I mean, we can discuss more of the elements of that but I look at the HHA process as refining the consequences of an event for which we have an input frequency. It doesn't tell me how to find that frequency, that input frequency, that hazard, that exceedance frequency.

MR. KANNEY: That's correct. HHH has not addressed initiating the frequency of any initiated event. You have to --

MS. SPEECE: And I think in the sense of what you discussed earlier and what Harold said certainly in this case, the real challenge is assessing what that exceedance frequency is and our confidence in that exceedance frequency.

Maybe we can live with it once we understand what that frequency is and what the magnitude of the hazard is. Maybe we don't need to do any further refinements.

MR. KANNEY: Then so with regard to probabilistic characterization, what we have put in the new draft guide, and in fact this actually isn't new. This was actually in ANS-2.8, you know, we don't provide any specific guidance on probabilistic hazard assessment in this guide. It certainly doesn't rule out any applicant doing such an analysis. Such an analysis would be reviewed on a case-by-case basis. If you look in the existing guide and in the new guide, the only really specific guidance there is really in terms of the target for combined events. You know, when you look at different combined events to come up with your design-based flood, you have to have in mind some idea really of some level of probability.

What was proposed in ANS-2.8 was 1E to the minus six. I have it here in this -- I have less than 1E to the minus six. That's not really true. I'm not sure why I wrote that. They have a target of 1E to the minus six.

CHAIR STETKAR: That means if I am 1.0001 E to the minus six, I fail the test. And if I am 9.9997 E to the minus seven, I pass the test?

MR. KANNEY: In ANS-2.8 and as far as I know in other areas, there is a lot of qualitative balancing that goes into this. I have not seen too many combined events analyses that do this rigorously.

CHAIR STETKAR: Well is it time to perhaps, in the United States in the year 2012 that we start to do things a little bit more rigorously?

MR. KANNEY: I would agree so.

CHAIR STETKAR: Okay.

MR. KANNEY: And we will talk about that later.

MEMBER RAY: Well I just don't understand how we associate this exceedance, probability of exceedance with the actual methodology that we go through. The two things just seemed like totally disconnected to me.

MR. KANNEY: In this, in 2.8 and every instance where I have seen it applied, it is applied in a qualitative sense --

CHAIR STETKAR: And we are cheating ourselves.

MR. KANNEY: -- and not in a rigorous sense.

CHAIR STETKAR: Okay.

MR. KANNEY: I have never seen it applied that way.

CHAIR STETKAR: But how do we have any confidence? And it is carefully stated in the Reg Guide that exceedance frequency applies when we think about somehow combined flooding scenarios, severe precipitation with wind or something like that.

Do we have any criteria for assessing the frequency of individual flooding scenarios? Individual flooding mechanisms. Let me call it that.

MR. KANNEY: There is some information. You can look at a historical record. You can do some frequency analysis on precipitation. You can do some frequency analysis on flooding. The problem that you get into is that the record is fairly short. And if you want to get to the return periods that we are particularly interested for design-basis flood estimation, you have done a great deal of extrapolation. And then your confidence interval around that gets very large.

MEMBER RAY: Well sure but in the seismic area they put together the shack process. Okay? They get a bunch of experts together and at the end of the day they come out with a curve. Nobody has any evidence at all on the upper end of that curve. I mean, it is strictly a consensus judgment of experts. But we don't seem to be in any way approaching that same methodology here.

It just seems anomalous.

MR. KANNEY: To my knowledge, that exact same process has not been applied in too many flooding analyses, with the exception of that type of process has been applied to dam failure. There have been instances where committees have been put together and they have tried to come up with some sort of generic dam failure probabilities. Those are the only things that I am aware of.

Just ask my colleagues in NRO if they have seen anything else. They are all nodding their heads no.

CHAIR STETKAR: Joe, let me ask you something. I am a big proponent of uncertainty. And I am a big proponent of telling the truth about uncertainties. So you said well gee it is really difficult to do a probabilistic analysis and our confidence intervals expand wildly when I try to do that. Do I have any more certainty about a deterministic analysis? Nature is nature. There is uncertainty. That is a fact. I either address it and show people what my uncertainty is today or I ignore it and delude people that I somehow have knowledge about how things work.

So how if I am doing a deterministic analysis do I have exceedingly more certainty about the results of that analysis, compared to doing a probabilistic analysis when I do in fact admit that I have very large uncertainties? Larger uncertainties about some mechanisms than others, perhaps, but large uncertainties.

MR. KANNEY: The advantage of doing the

probabilistic approach is that it gives you your estimate and an estimate of the uncertainty. That is the real value in that approach. I see the value in that approach.

Now I guess in my opinion what we were faced with here is were we ready to develop a guidance, provide guidance on the probabilistic flood hazard assessment. And at this point in time, we are not really ready to do that.

Now later on this afternoon I will talk to you about some of the activities that we have underway and we are trying to move in that direction but we are not there now.

But that being said, even if you are going to do a probabilistic analysis, you are going to use a lot of deterministic tools in that analysis. And we think that with this guide we have addressed a lot of the updating, if you will, in the deterministic approaches, which would be used in the probabilistic approach.

CHAIR STETKAR: You are absolutely correct in that.

MR. KANNEY: So we have sort of sliced it that way. We have tackled one piece and we would like to move on to the next piece.

Okay, I am going to try to speed up now.

CHAIR STETKAR: Yes, we are never going to get through all of this material. And I will try to be quiet.

MR. KANNEY: Well if you guys would look back to the outline, is there something specifically you would like to see or specifically something you would like me to skip? If you can tell me that right now, I can do that or I will just try to speed up and go through it.

MEMBER RAY: I don't know. I read the disc.

CHAIR STETKAR: I was going to say my topics tend to be at that higher level of addressing probabilistic analysis versus deterministic analysis and trying to understand what this guidance goes through.

Why don't you try to get through this and let's play it by ear in terms of time.

MR. KANNEY: Okay, I'll go through it quickly.

With regard to local intense precipitation, the key ideas here are this is an analysis which you need to do, regardless of where your plant is sited. Your plant can be sited very far from the ocean, very high above a river, very far from a lake or high above a lake. It is basically what you are looking at here is the hazard from an intense local storm that could overwhelm the site drainage or the grading. That is what you are looking for here.

One of the inputs I sort of called out here is those design storm documents. So all of the caveats that go with that go with this as well. And there is specific guidance given by the weather service in one of the HMRs for developing the hypothetical storm that you are looking at in terms of the area, the duration, the distribution of the intensities. And the key elements here, you know, you have that design storm. You have to specify it. You will model the generation of the surface runoff from that storm and then you will also model how that is routed through the conveyances. And in that analysis, we specifically give guidance that you need to address deterioration of that draining system. You know, assume that you may get some blockage because experience shows that that is what happens in large storms. There is trash. There is dirt. There is sediment. You know, there are things that can plug up drainage. So when you do that analysis, you need to account for the fact that you may not have it all there.

CHAIR STETKAR: Joe?

MR. KANNEY: Yes.

CHAIR STETKAR: You probably addressed sometime this afternoon the notion of probable maximum something or other. Are you? I mean, do you have an explicit discussion of that?

MEMBER BROWN: On the next page.

CHAIR STETKAR: Well, no. I mean the term will show up but are you going to discuss the concept explicitly? Because if you are not, I want to bring it up now.

MR. KANNEY: Okay, let's bring it up now.

CHAIR STETKAR: Okay. One thing that I am trying to get my hands around is as I read the Reg Guide and the supporting documents, the terms maximum credible, probably maximum appear often. And this notion of a probable maximum something or other, whether it is probable maximum precipitation, or probable maximum tsunami, or probably maximum hurricane, or probable maximum whatever is a fundamental concept in this way of thinking about design-basis hazards.

What I am struggling with is I would like to understand what that concept means. Because as I read through the guidance I see sort of three sets of terms that are used that are, to me anyway, different notions. I see terms, and these are just excerpts that I wrote down, the physical limit of a natural event thought to be meteorologically possible. The greatest depth of precipitation for a given duration that is physically possible. That to me is a notion of there is some physical constraint such that the event cannot be worse than this; cannot by physics. So that is one notion.

Another notion is considered to be the most severe reasonably possible, most severe that can reasonably occur, most severe combination of meteorological storm parameters that is considered reasonably possible. This a notion of frequency in the sense of what is reasonably possible within our state of knowledge about how often things can occur. That is different from the worst thing that could ever possibly occur.

And then there is another notion that says most severe of the natural phenomena that have been historically reported for the site. Now that also has a frequency but it constrains my notion to what is history. Is it 30 years? Some people look at 30 years' worth of data. Is it 50? Is it 100? Is it a couple hundred years? Is it a couple of millennia?

So I would like to understand and I think it is important that the regulatory guide defined and it has a nice glossary and I have excerpted all of these phrases from that glossary of what is the concept of a probable maximum whatever. Is it what is limited by physics or is it some frequency notion, which is something that is then not the worst possible thing that can happen, it is just something that we will accept that frequency of that severity.

MR. KANNEY: The third definition that you give there, later I will ask you to point out exactly where that is because that doesn't --

CHAIR STETKAR: Yes, okay. You are going to --

MR. KANNEY: I don't want to slow us down now but that third definition, that third flavor that you give, I wouldn't actually consider that consistent with the probable maximum concept. And so I would like to --

CHAIR STETKAR: Probable maximum tsunami. It is in Appendix I, the glossary. I will read it for the record.

MR. KANNEY: Okay.

CHAIR STETKAR: That tsunami for which the impact of the site is derived from the use of best available scientific information to arrive at a set of scenarios reasonably expected to affect the Nuclear Power Plant site, taking into account: 1) appropriate consideration of the most severe of the natural phenomena that had been historically reported at the site and surrounding area, which sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated; 2) appropriate combinations of the effects of normal and accident conditions which the effects of the natural phenomena; and 3) the importance of the safety functions to be performed.

Two and three are evaluations of the consequence of the tsunami. They don't have anything to do with the frequency of the hazard. That's where I got the third --

MR. KANNEY: Okay but the key word in that third one is the margin. That is what makes it consistent with the other two.

The fundamental sort of philosophical concept that the probable maximum whatever was based on was the idea at the time that these physical processes, that there were physical limits.

CHAIR STETKAR: Okay.

MR. KANNEY: If you look at various textbooks on hydrology, there is a very famous graph that shows the precipitation for various durations. And it lines up on a very nice linear plot as you go out in terms of duration. And when these concepts were put together, the thinking was that yes, there is a physical limit to many of these processes.

CHAIR STETKAR: And if indeed that is what we are calculating, I have absolutely no problem whatsoever of defining a probable maximum. I will call it a Joe.

MR. KANNEY: Right but --

CHAIR STETKAR: And to avoid this notion of probable maximum that a bounding hazard which cannot be exceeded at a particular site and use that as at least my starting point for evaluating the design basis for that site.

If we back off from that, we are now in the exceedance frequency realm.

MR. KANNEY: Chris wants to say something. Let me just make one point and then Chris, go ahead.

There is one -- philosophically, the basis for this is that at the time this stuff was developed, you know, meteorologists, hydrologists thought that there were physical limitations. Now, do we know what they are? The answer is not really.

This is where sort of the fudge comes into this concept is that even if we agree that there is a physical limit, you know how sure are we that we are modeling all the processes correctly that we are capturing it? That is a slightly different question.

In my opinion, this has always been an unfortunate terminology. These are estimates. The idea is this probable maximum, the maximum credible, it is -- we get away from the idea that these are still estimates. Estimates can be wrong. Estimates can be exceeded. We shouldn't fool ourselves that an estimate that we make today, knowing what we know, doing a deterministic basis, that we have got it right, that it will always be the maximum.

And the reason, one of the main reasons is although this has always been called probable maximum the starting point has always been the available record. Now there are various techniques to take the available record and apply these maximization steps to it. But these maximization steps have always been judgment-based. And so they are estimates. We shouldn't fool ourselves. They are estimates.

MEMBER RAY: Well I don't think that -- that being true without a question, to me the larger question is how do we go about -- do we limit ourselves in terms of the record that you referred to that we can access or do we attempt other means of hazard characterization such as modeling?

And it seems to me that we, in this agency, are not on the leading edge of how hazards are being assessed today through use of modeling that enables you to project events for which there is no historical record. Because you need to do that, given the consequences of the events, for some very, very low frequency for which it is doubtful that there is going to be any record at all.

And that is basically where I am in terms of assessing. The subject matter is why is it that we can't use models for low frequency events in lieu of historical evidence of those events, which we are never going to find?

CHAIR STETKAR: Well, it is not necessarily in lieu of. Informed by at least what we have available, and use the models to help us extrapolate, which is what the size model --

MEMBER RAY: All right, that is better said, maybe.

MR. CHOKSHI: Dr. Ray, I think you said -- the problem with the flood is that physical models you can only take compared to seismic. We are forced to assume stationary process. So you have like the seismic source characterization things and the attenuation you can model and assume that those are reflected in the time frame.

I think in the physics Joe went into this non-stationarity, you know the river channel will change and that there are some parts that they can model physically and that is what they are trying to use probabilistic like dam, bridge, or tsunami because the tsunami is generated by seismic eventually the land slides.

But things like PMP, it is really difficult to build a physical model which can apply generally. And I think Joe is going to talk about our plan to explore what is the current state of the art. But it has been the state of practice hasn't really matured or, and Joe correct me, physical models I don't think are available to do that low frequency extension.

MEMBER RAY: Well my assessment of it, after having looked at it since the Fukushima event anyway is they aren't available because we don't want to make the effort to create them.

(Laughter.)

MEMBER RAY: That is the explanation, period.

MR. CHOKSHI: And that is the one thing we were starting to explore and I think Joe is going to talk about that later on what is our plan systematically.

You know my way of thinking this, if you really want to get the science here to do what we did for seismic, SSRP, we need to go back systematically, look at it, identify gaps, and it will take some time and effort to get the profession to buy into that idea.

MEMBER RAY: Well that may be but I don't think by asking people about whether we should do it or not in a workshop is necessarily the best way to arrive at a conclusion.

MR. CHOKSHI: No, I think conclusion is to identify how do we approach this problem? How do we structure the program?

MEMBER RAY: Okay, well that is what we are trying to have a dialogue about.

CHAIR STETKAR: I think one of the things I think that bothers probably Harold as much as I is that it is seems as though the Reg Guide says until we have the unified theory about how to probabilistically address every single flooding mechanism that we can think about, we rely on the old deterministic ways. That is the message that I get anyway.

MR. KANNEY: I guess --

CHAIR STETKAR: And there are --

MR. KANNEY: You are correct. The exception I think is the storm surge. I think the research that the Corps did there I think lays out a very mature -- it is a hybrid approach but that actually is part of the beauty of it is to look at certain things which we think do have some asymptotic limits based upon the physics, take those to their limits, and then address uncertainty with regard to other parameters.

I think with the exception of the storm surge part, you are correct.

CHAIR STETKAR: And one of my points is though that at least having struggled with some of these issues from the PRA side of the line, I will grant you that the methods for evaluating the current state of the practice methods for evaluating some of the flooding hazards, certainly need work.

On the other hand, the current state of the practice methods for dealing with others of the flooding hazards, I wouldn't call them necessarily mature but they have been fairly well applied. And the notion that we can't do any of it until we understand how to perfectly do everything basically begs the question of just well it is just the status quo until we have the ultimate solution. And by the time we all are retired, we won't have to worry about that.

And it is a different philosophy. Is this in 2012 an agency that promotes the use of probabilistic methods, risk-informed methods whenever we can use them and tries to press the issue to promote it or is it that we use deterministic methods until we solve every single problem?

And that is another way to sort of provoke the industry to respond to help developing methods in addition to us.

MEMBER RAY: John, would you accept that it is not just deterministic methods but it is deterministic methods which are limited to available evidence?

CHAIR STETKAR: Deterministic methods in the context of --

MEMBER RAY: I don't mind a deterministic method of it is able to at least model a phenomenon for which we have no record and make some assessment of it.

CHAIR STETKAR: Yes, Harold, I absolutely agree with that. That is where I was falling back to, the notion of probable maximum whatever. If I can have some confidence that what I am assessing is indeed limited by my models for physics or my understanding of physics and I can live with that, that's fine. But that is not limited to the last hundred years' worth of storm records.

MEMBER RAY: Okay. We keep saying this and then not doing it but we had better let him get on with it.

CHAIR STETKAR: It is an issue at our subcommittee meeting.

MEMBER RAY: We have tried to convey to you what is really on our minds because we have read through all of this stuff.

CHAIR STETKAR: I mean there is a lot of good stuff in here and you will be given an opportunity to go through it but I think --

MR. KANNEY: But.

CHAIR STETKAR: -- you are getting a sense of our -- but.

MR. KANNEY: Okay, so moving on to riverine flooding, there is a couple slides here. You know, the key points, I guess.

Any drainage basin that communicates with a site needs to be assessed for flooding hazards. That communication with the site may be due to backwater effects, for example. So it is not just upstream. And there are a variety of hydrometeorologic conditions that need be considered.

One thing that we wanted to pull out is that in the previous revision there was an appendix -- there is an Appendix B which has maps and tables that were developed from envelope curve formulas. These really are no longer recommended. I think very quickly after some of them were put together I think some folks looked at them and said well for this basin, this estimate might be exceeded.

At a certain time in hydrology the envelope curve approach was widely applied. And the Reg Guide was developed in that era. We just, you know, we have no intention of going back and revalidating all of that information, if it was even possible. So we are just saying do not use those.

And the thing is those were put together to make it easy for folks to do the analysis because the analysis at that time was much more intractable than it is today. We have better models, faster computers. You can do the site-specific analysis much easier than you could do it back then. So the need for going to this sort of cookbook approach really has been overtaken by our capabilities in terms of data processing and new models. We just don't need to do it anymore. We can do a better job.

CHAIR STETKAR: And a simple-minded approach isn't too bad if you are interested in insurance company loss prevention or possible flooding damage in a coastal zone because your time horizon is probably on the order of once in a hundred years to once in 500 years, not the horizons we are looking at. So the simple approach is to give you confidence at intervals, it is okay.

MR. KANNEY: Right. And then the combinations of hydrometeorologic conditions obviously are going to be site-specific. But in general, there are categories such as sequential precipitation events, the timing and centering of a storm over a river basin. You need to play around with those. If there are seasonal variations in terms of antecedent moisture or maybe snowpack accumulations, those sorts of things, and of course dam failure, and in most cases, winds. You know strong storms have strong winds. Almost always the wind wave should be considered.

Sort of the key elements in any flooding analysis. This is very similar to the local intense precipitation. You are going to have to start with some design rainfall. I'm not going to go into that very much. Again, the basis typically have been to look at procedures developed by the weather service, either the probable maximum events, the weather service also provides information on precipitation frequency. Typically those, again, are not of the duration that we are -- or the recurrence interval that we are interested in. The weather service provides precipitation frequency out to one in a thousand years I believe is the longest duration they use.

Once you have that design rainfall, you will apply some sort of rainfall-runoff analysis to get the flux of water to the river channel. And then once you have it in the river channel, you would route that flood to the site. Okay?

Dam failure. Again the idea is that you can either consider dams both upstream and downstream of the site because of backwater effects. And also when we talk about dams in this guide really what we mean is basically any of these water control structures. It could be a classic dam but it still you could also be talking about levees either on or off-site or some sort of water-control structure. We have sort of lumped them into the idea of dams.

It is true that you can apply some screening arguments that certain dams might be eliminated from consideration because some combination of low head, large distance from the plant, very small water retention capacity, things like that.

There are several categories of dam failure that depending on the type of dam you would want to look at broadly hydrometeorologic dam failure due to a precipitation and flooding event; seismic dam failure; and then dam failure from some other causes, so-called sunny-day failures like piping would be the poster child for that type of failure. These types of categories need to be considered again, for the particular type of dam you have.

CHAIR STETKAR: One quick one.

MR. KANNEY: Yes.

CHAIR STETKAR: And this is not a philosophical. This is actually a real focus question. As I read it, the vast majority of the discussion of dam failures here focuses on dam failures leading to inundation of the site, flooding of the site.

A couple of places I stumbled across the notion of dam failures that also affect the plant's safety-related water supply or I will call it the ultimate heat sink. I will give you an example. An impoundment dam for the ultimate heat sink reservoir which may fail and either completely drain, which is unlikely, the ultimate heat sink, or drain a substantial volume of the water from that ultimate heat sink such that my design-basis, whether it is 72 hours or seven days or whatever cooling water supply is now compromised. That dam failure could be initiated by a seismic event. That dam failure could also be initiated by hydrologic conditions coming down the river valley.

Where do we integrate those notions of dam failures that not only inundate the site which are clearly addressed in the context of this NUREG but dam failures that take away a site's water supply, which may have the same causes, seismic events, other upstream dam failures, a sequential hydrologic loading or severe precipitation, are those other types of effects of dam failures -- where are those addressed? And are they addressed consistently so that if I am a plant owner and have to look at dam failures I don't look at them different from dam failures that drown me versus dam failures that make me dry?

MR. AHN: Hosung Ahn from NRO. When we evaluate dam failure, we evaluate both flooding effect as well as subprime or low water effects to the systems.

CHAIR STETKAR: It is the intent of this Reg Guide, then, to also include the issue of dam failures in that second context?

MR. AHN: Yes. I think we automatically include that part in into there.

CHAIR STETKAR: I will tell you it wasn't clear, if it was the intent of this Reg Guide, to include that second part. It really wasn't clear.

MR. AHN: It may not be clear on there but in SRP 2.44 that is already in there.

CHAIR STETKAR: Okay, that is SRP and I am looking for the regulatory guidance so that a reviewer can point to something that gives the guidance and somebody, the owner or operator of a plant understands how to think about that problem.

So I will just throw that out. As I said, it is a focus question. I did stumble across the notion of degraded plant water supply in a couple of places but it was a minor secondary notion. That is why I wanted to bring it up.

Because obviously, the same types of mechanisms can apply. And I would hate that people are using different sets of guidance to think about the problem differently.

MR. KANNEY: I mean there are sections of the safety analysis reports that deal with the loss of ultimate heat sink.

CHAIR STETKAR: Sure.

MR. KANNEY: Now if that loss of ultimate heat sink is from a flooding, if that is a credible mechanism for losing whatever ultimate heat sink you are worried about, then you would refer back to this guidance for methodology to analyze the flood. Is that what you are asking?

CHAIR STETKAR: No, you are not getting the point.

I understand a flood wave coming and taking away, for example, my intake structure. I can handle that, taking away my service water pumps. Fukushima can understand that. What I am talking about is either a precipitation-related or a cascading dam failure such that I have something coming down now through my, let's call it a river stream, that could result in flooding of my site. It may or may not, depending on the elevation of that water. It could also take out my downstream dam that is impounding my cooling water system.

Now maybe I am lucky and it didn't flood the site but now I don't have any cooling water left because as the wave went through it took out my downstream dam and took away my cooling water. A seismic event could do the same thing. It might not flood my site but it might take away part of my essential cooling water supply.

My only point is that if we are evaluating, in this case, dam failures for the effects of flooding the site, does the same guidance, regulatory guidance, apply to evaluating the dam failures that might take away my cooling water supply or the events that might result in either one or both of those things?

What I am hearing is that the staff looks at both of those when they evaluate an FSAR. What I heard you say is well they would point to this Reg Guide for the inundation. Where would they point for the other part?

MR. CHOKSHI: Yes, but I think it is specifically required in SRP 2.44 to review and it is also in Reg Guide 1.206 what licensee applicant has to address that element.

Because this is a design-basis flaw so it doesn't talk about loss of UHS. But when it comes to the matters, they look at this matters if the dam breaches for analysis.

So you are right. I mean it is identified in the SRP process but not in a separate record. But there is a consistency between we look at upstream dam and downstream dam.

CHAIR STETKAR: Okay but in 2012, I mean I could see easily how this Reg Guide could be tweaked just a little bit to say look at the same phenomenon in terms of taking away your ultimate heat sink.

MR. CHOKSHI: Absolutely. Right.

CHAIR STETKAR: The phenomena aren't any different.

MR. CHOKSHI: Or you could cross-reference.

CHAIR STETKAR: I think off-loading is no different. The seismic events are no different. It is just --

MR. CHOKSHI: I think that is a good comment and we could cross-reference and we just --

MR. KANNEY: I will --

CHAIR STETKAR: It is part of this

integration thing.

MR. KANNEY: I will certainly look at the wording that we have there and perhaps it can be beefed up.

But we talk about this, you know the methodology here is applicable to any safety-related structure, which needs to be designed to a standard --

CHAIR STETKAR: Let's see if we can move on.

MR. KANNEY: Okay, with regard to coastal flooding. Okay again coastal flooding are going to several different separate phenomena. There could be storm surge, seiche, and tsunami all of which may be relevant to coastal regions. Surge and seiche are almost always going to be associated with wind-generated wave activity as well. And any of these can be also you would have to look at the impacts of tides. That is sort of common to all coastal flooding phenomena.

With respect to storm surge itself, here we sort of call out again an appendix from the Rev. 2, which again had maps and tables for the purposes of screening sites which are no longer applicable again, based upon old data. In this case for the storm surge, based upon some very, very old and simplified models, essentially 1-D models which really didn't take into account the bathymetry or the topography of the site, very simplified. They were meant to be conservative but there is actually I think there is no reason to do this anymore.

And for a storm surge with the other flooding mechanisms, you know, if there are historical storm events in the region, these should be analyzed quite closely because they are going to give you a lot of information that you can use in the modeling that you are using for your site to parameterize that model, to validate that model. But the historical record is just never going to be enough. You are going to have to parameterize synthetic storms in order to arrive at a suite of storms which you think brackets or captures the hazards that you might see there. And there is going to have to be some meteorological reasoning that forms a basis for that.

Within storm surge there can be different varieties. For your region, you need to look at the types that you may see. Everyone thinks of hurricanes or tropical cyclones. But extratropical cyclones can produce flooding, which is much more extensive in terms of the spatial extent and its duration. And that is not often thought about too much. Also in certain areas squall lines can produce significant storm surge. The Great Lakes would be a good example of that.

And then there are these hybrid storms. You have hurricanes or tropical cyclones which interact with extratropical cyclones. There is a whole process where tropical cyclones transition into extratropical cyclones. They can still have significant wind fields and generate significant surges.

In some cases, simplified methods can be used to screen out sites which are not subject to surge. Again, based typically upon distance and height away from the coast. But the current state of the art here, and our colleagues from the Corps of Engineers can talk about this in more detail, is to use for sites where you need to do a more detailed analysis, a coupled hydronamic ocean circulation and wave model and that needs to be driven by an atmospheric boundary layer model, which provides your atmospheric forcing.

For seiche, I don't want to say too much about this. At any coastal site it should be considered. And the idea is that there can be local phenomena that are forcing that seiche due to storms particularly, barometric pressure fluctuations, strong winds that may change in direction, passage of local storms, these are very important, especially for enclosed bodies like lakes, bays, things like that.

But also there are some distant forcing mechanisms: tsunami, for example, earthquake-generated seismic waves, or say for example a distant storm where a wave train arrives at the coast and you have the particular configuration where those arriving wave trains can set up a seiche in a bay or in an enclosed water body.

For very simple geometric configurations there are some analytical formulas one can use. But in most cases you are going to have to use what they call numerical long-wave modeling or shallow water equation models, which will sole the shallow water equations for a complex configuration to figure out whether the natural modes of the water body you are interested in can be forced by the modes of any of the things which would cause a seiche in your area.

For tsunami, much of this is just taking -- I should call out there is a separate -- I didn't put it here unfortunately. It is referenced in the guide, there is a separate NUREG/CR report, CR-6966 that the folks at PNNL put together for NRO. And that was actually before much of this work got underway and the stuff that you see here about the different tsunami hazard zones, the tsunami assessment, the screening and detailed assessment is all from that particular NUREG, CR.

Okay, very quickly ice effects. There are certain areas where these need to be considered. There is again some very good databases that are available from NOAA regarding the temperature ranges for various areas of the country, the temperature history that you can compare, that you can consult for seeing whether a site is at risk. And there is also a very good database put together by the Army Corps of Engineers Cold Regions Research Lab where they actually track ice-jams on a variety of northern rivers and lakes and that information is available online. So in any region where ice effects may come into consideration, these are two very, very valuable and currently maintained and up-to-date data sources.

Now one of the key aspects of the ice-jams is that it is really not possible to predict precisely where one is going to occur. So again, you have to come up with a synthetic, a hypothetical ice-jam and then look at its consequences. And ice-jams both upstream and downstream can be important. If there is an ice-jam that forms downstream, you would have backwater effects. If you had an ice-jam that forms upstream when that dam then breaks, you can have inundation of the site.

One thing about when you have an ice-jam say that is downstream of the site, one of the things that is often overlooked is that even if you have a stream that the water levels don't rise very rapidly due to hydrometeorologic floods, that rate of water level rise due to an ice-jam can be much, much, much faster. So in terms of your lead time that you are thinking about for flooding, that would be quite different in terms of effects versus the meteorological floods that you might see in the same river.

Combined events. Basically for any particular site, you will have events which are possible for that region and you want to combine these in reasonable ways.

Now when looking at probabilities, again you need to account for the fact that many of these mechanisms are not independent. So that you may have say a frequency of one event and a frequency of another event. But if they are not truly independent, they are common cause from a hydrometeorologic perspective, you can't treat them as independent events and that needs to be taken into account.

Certain things I would say should almost always be considered say for example if you are at the coast, you know, astronomical high tides could certainly coincide with something that is hydrometeorologic in origin for example or could be combined with a seismic or seiche events.

But again, the combination or sequences that you are going to have to consider are going to be on a site-specific basis. And the guide outlines a number of candidate combinations for various sites, whether you are beside a lake or river or at a coastal site. These were basically adopted from ANS on 2.8 and these combinations were put together again with the target, qualitative target I guess is probably the best way to describe it, of having exceedance of about 1E to the minus six.

CHAIR STETKAR: The question I have, and again we are running short on time so I will try to keep this short, is that as I read through that list, that is Appendix H, there all kinds of caveats in the introduction that says look, this is not a cookbook list. Don't treat it as a cookbook list. It is examples of things you ought to think about. And then it degrades into a cookbook list. It says you take a two-year wind event with a maximum precipitation. And the notion is that you don't want to take necessarily the worst possible combination of two things and infer that they could occur coincidentally. It is an attempt to be some sort of compromise without being too quantitative about any basis for anything. I understand the intent at that level.

On the other hand, the concern is that people will indeed treat it as a cookbook and that staff reviewers will treat it as a cookbook. If I do not evaluate that list of things at my site, I don't pass the muster. And if I don't justify why I didn't use a two-year wind event instead of a four-year wind event or a 12-year wind event, I might not pass.

So my question is why do we need that very detailed list of things that regardless of what you say will, I believe, anyway, degrade into a cookbook.

Now people have been using the Reg Guide. And I don't know how the reviewers use the Reg Guide but there is a big concern there, especially when I start thinking about combined exceedance frequencies, which is the way I think about everything.

So I just throw that out as something as I was reading. Believe me, I understand your intent but I am worried about how it will be used in practice and how those examples are actually interpreted by people.

MS. CAVERLY: Jill Caverly. I'm a reviewer here at NRO and I think I might just speak for some of the Staff here. We use it simply as a starting point for our reviews. And we believe that we need to look at other combinations of events that are pertinent to a certain site.

CHAIR STETKAR: But for example if I were to do an analysis and said I am going to take some level, some stillwater level and apply a 19-month wind speed instead of a 24-month wind speed, how would you react to that?

MS. CAVERLY: Well I think I would need to have some explanation as to why you would choose those two things but --

CHAIR STETKAR: Okay.

MS. CAVERLY: -- at a minimum we would start with -- this would be our starting point.

CHAIR STETKAR: Okay.

MR. KANNEY: Yes. I guess I would just add to that that for many of these I would look at the sensitivity. If there is, for example, the 24-month versus the 19-month, are we sensitive to that? Are the results sensitive to that? Then yes, you would have to dig deeper and look for a real rationale, a basis for that.

If the results are not sensitive to that, then it really wouldn't matter.

CHAIR STETKAR: If I get out to my ten to the minus six, taking a 0.5 per year exceedance frequency for a wind, which is a two-year recurrence interval, 0.5 per year, and multiplying that or combining it now with some elevation, stillwater elevation of a water body must mean that the frequency of that stillwater elevation is something on the order of about two times ten to the minus six per year.

Otherwise, when I combine a 0.5 event per year with a number I get something greater than 1E to the minus six. So why am I only looking at a 0.5 times a two times ten to the minus -- why am I not looking at a once in a thousand year wind speed in combination with a once in a thousand year stillwater elevation? Much more likely to have that elevation. Much less likely to have that wind speed, perhaps. You know, why am I stylized that I use a 0.5 exceedance frequency for a wind speed with some guess about what some elevation might be at some exceedance frequency and infer that if I am okay for that I need my ten to the minus six per year exceedance frequency for a design-basis flood? I don't understand why that is the case.

When I look at once in a hundred year in a combination with a once in ten thousand year stillwater elevation, that also will give me a ten to the minus six, perhaps more likely than my 0.5 with a two times ten to the minus six stillwater elevation.

And I will just leave it at that. That is the danger of using those very explicit criteria. And you are saying well I didn't use an 18-month wind speed because it says here I am supposed to use a once in 24-month wind speed. Okay, the 18-month wind speed with a much less likely level would give me the same problem.

MR. KANNEY: Okay.

CHAIR STETKAR: So regardless of what you say about it, it shouldn't be a cookbook. It will be used that way.

MR. KANNEY: Okay. All right, point well taken.

Okay, very quickly concurrence reviews. The draft guide is concurrence right now. We actually have the Reg Guide development branch handles this very nicely, all the mechanics of shipping this out to the various offices for us. And all I wanted to show you here is so you guys here have a sense of all of the different offices and divisions who use this guide and have an interest and that they are in fact being consulted in the process.

And we are good way through the process. Two of the regions have concurred already. Several of the divisions and NRR have concurred. Some of them with comments, some without, obviously.

I guess one point we had a discussion in terms of scheduling with you and I believe Dr. Ray a few weeks back about how the concurrence reviews may interface with the activities for the recommendation 2.1 implementation, the flooding reevaluations. And our colleagues in NRO came to us and said well we have this process going on. We are actually going to be reevaluating or the licensees are going to be reevaluating their flooding hazard for all of these sites which hasn't been done in years, and years, and years. We certainly have an expectation or they have an expectation that we are going to learn a lot as we go through that process. And they would like to fold the lessons learned from that process into their concurrence on this guide. And that has been discussed with the Reg Guide development branch and with my branch. And we think it probably won't result in large delays in getting the guide out but that is the current plan is for us to work several months through the 2.1 process.

As part of that process there is going to be the industry representatives have mentioned that they want to from time to time come back to the Staff with clarifying questions with what they call frequently asked questions. And the Staff's response to these questions may provide some very good input for the guide.

CHAIR STETKAR: Joe let me just make sure I understand. Is your plan then to not issue the Reg Guide until you have this interchange with not only internally but with external stakeholders regarding the analyses that are being done under recommendation 2.1 or is your plan to issue the Reg Guide as it exists today and then have people use this Reg Guide as a basis for those evaluations? Because I wasn't quite sure.

MR. KANNEY: The Reg Guide as it stands is meant to incorporate the lessons that the Staff has learned in reviewing the Early Site Permits and the Combined Operation License Applications that we have done to this point in time. And that is also the basis that Staff is using to provide guidance. That is the guidance that the Staff has given to the licensees regarding evaluations they are doing under 2.1. But everyone recognizes that there is a potential to learn some new things as we go through the process.

You know, we are not talking about delaying the guide until everybody's 2.1 reevaluations are done but the sense is that there is a space of time of a few months, I think is what we are talking about here where we hope to process a fair number of these frequently asked questions and have a lot of interaction with industry with regard to the expectations for the 2.1 flooding reevaluations so that that body of lessons learned can be incorporated in the guide.

CHAIR STETKAR: Thank you. I was just going to ask if any of the other members -- Charlie, any other questions?

Let's talk a long-needed break here.

MEMBER BROWN: I don't need it.

(Laughter.)

CHAIR STETKAR: And let's recess until ten minutes until four.

(Whereupon, the above-entitled matter

went off the record at 3:32 p.m. and resumed at 3:52 p.m.)

CHAIR STETKAR: We are back in session. Joe, tell us what we are going to hear about.

MR. KANNEY: Okay. The next speaker will be Rajiv Prasad from Pacific Northwest National Laboratory. And Rajiv has prepared a few slides that goes over the hierarchical hazard assessment approach. And I guess the game plan is Rajiv will talk about this and I guess have some interaction with the subcommittee. And then after that, we had a little discussion here off-line, we really do not have time for the folks at the Bureau and the Corps to go through all of their slides. But I think what we would like to have is, I think, correct me if I am wrong, Dr. Stetkar, but basically what the subcommittee would like is actually if the folks at the Bureau and the folks at the Corps could actually just address some of the questions about probabilistic assessment that we have been hearing, your ideas on how that can be done with regard to the particular phenomena that you have been looking at.

Correct me if I am wrong but I think you guys would really like to do that anyway.

CHAIR STETKAR: Yes, I think that would be an excellent idea. And I have to apologize. It is one of the problems of this format, especially when we have people in remote locations that if we have the phones un-muted it causes all kinds of problems with background noise. And I would certainly like to get some feedback and also have them on the record because I am sure they have number one, a lot of experience, and I am sure they have a lot of opinions that they would like to get in. So let's do that.

MR. KANNEY: Okay. Rajiv, are you ready?

MR. PRASAD: Yes, I am. Thank you.

So we have been discussing the HHA approach throughout the presentation that Joe made but let me go over some of the specifics and we can talk about the pros and cons of this method if time permits.

So the objective of the flood hazard assessment as we sort of understood going through all of the ESP and the COL applications and the reviews for the nuclear power plant sites was to provide a reasonable assurance that the plant SSCs that are related to safety would be safe from these flooding hazards. It needs to account for the worst historical flood hazard, account for limited datasets, and demonstrate sufficient margin.

Now we would recognize that these topics or these objectives sort of have derived from GDC-2. That is ultimately what we want to conform to or meet the objectives prescribed in GDC-2.

So the notion from that point on was as hydrologists how do we meet these objectives. And the first one that comes to our mind is that at any site you do have historical data and observations about flood and the first thing you would do is try to analyze that to try to gain understanding of what flood hazards sort of appear at a particular site and to basically have an historical database that we know would be used in some sort of validation context.

And then second aspect is we need to consider all plausible flood causing phenomena that are associated with a particular site. And in this context we sort of characterize as inland sites or coastal sites or in-between where you have these special sort of considerations that we need to do. For example, if you have a coastal site and we are also concerned with storm surges and tsunami, at the same time you might have a coincident rainfall runoff perhaps is occurring upstream of the site and that might have an incident flood in the river or estuary that you need to be worried about. So all of those need to be considered in this assessment approach.

And then one assumption we make and let me lay this out right up front, HHA approach and all of this I am going to describe is going to be based on application of deterministic approaches. There is nothing probabilistic about it. We don't even consider that this approach would be suitable for a probabilistic approach in any case.

So everything is driven by deterministic approaches and one assumption that we make up front is probable maximum events, whether they are driven by probable maximum precipitation which results in a probable maximum flood event or a probable maximum tsunami, a probable maximum hurricane. Those are given to us as plausibly the phenomena that are going to produce reasonably the worst case scenarios as far as flooding at the sites.

So we do that have that assumption. If we needed to tweak that assumption, that is an upstream case so it would need to be the PMPs would have to be updated or the PMH would have to be updated or the probable maximum tsunami would have to be specified differently but the hazard assessment approach, the HHA, would remain virtually the same.

CHAIR STETKAR: Rajiv, before we flip to

the next slide and I think we have got that, let me ask you a question.

You made the statement that this approach is not a probabilistic approach. You very clearly drew the line in the sand and said this is strictly a deterministic approach. I would challenge that because I come from a world of probabilistic analysis and I mentioned earlier NUREG/CR-6850, which is a methodology for evaluating internal fires in nuclear power plants. It is a, I will call it a probabilistic method but indeed -- I call it probabilistic because it explicitly quantifies uncertainties. In frequencies it quantifies uncertainties in models. But it indeed does use deterministic models. It uses models for the behavior of fire protection systems. It uses models for let me call it fire physics, fire flame growth, thermal hydraulic models. They are fundamentally deterministic models. Now they have uncertainties and those uncertainties are quantified but it is, in my mind, the same type of progressive refinement to an initial hazard. The initial hazard in that case is any fire in this particular room burns everything in the room in the worst possible way that I can think about it in terms of fire damage.

And if I can't live with that, I now start looking at both the damage that could be caused by the fire and my understanding of a particular fire from a particular fire source, which to me sounds very similar to the type of process in HHA. Am I mischaracterizing the HHA approach?

MR. PRASAD: No, I think you are right that we do a similar sort of analysis. The idea is to come up or try to estimate a bounding event. And if that bounding event with very conservative assumptions that we make about the underlying phenomena, if that happens to not pose a credible hazard to the SSCs, then we say we are done.

What we don't -- now we do refinement. So for example if our bounding event that we came up with the first analysis in HHA and that pose hazards to SSCs, for example inundated the site grade and something related, SSCs might have been inundated. Then we realize that we need to do some refinements because the assumptions that we have made have been conservative in all of the aspects of the flood hazards.

Now what we don't do is that we don't use any probabilistic notions to make those refinements. We don't have any consideration saying that we would knock down a particular conservatism by assuming say a probabilistic or a PDF for that particular plan because of that particular assumption and we will scale it back from its bounding level to say 90 percent exceedance.

MEMBER RAY: Well why do you use the word probable in probable maximum if there isn't any probabilistic aspect to what you are doing?

MR. PRASAD: That is a very good question. I think these are terms that were coined well before we got into it. I disagree with using probable in those terms because for precisely that reason, that it gives people a sense that there is something probabilistic behind how they are derived. But they are not.

They are essentially a bounding concept tempered by some sort of understanding or some sort of assumption that there could be physical limits or there could be reasonable limits how these events are possible or not possible at a particular location. But here is nothing probabilistic in their definition. There is nothing probabilistic in how they are derived. They are one event and then from that one event, we do a deterministic analysis.

Now there is a caveat to that. If you look at how the probable maximum precipitation were derived, there is an underlying probabilistic concept behind it. They have taken a set of extreme events and then those extreme events were described in a probabilistic fashion. But by the time they applied the maximization approach, the transposition approach to that concept what we get out of this particular approach is one number for a PMP for a particular location and a particular duration.

MEMBER RAY: So Rajiv, Joe wants to say something and then I want to say something more and then we should move on, I think. Go ahead.

MR. KANNEY: Yes, I was just going to say that the terminology probable maximum was actually originally, the original terminology that was used, this was like back in the '30s and '40s was maximum possible. That was the original language that was used. And after using that language for probably about a decade, hydrologists and engineers realized that that was a poor choice of words and the probable maximum was used instead. And the intent was to convey that it is uncertain, that it is an estimate. That was the intent. I am not defending it. I'm just saying --

MEMBER RAY: Okay, all right.

MR. KANNEY: -- that is what they were

trying to do.

MEMBER RAY: I think what Rajiv said is fair that it nevertheless today conveys something that isn't intended.

Now you earlier said used the term maximum credible. I licensed a plant back in 1970, which is forever ago. And maximum credible was what we used, referred to in terms of seismology. We now we don't do that anymore. But at least it had the attribute that you could say well anything bigger than that is not credible. But when you use probable maximum, then people say well you mean it is not likely in the next 40 years is what you mean. Well, no, I mean it is not likely in the next hundred years or thousand years, or two thousand years. I have no clue. I don't know what you are talking about.

And so it is problematic from the standpoint that probable maximum clearly conveys the idea that there is something that maybe improbable but it is bigger than the probable maximum. Not incredible, just improbable.

And so we are into a dilemma in that regard but this isn't the meeting to talk about semantics, even though that is what I have been doing. The problem that we have, I think, that we have got to grapple with is although this is where we are today and you guys are describing it in a lot of detail and I think we appreciate that an largely understand it. The question is when are we going to move off of this position. And if the answer is never, okay, then we will process that. But if the answer is we are going to move on to something that does address things greater than the design-basis, which let's face it that is the world we are in now, right, we are having to deal with things that are beyond the design basis, not just pick a design basis that we are satisfied with.

And so the issue is what is the likelihood that something will exceed the design basis? And if we are not prepared to deal with that, we had better get prepared.

CHAIR STETKAR: Harold, I even think that certainly we are in the world of thinking beyond the design basis. As a part of that, we need to understand coherently what is the design basis. You know, are we saying that we think we are designed a million-year flood when indeed we are probably designed to a 5,000-year flood.

MEMBER RAY: Maybe.

CHAIR STETKAR: And that is really our

design basis, even though we are saying it is itsy-bitsy instead of teeny tiny.

MEMBER RAY: Yes, if you look at --

CHAIR STETKAR: Use those you know what is credible versus --

MEMBER RAY: The license that I am referring to, it uses the term maximum credible. When you finally go and ask what the hell are you talking about, it turns out it is like ten to the minus two.

CHAIR STETKAR: Yes.

MEMBER RAY: I mean, it's ridiculous. And so that is a big problem. Okay? And I just don't want us to repeat that, particularly now in the wake of Fukushima to say well they thought probable maximum was this, well now we find it is that and so on. We have got to get beyond where we are with this. But having said all of that, that is about the third time I have said it so we ought to get on with the meeting, I think.

CHAIR STETKAR: Rajiv, go on with these slides and I, as I said, semantics are semantics. Sometimes they do make a difference and I will still float the notion that as much as you defend the HHA as being a completely deterministic and you never will characterize it as a probabilistic approach, I believe that it could equally be applied in a probabilistic assessment, the basic thought process.

MR. PRASAD: It could but the way we currently do, we do not use any probabilistic.

CHAIR STETKAR: I understand.

MR. PRASAD: And that is the reason I say historically this has not been a probabilistic approach.

CHAIR STETKAR: Right.

MR. PRASAD: So moving on, we do consider combined events in this approach and use conservative assumptions. Let's talk about an example. Joe, you can move on to the next slide.

MR. KANNEY: Okay, slide three?

MR. PRASAD: Slide three, yes.

MR. KANNEY: Okay we are there.

MR. PRASAD: It is talking about the steps. And we have talked about this progressively refinement of the estimation and that is what these steps basically say. you start with identifying the flood-causing phenomena. You sort of look at everything that can happen in terms of producing a flood at your particular site. You document what is implausible. If I have a site which is a hundred miles inland, is a tsunami a plausible phenomenon?

Maybe, maybe not. So we need to document all of that and then come up with a set of events that comes up as part of Step 1.

In Step 2, you take all of those plausible events and you look at ANSI/ANS recommendations for the combination and you try to perform a conservative estimation of the flood for all those combinations. And this is Step 2, which will give us a range of floods but these are again derived from combinations of those phenomena in a deterministic fashion. We have a model, a set of models for different processes and that if you will flood at that site.

Step 3 would be, okay I know where my SSCs are in relation to the flood elevation or in relation to some other design-basis. For example, missile set might be carried with the flood base or the dynamic loading because of the drag forces and stuff like that. And you compare all of that and see if the SSCs are going to be safe or are not going to be safe.

If one SSC is probably said that well we have a door opening at a particular elevation, your flood elevation comes up higher than that and obviously that SSC is not going to be predicted against that flood hazard. So we narrow down our list of SSCs at that point that cannot survive this particular hazard.

At the end of that step, Step 3, you basically have performed or determined whether that event that you modeled, whether those sorts of events have a flood which is conservative to begin with but results in a hazard to SSC. And then we tried to do a sort of refinement, go back to Step 2, sort of narrow down the conservatives that we used and back off some of those conservatisms, the refinement step-by-step approach.

Now how we do that is not based on probability. It is not based on anything that gives you the notion that if we backed off, if I am ten percent, that it might reduce the return period for that parameter but a specific amount. We don't do that. It is just a judgment-based approach saying that can I reduce my -- can I back off from saying that there is no translation in a flood channel and do some routing. Is that a hazard approach? Yes, it is more realistic. So in that sense it is going to be less conservative.

But then in that routing approach you need to apply a particular routing model. A routing model would come with its own sets of parameters that you can still pick conservatively. But you have backed off from the initial assumption, which may have been even more conservative.

So we do these refinement steps until we come to a set of flood hazards for which no SSC is exposed or faces that hazard. Or you have run out of your judgment and available data based on which you are making those judgments to relax those conservatisms.

And once you do that, then you have arrived at the conservative flood hazard and then you go to Step 4 to specify the flood hazard characteristic.

CHAIR STETKAR: Rajiv, how do you know that that result from Step 3 that you just characterized as we have a conservative flood hazard is indeed conservative? If you have applied in some cases successive refinements that I will characterize as going from a -- I have to be careful in the words that I use here -- big bad to something that is less big and less bad or perhaps what I will call more realistic or more best estimate, so you are progressively applying refinements to go from something that you consider to be a -- I will use these words, a bounding case for your site and are working your way toward a best estimate case for your site.

MR. PRASAD: Yes. Let's go to --

CHAIR STETKAR: How do you then characterize the output of that process as conservative? Suppose it is the best you can do? It is now your best estimate. It is not necessarily conservative. It is what you believe, the way you believe the world works. And if you get to that point and you finally have to take it to that point and you are okay, well fine.

MR. PRASAD: Yes.

CHAIR STETKAR: If you are not okay there -- but that is not necessarily conservative. That is your best estimate. That is what you would bet your life on as being your knowledge of the way that the world works. That is not conservative. It is not optimistic. It is your best estimate. There may be some degree of uncertainty about that. And part of the problem that I have is this word conservative that we tend to throw around.

MR. PRASAD: Yes, I --

CHAIR STETKAR: There is no guarantee that that is still conservative. It is not bad. And it is not bad to not be conservative. It is perhaps not good to be optimistic.

MR. PRASAD: Yes, I think I understand your concern. So let's get to an example where it becomes -- while I have been talking in the abstract, it becomes a little bit more concrete.

So Joe, if you can, go to slide four.

MR. KANNEY: Okay, we are there.

MR. PRASAD: Now looking at estimation of probable maximum floods at a hypothetical site. I mean some of us can recognize where it is. I won't say where it is. But the idea is to come up with a probable maximum flood on a river channel. You see the topography on the bottom left. And then the watersheds that sort of comprise that basin up to the site.

So the assumptions that we make in HHA is that we are assuming, first of all, that the PMP event is actually a credible maximum event for this site. Now that is up for debate and there is a lot of things that can be said for and against it. So let's get beyond that.

We start with PMP being the credible maximum. So what we do here is say that okay if you take this PMP event and you apply it to that watershed and then I can make certain assumptions that would turn that PMP event into a credible maximum flooding event.

How do I do that? Okay. You have to realize how the physics or how the rainfall runoff generation process works in a watershed. You have part of the rainfall that would infiltrate into the soil, what we call losses. Some of it might be intercepted by vegetation. Some of it might be evaporated or evapotranspired by plants that you have on the watershed. So some of it might be lost.

Now if we were to assume that we would set these losses to zero, in other words to say that everything that falls on that basin would come out at the downstream end of that catchment where my site is located. That way what I am doing here is I am maximizing the flood volume coming out from that catchment. That is a physical maximization which is conservative.

Does that make sense? Okay. So that is one aspect of it. Can you maximize the volume? Yes, we can by making some pretty conservative presumptions.

The second thing, when water falls in a catchment and this catchment is I don't about five thousand to six thousand square miles, when you have that big a catchment, water moving from the upstream end to the downstream end takes a little while to get out there. Maybe today, maybe it is couple of days. What if we were to assume that water falling anyplace in that catchment would instantaneously appear at the downstream end? That is demonstrably a physically bounding assumption. If we do that, then we are not only maximizing the volume by the first assumption, but we are also maximizing how quickly this volume gets to the outlet where my site is located and I have to estimate the bounding flood.

So if we do those two assumptions, we call these no-loss scenario and no-translation scenario, in the sense that there is no lag in the way the flood reaches the site of concern. So if we do that, then we are going to have a PMF which is very, very conservative and demonstrably some people have even called me are you crazy by making those assumptions. But this can be done and if you get PMF that would be in some sense a bounding effect because we have knocked out any losses. We have not assumed that there is any delay in the way that the runoff generates and when it appears where I have a safety-related SSC.

Now, suppose we come up with this estimate of the PMF and we see that at my site there is nothing that is inundated, no safety-related structures that are exposed to this flood hazard. Then they are free and I am done. There is no SSC anymore that I need to care about. So I need to go to Step 4 and say that well the site is dry and it would never have any problem with flooding, at least for this particular mechanism, which is a marine flooding and the PMP. And that PMP is the only assumption then that I have to be worried about, whether that is actually a critical maximum amount. Does that make sense?

CHAIR STETKAR: Yes, it does.

MR. PRASAD: Okay. Now suppose the other case happens on PMP and I still have some SSCs that are being inundated. So I go back to my assumptions that I made during this -- and there are two critical ones that I made. One was I assumed no losses. The other one was I assumed no translation. Well it is up to the judgment of the hydrologist to relax one of those. My personal feeling if I were to do that, I will do the routing one first. So I would say that the translation is a critical one, is a more in critical one. So I will try to build in a routing model first before I do the losses.

And then when I do the routing model, then I have to come up with okay, what sort of stream that what we are talking about. What are the properties of those streams? What model do I use? How do I characterize the channel? How do I characterize the delay, the run-off delays in those channels? And then you start building up the model that is more detailed, more refined than the first analysis which basically said everything is a conduit dropping out right at the outlet.

So then you get into this more refined model. I will pick a model that will assist us in practice and try to come up with a routing of them. And then I will have to use more site-specific data because now I need data about channel length, channel slopes, what the roughness in those channels might be, what are the overbank areas they look like. Are there any vegetation, obstructions to these channels? Are there any dams that might affect how the water moves downstream in this channel network?

A suite of things that you have to put your model together. But that uses specific piece of site-specific data for this basin and I will try to build that in. And then we are on the second equation of the HHA.

And at the end of that model run, I will come up with another set of flood scenarios for flooding and then I will compare it with the elevations of the SSC or the properties of the SSC that they should be designed to to try to see if that flood, which is less conservative than my first flood scenario but still conservative because when I am putting together this channel network model, I will make sure that each of the parameters that I come up with I have a basis with the available data to make those parameter choices conservative. And principal among those is the roughness for the channel network that we use.

So everywhere when we come up with these refinements in these steps we have some sort of basis to say that because of this data I am going to relax that particular assumption or that particular conservatism but at the same time I want to stay as conservative as possible and then try to do the second step.

But this is how HHA would work. At the end you may have to become even more realistic and say that okay, I have to now do an accounting for rainfall losses also or I have to do a more dynamic modeling rather than just a one dimensional modeling. Maybe I need to do a three-dimensional modeling in terms of watershed areas like below the dam, if there is one dam, or maybe you have to take into account of two-dimensional flooding in the flood plains.

I have to do heterogeneity characterization. Maybe I need to account for what sort of vegetation pattern is all over the basin over land use types and try to build a model which becomes prolifically more complex as the HHA proceeds through its various refinement steps.

But we tried to stay with, given this amount of data that is available to us, that we can defend the parameter choices as still being conservative.

CHAIR STETKAR: Thank you.

MR. PRASAD: So that is how the HHA works. And the steps I think the rest of the slides, Joe, are pretty much the steps that I described.

CHAIR STETKAR: Let me suggest something. And believe me, you know, I am not a hydrologist. I'm not a meteorologist. I understand the basic concepts.

Let me suggest something that the folks in this branch of Research sit down and talk to the folks in the fire-modeling branch of Research because I can tell you everything that I have heard this afternoon has a direct analogy to the way the fire analysis people evaluate fires. A precisely direct analogy.

There are three levels, for example, of fire models: simple algebraic models, zone models, computational fluid dynamics models. Each one of them becomes progressively more complex, theoretically progressively more realistic. Each one of them accounts for more refined analyses of the specific properties in geometry of a fire location. The analogy is your drainage basin here.

They have developed techniques to assess both modeling, uncertainty in the models themselves, which reduce as you go from the more simplistic linear algebraic models to the complex, the fluid dynamics models. They have also developed methods to address uncertainties in the parameters, the input parameters that are used in those models. You know, you mentioned things about surface roughness and grades and things like that. There are methods that have been developed by this agency to address similar problems with evaluating I will call it a bounding fire and getting improved confidence about more realistic fire damage.

And that notion, if we are applying that same basic type of process to floods in the context of this HHA, those basic notions, I think, ought to be done in parallel. We ought not to be reinventing the wheel. We ought not to be saying you think about models for flooding or refinements of a flooding analysis differently than we think about models for fires or methods to refine a fire analysis. Because that again it says that for some reason this agency needs to think about flooding as fundamentally different than fires. Granted, it is a different topic but we ought not necessarily think about how we address that topic differently simply because it is water or flames, if you follow my notion.

We ought not to be then saying let's invent this wheel to go this way for flooding when we have already invented a wheel and a direction for fires. So I would suggest that you talk to the fire folks, Mark Henry Salley, and see what they have done because I think there are a lot of analogies.

I like this process. It works really well. You characterized it as a deterministic process. Well the fire guys five years ago characterized theirs as a totally deterministic process. And there is a lot -- I mean there are fundamentally deterministic models. I mean we have already said this. So I would suggest talking to them because I think what you have here makes a lot of sense and it is indeed fundamentally consistent with what is being done in the Agency to address other types of hazards, in this case internal fires but there is sort of this physics involved phenomena. Their process also, by the way, does not address the fundamental forcing function, which is the frequency of that fire. It does address, for example, distribution of that fire in this room. So it looks at different hazards but that is analogous to you looking at different parts of a drainage basin instead of treating it all as one single lump parameter.

I would suggest do that a little bit. Because it is a good process. We just ought not to say that it is somehow fundamentally different.

MR. PRASAD: Yes, no I think that makes a whole lot of sense. If somebody else is doing it already and they have probably gone beyond what we might be doing here, I think that it is a very good idea to actually talk to them.

CHAIR STETKAR: I think some of the basic concepts, you know, obviously the details are different. There is a lot of good stuff in that NUREG about what to think about in the context of flooding, obviously. But sort of the basic thought process in what needs to be considered on how it can be addressed could then, regardless of the way we treat the fundamental hazard, which in this case is that mystical PMP, we would then at least have a process of dealing with that hazard in terms of its progressive refinements or going from what we consider to be a bounding case to a more realistic best estimate case and ways of treating and documenting the uncertainty, at least in that part of the process, that refinement part of the process. It doesn't address what a PM, whatever it is, is. But certainly at least that part of the analysis would, I think, make a lot of sense and could then equally be applied in the context of something that somebody might use the dreaded probabilistic method in terms of characterizing the exceedence frequency of the hazard.

Rajiv, do you have anything more?

MR. PRASAD: No, I don't. I think the rest of my slides were pretty much the steps that I was referring to.

CHAIR STETKAR: Yes.

MR. PRASAD: So if you want to look at the observations and conclusions, those are Slide 7 but they are pretty much everything that I covered.

CHAIR STETKAR: Okay, good.

MEMBER BROWN: My only comment is that -- I have a comment. Is that alright?

CHAIR STETKAR: Yes. I would ask the other members but that would imply you have multiple personalities, which I know you do but --

MEMBER BROWN: Based on your presentation, I didn't see a methodology necessarily for making assessments of the various flooding process like this. It was more of a discussion of things to think about and put together, as opposed to a process it develops.

For instance, take John's thought process. I am kind of simple-minded. And since I am electrical and a lot of mechanical engineering is part of my background, I think of how you design a bridge. You know, you go say here's a bridge. There is going to be X number of lanes. You can have every lane filled with cars as you are going across the river and you are going to have some distribution of trucks in there and they are all heavy. So you come up with what the stresses are and you decide what you have got -- and then you multiply it by three.

Okay and my perception of the flooding would be you pick the various phenomena, whether it is rain, whether it is ice-jams, whatever it is, you take what is the historical data you have over the last hundred years and that data is there and you say it occurs over this period of time during calendar years or what have you then say okay, the maximum is this. I would multiply it by three and say okay, that is the number I am going to use.

But the first step in this process is, if I can find it, in the example -- no that is the wrong page. At that point on page five. Flood-causing phenomena. In other words, you have to have a phenomenon. And then it says estimate using no precipitation lost, it's taking translation, et cetera. You have got to start off with some input of fluid. And you have got to pick that somehow. And literally I would have taken the old engineer's approach and just like I said, history is there. Louisville, Kentucky has 200 years' worth of flood data. Kick it up, Ohio Valley, locks, bridges, stuff to jam up everything. Pick a big number, multiply it by three. It's just a number. And then you start walking your way through the process. That is not in the Reg Guide as a process that I see.

And that would have been my suggestion, based on the discussions. I know you all have already done all of this and you are ready to go but I think you are missing something by not having -- and I'm not saying this is the exact process. It is just so open and the words are so general. And the probable maximum, what does that mean? And all that other kind of stuff just creates angst. So I will stop now.

MR. KANNEY: Well, in the guide, we don't repeat word for word what is in NUREG/CR-7046.

MEMBER BROWN: Well I don't know what that is.

MR. KANNEY: Oh, okay. That is --

MEMBER BROWN: I'm the electrical guide.

MR. KANNEY: That is the NUREG/CR that describes the HHA process in some detail.

MEMBER BROWN: Okay.

MR. KANNEY: So what we do in the guide, we reference that NUREG/CR instead of repeating it.

MEMBER BROWN: Well I'm trying to help you with the input of flood-causing phenomena.

MR. KANNEY: Well I think the flood-causing phenomena in this case you are going to have a precipitation. But the process for arriving at the probable maximum precipitation actually is very similar to the process you just described.

MEMBER BROWN: Is it described in the Reg Guide?

CHAIR STETKAR: No.

MEMBER BROWN: Is it described in the NUREG?

MR. KANNEY: The Reg Guide references the NOAA hydrometeorologic report that do go into the detail of how it is done.

But the process is very similar to what you described. You have a historical record of storms. Okay? Then they don't just multiply by a factor of three. They actually look at the moisture in-flow for those storms. They compare it to the maximum persisting dew points that have been observed in that area to come up with a moisture maximization factor. That is one way of maximizing in a meteorologically credible way, not just pick a number three, but look at the ratio of the moisture that that storm saw to the moisture that may have been available in this region based upon looking at the record.

Then they also do a process called transposition where okay I am looking at storms in this area but well there is a storm that happened 200 miles away. Who is to say it couldn't have happened here under the right condition, so that that storm can be transposed into your region of interest and you make some adjustments for changes in elevation as you go but you can move storms into the region. That is another way of trying to put some conservatisms into it. You know, not just picking out a factor but making maximization based upon meteorological criteria.

MEMBER BROWN: I don't object to that. It's just that I would look at the Reg Guide as providing a roadmap for how to use the Reg Guide and the methodologies that are there to get you into the process that you are talking about, as it was described. I am kind of a frontal attack guy as opposed to leaving everything kind of these little fiber tendrils going all over the place because it just makes it difficult to assess what you are trying to come up with, which is how I have been reflected in the NRC world several times.

I don't disagree with that. I mean you can take the precipitation. You can say what are events in this continuous area. You have got to evaluate those to see what their impact may be. What is the probability of tornadoes coming through and providing a giant storm surge that overwhelms everything. They are not likely to happen in the winter but they are more likely to happen in certain -- and combine that. And then that provides you with the input into that first part where you walk through the steps.

But you don't leave it up to all these

guides to kind of have all these nuances in it to come up with stuff. You give them a roadmap of trying to give them a thought process to how to do it. If it is process-oriented, you are not telling them what the answer is but it is process-oriented to get the result. That is the way I would have thought about it, trying to shift from the other paradigm, that's all.

CHAIR STETKAR: There is -- we need to leave time to make sure we get to the Bureau and the Corps folks who are out there --

MEMBER BROWN: Well, I'm done.

CHAIR STETKAR: -- you know, screaming.

MR. ENGLAND: I can speak up now?

CHAIR STETKAR: Hold on a second. It is good to be queen.

There are -- this is not an easy problem to solve, obviously. And the reason it is not easy is that there are a number of different flood-causing mechanisms, if I can call it that, precipitation is one. There are different types of precipitation. You know, if I can characterize large intense storms versus longer, less-intense but the longer duration events, dam breaks, seismically-induced dam breaks, dam breaks just sunny-day dam breaks, seiches, tsunamis, you know. All the list that Joe went through initially are different problems that need to be addressed to characterize the input hazard for a particular site. And I always think of the input hazard in terms of a set of exceedance curves. Each one of those hazards could have a different set of exceedance curves.

The NUREG doesn't say much of anything about how to develop that hazard. It says it provides very good guidance about what one might do with it once you have characterized it. And that is, how you address progressive refinements to the thing, which is an important part of the problem. I mean in a realistic assessment, that is a vital part of the problem.

And then finally the folks at the power plant at the particular site, if you can't make it go away by sharpening your pencil and looking at frequencies in more realistic models then you have to either put up barriers or something but that is their problem. And this NUREG and the Reg Guide certainly don't address that and that is perfectly appropriate.

And I think it is important to sort of think about that. And as I said, there are analogies in both the seismic world, there are analogies in the fire world to thinking about the problem in that sort of three-step process.

The HHA addresses sort of the middle part of that process. It doesn't address the hazard. Your analogy of looking at the trucks and multiplying it by a factor of three gets toward the hazard assessment but again, once in 500 years or once in 200 years is only five times ten to the minus three. We are a long way away from ten to the minus six.

So I think the biggest part of the problem is not what is in the HHA. I think there is a methodology. And as I said, there is NUREG/CR-6850 that sort of outlines the methodology. The other NUREG is 1934, I think, which is the prior models themselves. Both of those together sort of address the HHA part of the problem.

The bigger part of the problem is characterizing the hazard and having some confidence about how we are thinking about that hazard. And I think that is where Harold has expressed his concern and I think that is where I have expressed my concern. I think once we understand that, we will know how to deal with it. And indeed the Agency has methods that have been developed that are not -- they are entirely consistent with this HHA methodology.

So with that, let's open it up and see who wants to provide input first in terms of -- I understand we have people from the Bureau of Reclamation and also Corps out there.

Joe, I will let you guide the discussion seeds for that. You know who is out there and what their areas of expertise are.

MR. KANNEY: Okay. Actually since we have really been discussing a fair bit about that initial input, I guess it might make sense to go to John England at the U.S. Bureau of Reclamation.

John, I guess in the interest of time I think probably what would be best if you would like to really kind of throw away the slides, unfortunately although you spent some effort in putting them together or pick and choose. Spend like maybe just about ten minutes just describing the basic PNP approach. You know, I think I described it but probably not nearly as well as you could.

And then I think probably what the subcommittee would actually like to hear would be then your -- maybe a description of what the Bureau of Reclamation does as far as probabilistic flood hazard assessment, what you are doing right now, where you see the gaps that need to be filled in. How does that sound?

MR. ENGLAND: That sounds great. Hi, everybody this is John England. I am with Victoria Sankovich, my meteorologist here at the Bureau of Reclamation.

In the interest of time, Joe, I am going to ditch the slides except for one. So if you get a chance, pull up slide number 21.

MR. KANNEY: Okay.

MR. ENGLAND: The title is called "Discussion, Implications, Future Work" and that sort of thing. What I want to do is basically read off the six bullets that I have written down here to answer the panel's question.

And a bit of background. I don't want to pejorative here but Reclamation has been working on probabilistic flood hazards for 15 years. We essentially threw out PMP in the late in the late 1990s because we had to go to probabilistic 401(b).

So let me start off with point number one. Reclamation has been doing probabilistic flood hazard analysis equivalent to the PSHA since about 1999. I have led the technical development of the methods. These are exceedance curves just like PSHA.

If I speak too fast and you guys can't

write it down or there is no transcriber, I can type these up and send them to Joe and the team there.

CHAIR STETKAR: John, --

MEMBER RAY: You are creating a transcript.

CHAIR STETKAR: -- you are on the transcript. All of our -- there will be a full transcript. It will be available publically.

MR. WIDMAYER: And your slides will be, too.

CHAIR STETKAR: And your slides will be included. Your entire set of slides, by the way, will be included.

MR. ENGLAND: You guys can read the slides at your leisure but I have been basically diligently trying to write down these questions and provide answers to them that I see fit to you reclamation. As you can tell, we have got a pejorative biased viewpoint here because we spent a lot of time integrating seismic hazards and flood hazards in the Western United States and in particularly in California.

So the particular last question was when are we going to move off this position? My view is it can be done now. Reclamation is doing it. We are sizing modifications to our existing dams based on PRA using probabilistic flood hazards for existing dams and we are looking at modifying dams according to these things. We call these hydrologic hazard analysis, as we wrote down in about 2004, so we have a slightly different acronym for HHA.

Point number three is you turn to page A1 in the draft of DG-1290, our approach is summarized in references 28, 29, and 30 in Appendix A and reference 22 in Appendix B. Reference 22 is an American Geophysical Union monograph that I have a chapter in, as well as my coworkers have written on paleofloods. We spent a substantial amount of time in the field on paleo data. But essentially we have got guidelines and standards on how to do the technical methods behind our HHAs. They have been sort of superseded and we are trying to catch up. But those references I honestly provided those to the NRC in 2008 in July in technical update lectures. So I could do that again. I am hoping to come out in January with Tom Nicholson and Richard Raione.

Point number four, in our view, PSHAs, PRAs, and probabilistic flood hazard assessments require full distributions because we don't want to focus on the single maximum points. You know, PMS can limit these things if we choose to, but with uncertainty we could define what we want. Maybe we need the one in a thousand, one in two thousand and we can do this with hydrologic hazard exceedance curves.

This requires, in our opinion, full integration of hydrometeorology, -- that is why we have staff of meteorologists -- paleoflood hydrology and geomorphology and flood hydrology. It is an integrated discipline. Frankly, I am leaving out the engineers in my office that do the response probability parts.

But so point number four is that we require full distributions and multidisciplinary efforts to do this.

As an aside, our best practices and risk analysis describes how we separate low probabilities, response probabilities and consequences separately.

MR. KANNEY: John, I think we have a slide number problem. Our slide 21 I don't think is the one you are referring to.

MR. ENGLAND: This is extemporaneous here.

MR. KANNEY: Okay.

MR. ENGLAND: I will get to that. I just want to get these points taken care of first.

MR. KANNEY: Oh, okay.

MR. ENGLAND: I guess because I am trying to answer the questions that was posed by the subcommittee first.

MR. KANNEY: Okay.

MR. ENGLAND: My research was, frankly, maybe not of poignant interest at this stage of the game.

(Laughter.)

MR. ENGLAND: But my point number five is look here is the problem. Much applied research and technology transfer work is needed to convert probabilistic flood hazards for people to understand them. Four years of flood people have been ingrained in using maximum concepts and they don't know what to do. We have been doing it but lots of other people haven't. And so there is lots of technology transfer pieces and applied research that need to be done. And Joe has the summaries on those slides that he can cover later.

And I guess point number six is we are modifying large dams in the Western U.S. using that hazard curves.

So I think that covers when are we going to move off position, at least in the position of the Bureau of Reclamation.

The Corps of Engineers is not quite where we are. I don't want to speak for them but I think Tom Nicholson and Richard in his workshop may bring that forth.

So my slide 21 is on essentially precipitation frequency risk that we did under our task, our Phase 1 proposal of research for the Nuclear Regulatory Commission that you have three reports summarizing those slides.

So without belaboring it, what we found was that you can use some existing techniques to estimate return periods or annual probabilities, whatever your favorite lingo is of PMP. But these concepts are not universally held. So PMP amounts are estimates and can be exceeded.

Looking at report number two, on applications, we found two storms off the coast of North Carolina that if you maximize them would break the PMP from HMR-51. So new datasets and new data matter. If you go probabilistically, you can handle this a little bit better.

We can quantify uncertainties and that is described in the report on sensitivity uncertainty.

There is further work to be done at the last bullet on areal estimates.

So that is really all I have to say. If you have any questions or comments on that I have just said that is not in the slides or any of the slides that I have provided in advance, I would be happy to have discussion on those.

Thanks for the opportunity, Joe.

CHAIR STETKAR: John, this is John Stetkar on the ACRS Subcommittee. I have to admit that I didn't look at your slides earlier. So I am -- I just didn't get to everything.

MR. ENGLAND: They have nothing to do with what I just said. They were trying to answer your questions. But we did some pretty interesting research, mostly done by my meteorologist here that looks like the key point is our existing design PMP numbers are way out of date.

CHAIR STETKAR: Yes.

MR. ENGLAND: They could be changed by new storms.

CHAIR STETKAR: But some of the notions that you talked about here and in looking at that slide 21 that you referred us to and what you said as an introduction, you said you have some confidence or that the Bureau of Reclamation has been developing exceedance curves for flooding hazards for some time and that you also address uncertainties.

Are your exceedance curves developed in a classical sense where I have a frequency of exceedance as a function of severity and uncertainty about that frequency of exceedance or is it -- in other words, are they families of curves or is it a single curve that just gives me frequency as a function of severity?

MR. ENGLAND: The short answer is it varies.

CHAIR STETKAR: Okay.

MR. ENGLAND: So the long answer is just akin to PSAJ we have peak flow frequency curves that are done in a classical sense so the magnitude of the variable is the flood peak versus AEP. And we used various models to do that; some Bayesian maximum likelihood, some moments-based things that would give 95 percent confidence limits. So they are basically data-driven from historical and paleoflood data and streamflow records.

That is one particular technique. We try to combine that with rainfall runoff models. Because the problem for our runoff reservoirs and the same thing for nuclear facilities is that the multivariate hazards. So the same thing with PSHA. Is the problem peak dominant? Is acceleration the deal? Is it the ground motions for the time histories at the site of interest? Our parallel in floods like Rajiv mentioned is the duration of the flood and the coincidence of the flood against the big volume. So we in some cases do families of hazard curves based on volume as well.

And then for our reservoirs, the variable of interest there is Bayesian.

CHAIR STETKAR: I'm sorry, I didn't --

MR. ENGLAND: The short answer is it depends. And the long answer is we try and do in some cases rigorous quantitative uncertainty and in other cases guesses.

CHAIR STETKAR: Okay, thank you.

Do any of the other members -- Harold do you have anything?

MEMBER RAY: No, I think it was very appreciated.

CHAIR STETKAR: Thank you. That was -- I'm sorry that we didn't get a chance to go through all of your slides. And we may be talking again.

MR. ENGLAND: I think the most thing you are interested in, that is why I ditched the slides, frankly, is because Joe put together some other ones that he hasn't presented yet on their near-term activities and we are trying to fit in with that.

CHAIR STETKAR: Right. And what I would like to do, Joe, by the way, is get to your near-term activities by the end. But I want to make sure that whoever is out there from the Corps also gets a chance to be heard and have some exchange.

MR. KANNEY: Okay, do you want to move on to the Corps now?

CHAIR STETKAR: I would, yes, unless anybody has anything more for John.

MR. KANNEY: Okay. Ty or Don, let me just queue your slides up, I guess, but with the same qualification. I think probably just take about ten minutes to discuss the actual work you guys did and then take your best swing at the sort of prevailing question of the day.

MR. RESIO: Ty, do you want to go ahead and go first?

MR. WAMSLEY: No. Why don't you go ahead, Don? I know you are on a tight schedule here.

MR. RESIO: I do have to go somewhere in just a little while.

Let me first answer there was one question early on about the difference between wind hazards that are used for structural -- by structural people and wind hazards and the winds that were used to drive hydrodynamic models. And we have actually looked quite a bit at both of these classes. And what we have found is that their fundamentals are very similar. The parameters that they feed them probably fit the people, Peter Vickery as an example, his work on the land winds certainly seems to fit the on-land winds better than the people who do the meteorological work offshore. But they, the people who do the offshore work actually fit better right there. And it is more the parameters they drive them with than the differences in the models, however.

So there is really -- I think it is not so much that there is a dichotomy the land hazard winds and the water hazard winds. I think it is one group has worked more at perfecting their estimation procedures to the parameters that they drive them with.

I would like also to go back to some of the questions that started. What we were trying to do was very much along the lines of what the subcommittee was discussing, which is to try to look at the uncertainty that is inherent in a lot of this data and see where we could work in to determinism where we could. But even when we would work in the determinism, a good example is if you model the maximum, what they now call the maximum possible intensity which is a little variation on a theme there, but it is still somewhat of a random variable. But if we look at all of these things, they still have randomness about them and we actually think that that randomness should not be thrown out with the wash but should be considered in a lot of the work that is done.

So what we were trying to do is put together an approach that looked at both the probabilistic aspects of the surges and the deterministic upper limits because we were able to show some functions. For example, the angle of the storm, it is obvious you can rotate around as many times as you want but there is one area for a particular coastal scenario where you would have a maximum for that.

And similarly we found that the size of the storm was very asymptotic and there is a lot of reasons for that. There is some good mathematical reasons and some good physics reasons for that.

So but on the other hand, there was some, such as the storm intensity that even though there is a stated quasi-empirical, quasi-theoretical argument for in existence of a maximum potential heat engine rate of extraction of energy and this sort of thing and it has been debated, I'm not sure how finely tuned that estimate is at the moment.

So there is still quite a bit of uncertainty but given all of that, I think what we have done is to then supplement some of our work with some investigation into the sensitivity, which I think was a good point that was also brought up by the subcommittee that you really need to understand is this a parameter that it is extremely sensitive to, in which case wow, you can't use that aspect or something that it is not so sensitive to. A good example was we did look at the variability or the sensitivity of the storm surge to the maximum possible intensity which was dependent on the sea surface temperature and some variability of the climate expected over the next 50 to 100 years.

And that actually turned out to be a fairly smaller term than we expected; whereas the modeling errors just the fact that surge models are sort of all hydrologic models are fairly crude when they come down to it because roughness, topography, and changes in the middle of the run and we don't know exactly how or why. There is just a lot of uncertainty in the situation. So when you start putting all that in together, some of the things kind of dropped out.

And if you do get a chance to read through there, it is somewhat explained in a little more coherent form than I just did in that bit of time. And let me pass it on to Ty because he was more on the modeling side.

I guess I just wanted to make it clear that we really were trying to actually pay the proper, what in my opinion anyway is the proper attention to the uncertainty, both in the statistical sense sampling. When you start extrapolating to the one in a million event, your error bands are huge. And if you don't factor them back into, if you don't do a convolution and put them back into the distribution, you really are omitting a huge difference in the estimates.

Okay, anyway with that, Ty, all yours. Any question? I'm sorry.

CHAIR STETKAR: Yes. Don, this is, again it is John Stetkar on the subcommittee.

You mentioned something that caught my interest. you have dealt with characterizing and quantifying uncertainties in the models themselves. Did I understand that correctly?

MR. RESIO: That is correct.

CHAIR STETKAR: Okay, thank you. And from at least the example you gave, I think you said that your conclusion was they may be more important than perhaps other sources of uncertainty in terms of meteorological parameters or something like that.

MR. RESIO: Yes, this is true. What we found was when we were trying to do the redesign for New Orleans we did have to consider the uncertainty in the modeling capabilities. You can't do a statistical estimate based on simulated data. It is one thing if you have measured data but we don't. If you are simulating the data, you have to make an assumption that the model is reasonably calibrated and they usually are. But once you put that in there, we were a little surprised at how much random variability there was around the surge estimates. We could kind of fit through the middle of everything but we couldn't get rid of that random variability and there is probably lots of some geophysical and some statistical and some just plain sampling reasons for that.

CHAIR STETKAR: Great. Thank you. Any -- Charlie or Harold, do you have anything more for Don?

MEMBER RAY: No.

CHAIR STETKAR: Don, thank you. If you are on a tight schedule, thank you very, very much for hanging around.

MEMBER RAY: One more --

CHAIR STETKAR: Yes, I know. I just wanted to make sure Don, in case he wants to run away quickly, make sure that he could do that. Ty?

MR. WAMSLEY: Okay, yes. I don't really have much to add to what Don said. I will just touch real quickly on the modeling aspect of it. As he said, that it is important to quantify that uncertainty. And of course the quality of the modeling that you do is going to be directly related to that. And so that is one of the recommendations that we had in there was the application of a very high resolution physical system that includes all of the relevant processes so that you can do as well as you possibly can in that.

You know, where a lot of the uncertainties come in of course you are just trying to represent a very complex thing with a numerical model, which is difficult. And then really a lot of where we found when we were more often in places than others has to do with how well you actually are resolving the physical system. Do you have the right bathymetric and topographic features in there. And so it is really important to try and resolve and get as good a representation of that coastal flood plain as you possibly can to try to minimize what that uncertainty is associated with the model. And so that is the approach that we presented in the report.

CHAIR STETKAR: Okay, thank you. Again, Charlie, Harold, anything for Ty?

MEMBER RAY: No.

CHAIR STETKAR: Thanks, Ty.

MR. WAMSLEY: All right.

CHAIR STETKAR: I guess, Joe --

MR. KANNEY: Back to me?

CHAIR STETKAR: -- back to you. And I think what we would like to hear because you have referred to it a couple of times is your characterization of your term or whatever term that is path forward here.

MR. KANNEY: Okay. All right, thank you. Okay, let me give you a little bit of background just so you get a better understanding of where the staff is coming from.

Over the last several years since, I think certainly since I have joined the Agency three years ago and I think discussions were going on before that between Staff and Research and NRO and NRR and the Regions, there are several areas which have been identified which really can benefit from a more risk-informed approach with respect to the external flooding events. Some of the items which have been flagged, of course, you know, the review of the SARs for COLAs and ESPs but also the risk assessment standardization project within research, the SPAR model development program. There is an external events SPAR model that you are probably aware of. You are probably aware that they are not very well developed with regard to external flooding.

But also in terms of our colleagues out in the Regions, the senior reactor analysts themselves, when they get into the significance determination process, they really are trying to put risk-informed numbers or risk-informed information to these problems.

And then also there is also the accidence sequence precursor program where you are really, you are trying, one of the basic inputs there if it is an external hazard caused event, you are looking for reasonable estimates for initiating event frequencies. Okay?

CHAIR STETKAR: Right.

MR. KANNEY: So a lot of different areas where risk-informed approaches can be useful.

And also the interactions that we have been having with the contractors that have supported this work for the update of 1.59, the folks at the Corps, the folks at Bureau of Reclamation have been describing the work that they are already doing and how they are incorporating risk-informed approaches.

There is a discussion of this in Rajiv's NUREG as well. Recently, the GAO came out with a report indicating that they also thought that our natural hazard assessments could be more risk-informed. And we also have your most recent review and evaluation, the NRC Safety Research Program.

So both internally and from external sources there is a lot of agreement on the need to move in this direction. So I wanted to talk about a few activities that I characterize them as current, near-term and longer-term.

Actually there is a current activity that is going on within Research right now. We have put together a long-term research plan. You are familiar with the Research's long-term research plan that was aimed at Assessing Climate Variability Contribution to

Risk at Nuclear Facilities. That is a very long-winded name but what the idea was that just within natural variability in the climate, not -- that is why we were trying to get at the climate change question here. We are just saying okay within natural variability and all the phenomena that we have been talking about, can't we do some things to better look at how those things may contribute to the risk profile plans.

That was originally scheduled for funding next year but when that was sort of reviewed by SLs in various offices the folks in NRR picked up pieces of it and we put together a user need. And the user need is concentrating on enhancing the external SPAR model, external events SPAR model. And there is three items there that we are looking at in ongoing project. One is probabilistic rainfall modeling. That we actually have a contract with folks at Oak Ridge and some folks from Northeastern University that are putting together based more for the review and for a state of the art type document on data and methodology for probabilistic rainfall modeling. They actually are looking at how you would put climate information into that.

And then the other two bullets are bullets that I am actually working on myself is to come up with guidance for a flood frequency analysis, as you would put it into the SPAR model and also look at what we might be able to do in terms of continuous simulation approaches for flood frequency.

And again, this is aimed at information that you might be able to put into an external events SPAR model, not necessarily the extreme probabilities that we might want to look at for design-basis or beyond design-basis but more the more common occurrence which may impact the risk profile of a plant, even though they are not the most extreme.

I guess a good example would be say for example at Fort Calhoun the switchyard was flooded and so then they went, so they lost off-site power for a while. You know, what does that do to the risk profile of the plant? That wasn't beyond their design-basis but there are good questions to ask about how did that affect their risk profile. So that is the sort of thing we are looking at there.

And then also earlier on we talked a little bit about paleoflood information. And we have a project that we are putting in place right now, the actual work hasn't started, with the U.S. Geological Survey to help us better assess how useful paleoflood information might be with regard to flood risk assessment at power plants.

I mean John England mentioned that they use it for their dams out West very, very frequently. They use it quite a bit. Now it so happens that out West is a better place to be looking for paleoflood information because of the geology and the geomorphology.

In the East, it is not as clear-cut that you are going to find good paleoflood information. And so this is one thing that the U.S.G.S. is going to help us work through is to look at more the eastern U.S. and assess how likely is it that we are going to be able to find good paleoflood information and then put together sort of a process for how one would go through and do a paleoflood analysis for the eastern U.S.

And then also as part of this project they are also going to look more sort of as a literature review process really for paleotsunami evidence on land. There is an existing research program that Annie Kammerer and Henry Jones are doing with tsunami that I think you guys are well aware of. This would be looking at the geomorphic and geologic evidence of the inundation on land, not the source terms that --

CHAIR STETKAR: Not characterizing the sources.

MR. KANNEY: Yes. But there is evidence that you can find geologic or geomorphic evidence for the inundation from the tsunami.

CHAIR STETKAR: Right, regardless of where --

MR. KANNEY: Right. There is also a source term.

And then also analogously you could do the same thing, some researchers have started doing the same thing for storm surges themselves. And there have been some evidence of hurricanes that have it that people didn't really know about but they found evidence in terms of in geologic deposits, for example. And those are going to be really just sort of a literature review. What is the state of the art rate now? Not a detailed treatment of those. Okay?

Okay, then some proposed near-term activities. These are like late, very late FY12 through next year and the following year. As a follow-on to the work that the Bureau of Reclamation did in support of Reg Guide 1.59 update, the work that John and his colleagues did taking the existing PMP methodology, looking at the impact of including newer storms. What does that do to the estimate? As John mentioned, for certain area sizes and certain durations, you basically break the PMP in the Carolinas is what they found. Okay?

And John mentioned that there is, you know, NOAA has regional precipitation frequency information available. They routinely do this for estimates of like out to one in a thousand years.

And the follow-in project that we are proposing, it has not been approved yet, this is a still proposed item, that we would try to do two things which John and his colleagues found we still need to look at. One is can we take a regional precipitation frequency approach and use that for the more extreme precipitation beyond one in ten thousand, beyond the one in a thousand years that typically is available for engineering type applications.

The other things is we didn't really -- John would have mentioned this had we gone through his full presentation but the work that he and his colleagues did in the Carolinas did not look at orographic regions. They looked essentially, the impact they studied was mainly the impact of like an additional ten tropical cyclones that impacted sort of the coastal areas of North Carolina. Now as you get into the more mountainous areas of the Carolinas, then orographic influences will come into the precipitation estimates. And that wasn't looked at in that study.

And so what we want to do is look at the precipitation frequency approach that John and his colleagues just were able to touch on just a little bit in their previous work and combine that with an orographic region and try to look at both of those impacts. Okay?

And then another proposed piece of work that we are working with Pacific Northwest National Laboratory on right now -- I'm sorry. I should take that back. We are not working right now. We are working to put together the project is basically to look at putting together a technical basis document for riverine flooding. We think that is an area that is sort of right because of, as John England mentioned, the Bureau of Reclamation has been doing this for several years. We really think that there is enough maturity there that we can work with Pacific Northwest National Lab and put together a technical basis document for riverine flooding for power plants.

And really just because of sort of the amount of funding that we think we might have available, there are certain things which I have listed that we are not going to treat, not because they are not important. That is actually the last bullet, like the dam failure ice effects and channel diversion, they are out of scope for this project just because of the amount of funding we think we are going to have for it. It is not because we don't think those are important or that they don't need to be treated but we are going to have to treat that in some other project or in some other way.

So the scope that they are really going to look at is data sources, analysis approaches, mathematical models, model parameterization, the uncertainty and the sensitivity analysis, and available software for doing that type of work.

Then coming up the beginning of next calendar year we are planning an multi-agency workshop on probabilistic flood hazard assessment. There is a joint NRO/NRR user need for this, for the workshop in place. Research is going to host that. And Tom Nicholson and Richard Raione are going to bet he co-chairs. Tentatively it is scheduled for January 29th through the 31st.

We are looking at other federal agencies as co-sponsors. There is a list of folks that we are talking to.

And the proposed topics basically are we are going to try to cover probabilistic modeling of the various phenomena that we have been talking about today, also look at the treatment of combined events, and look at how to interface this with PRA models.

And the idea here is, the purpose of the workshop really is to identify where are there gaps, where does additional work need to be done to be helpful for our use in our regulatory approach. You know, the point is not to, I think as you may be mentioned John, develop the entire big framework because we think many of the pieces are there but we think that there are some gaps. We want to identify those gaps, identify what needs to be done to get us to a position where we can use this more in our work.

MR. NICHOLSON: Joe, can I make a quick comment?

MR. KANNEY: Sure.

MR. NICHOLSON: Yesterday we presented this to the subcommittee in hydrology. We have gotten a formal response from the Army Corps of Engineers. Their HEX Center in Davis, their risk management people have formally bought into this workshop. They will be a sponsor.

We have gotten verbal agreements from

U.S.G.S and the Bureau of Reclamation and FERC. So we are going to have our first organizing meeting within the NRC Staff between the risk assessment people and the hydrologists now we are going to have our first meeting with the feds the end of July. Thank you.

MR. KANNEY: Thank you, Tom.

Okay, then last slide, sort of the longer-term activities is basically we want to take the information that we get from the workshop with regard to really with regard to addressing the gaps and then figure out what we want to do with that.

You know, the options there obviously the user offices could draft additional User Need Letters that Research would then implement research to address those. Another option would be that Research would develop a full-fledged research plan around the gaps coming out of that workshop.

And then further along then we would evaluate what the options for NRC have in terms of providing guidance. Sort of at a ten thousand foot level the two options are, do we develop NRC specific guidance or perhaps adopt industry consensus standards because we are aware and we are participating at a certain level in these industry consensus standards development. Certainly two that are of most relevance are ANS-2.8 for design or flooding hazards for nuclear power plants and that is currently under revision. And the working group is driving at a probabilistic standard. ANS-2.31, which includes precipitation is also under revision right now and that is also driving towards a probabilistic standard.

And that is all I have on that.

CHAIR STETKAR: Well thank you.

MR. KANNEY: Do you have any questions?

CHAIR STETKAR: Charlie? Harold?

MEMBER RAY: I have spoken enough. I'm ready to go to the full committee.

CHAIR STETKAR: Good. Yes, and I don't -- thank you a lot. We actually got through more information than I thought we were going to get through. I think it was a good exchange.

I think you have heard what we have had to say. Granted there are only three of us here. We do have a presentation to the full committee scheduled for, I believe it starts September meeting. I think we should proceed with that. I don't know whether the committee will refuse to write a letter. That is not my decision to make.

For the full committee presentation, I think one area of interest, and I am not sure whether it is addressed in the material that we have today, but something that kind of came out of the last 45 minutes or so of discussion would be some appreciation of which areas, for example Joe you started with the different flooding mechanisms, out of those areas, if I consider those different sources of a flooding hazard, where do we have better or lesser capabilities to address them probabilistically? For example, if we heard from the Bureau who obviously has a certain mindset about their experience addressing things. We heard from the Corps. There are other areas where perhaps we are on the fringes of where are we in terms of the state of the practice. I think that would be valuable information to kind of set a perspective for the full committee in terms of not necessarily the need to holistically solve the entire problem of how do you address a probabilistic flooding hazard analysis but where are we. Are there certain parts of the problem where we are fairly close and others where we are less close?

I think that the HHA is worthy of discussion only because of its parallels at least in my mind of things that are already done. So this notion that there is a methodology for dealing with however the hazard is specified, dealing with its progressive refinement and how one might do that, I think that is useful information. And to make sure that the committee understand that at least in my interpretation the NUREG/CR-7046 is focused at that part of the problem, primarily, although it does talk about other parts.

So in terms of guidance and you can obviously discuss things. Derrick and Dana may have other ideas but at least from the perspective out of this, things to think about in terms of coming to the full committee in September, I think those topics would be of interest and quite useful.

I will ask for input from any members of the public who might be here. Hearing none --

(Laughter.)

MR. OTT: I was going to say I have one clarification of a question that we didn't answer before.

CHAIR STETKAR: Okay.

MR. OTT: You asked about how we were going to go with regard to the review of the Reg Guide.

CHAIR STETKAR: Yes.

MR. OTT: And I sort of backed off from saying anything directly. I discussed it with NRO and we were actually anticipating that we probably would get a letter out. But apparently that is still up in the air whether we do or not.

CHAIR STETKAR: I can't make the commitment because the subcommittee doesn't make that decision.

MR. OTT: I understand. But on the assumption that we would, we planned for it because we still have some offices that have not completed the current process yet. So we will be looking at getting out a letter towards the end part of September, assuming that it didn't tell us to stop and go back and start all over again, we would be anticipating responding to comments and probably trying to publish towards the end of October. And going into a public comment period then before we get directly NEI comments as well as the public.

And that will give NEI and the industry lots of opportunity to go through this 2.1 process and learn things.

So that is where our thinking is right now because we are still in the draft guide stage right now. So we have got lots of opportunities.

MEMBER RAY: Well in that regard, given that schedule that I am sure will result, I can tell you that the impression is going to be in the industry that well now it is settled for the next generation. I'm telling you that is what it is going to be.

And you know, I think the main concern that I would bring to the full committee, anyway, is if that is the case, we have made a mistake.

MR. OTT: Well it is not our intent. And I think everything that I have heard from the Staff internally is that although we think it is worthwhile doing this and at least getting all of this information down in guidance, which is been vetted and all that kind of stuff, that we think that conservative language should be put in to developing a risk-based approach to doing this.

PFHA is the subject of this workshop. I would actually have preferred it if they told us to go ahead and start developing the skeleton now even before the workshop so that we can have it vetted at the workshop.

MEMBER RAY: That is exactly one of the things now we can't commit to in this context.

(Laughter.)

MEMBER RAY: But in a very related context, we expect to have a discussion on that point. Not because of this, but something else.

MR. OTT: In that context we anticipate it will take some time to address the observations that come out of the workshop, there will be some research involved. We won't be able to do it next year. We are probably looking at three to five years down the road before we would be coming back to you again with Revision 4 of that.

CHAIR STETKAR: But on the other hand, there may be ways to change some -- if there is a driving force to get this update out within the next about six months or nine months or something like that, there may be ways to change some of the context of this revision, not content but context, to at least nudge people in one direction or another without this notion of okay we are now wired into a deterministic process and three to five years in the future we are going to switch gears or something like that.

MR. OTT: We would certainly like to get to the point where we are not trying to put more Band-Aids on deterministic processes and can actually switch on to the other train. So we would like to put this together, put a ribbon around it and move on an try and get that out and do that.

And I wanted to make one observation about John England's enthusiasm for what the bureau has done. And that is one of our problems. One of the problems we face with other federal agencies is the recurrence intervals that they are concerned with is those are the recurrence intervals that you are concerned with.

MEMBER RAY: Well yes, exactly. But that is part of the problem is that we are concerned about long recurrence intervals but we actually wind up dealing with short ones, like before. And we have got to get out of that.

MR. OTT: Well I understand. It is just that we happened to take what John said with a little bit of a grain of salt here and there. Because we may take it but we are going to have to change it.

CHAIR STETKAR: I understand. And part of the process might be admitting that a ten to the minus six event, a ten to the minus six a year event is not what we are really designing the plants to. Get over it.

MEMBER RAY: That is one way. There are other ways to say well my God, we have never experienced the seismic events that we designed the plants for today either and there is really no evidence for it. It is purely mechanistic modeling, based on the structures that exist. So anyway.

MEMBER BROWN: Well didn't North Anna gave a seismic event as part of what their design-basis was?

MEMBER RAY: That's why I used the word today.

MEMBER BROWN: Oh, okay.

MEMBER RAY: North Anna was designed a long time ago, like the plant I was talking about.

MEMBER BROWN: Okay, got it. I was just saying --

MEMBER RAY: Unit 1 and 2 is a design for what 3 and 4 are.

MEMBER BROWN: Yes.

MEMBER RAY: But that is another story.

CHAIR STETKAR: Bill, thank you very much. Charlie, anything more? Harold, anything more?

Joe, thanks a lot for sitting there and calmly listening. I think it was really worthwhile. And with that, we are adjourned.

(Whereupon, at 5:38 p.m., the above-entitled matter was adjourned.)

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission

Proceeding: ACRS RPP Subcommittee

Docket Number: n/a

Location: Rockville, Maryland

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken and thereafter reduced to typewriting under my direction and that said transcript is a true and accurate record of the proceedings.

Neal R Gross

Official Reporter
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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
Regulatory Policies and Practices Subcommittee Meeting

Hierarchical Flood Hazard Assessment

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July 10, 2012

Pacific Northwest NATIONAL LABORATORY

Hierarchical Hazard Assessment Approach

- Objective of Flood Hazard Assessment
  - provide reasonable assurance that plant SSCs would be safe
  - account for worst historical flood hazard
  - account for limited datasets
  - demonstrate sufficient margin

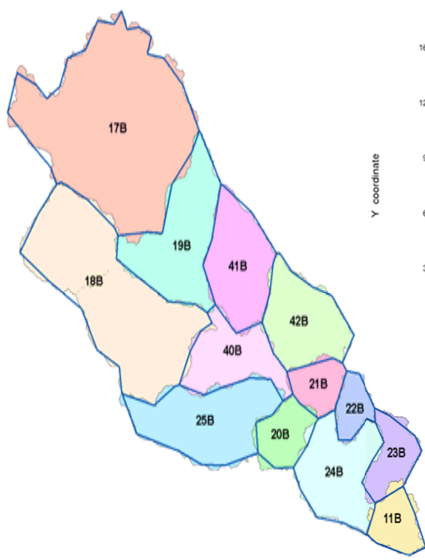
- How do we meet these objectives?
  - analysis of historical data and observations
  - consideration of all plausible flood causing phenomena
  - floods generated by probable maximum events
  - consideration of combined events
  - use conservative assumptions

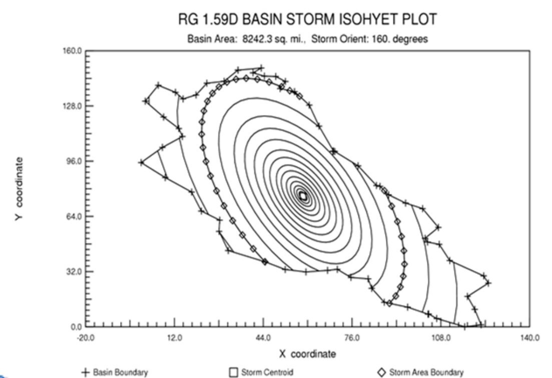
Hierarchical Hazard Assessment Approach

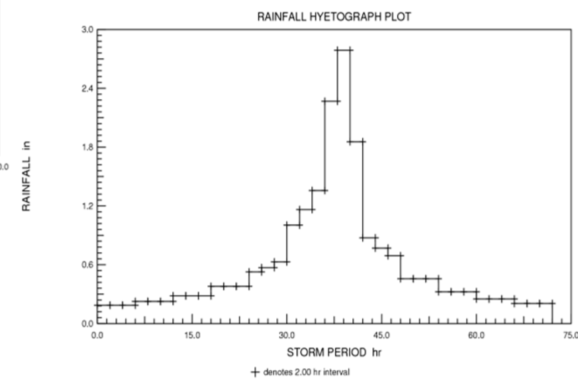
- What is HHA?
  - a set of iterative, progressively refined flood estimation steps
    - **Step 1**: identify flood causing phenomena by inspection of historical data and an assessment of all plausible hydrological, geoseismic, and structural failure processes in the vicinity of the site; document implausibility
    - **Step 2**: for each flood causing phenomenon, perform a conservative estimation of the flood hazards using ANSI/ANS-2.8-1992 combinations
    - **Step 3**: if any safety-related SSC is exposed to adverse effects of flood hazards, perform a more site-specific flood analysis ensuring that the flood-producing conditions are at least as conservative as and are consistent with what Federal agencies use in similar design considerations and repeat Step 2; else perform Step 4
    - **Step 4**: specify site characteristics for flood hazards

An Example of HHA

- Probable Maximum Flood (PMF) at a site
  - is caused by a Probable Maximum Precipitation (PMP) event
  - Step 1:
    - estimate PMP hyetographs for subbasins of upstream drainage area







An Example of HHA (cont.)

- PMF at a site
  - Step 1:
    - flood causing phenomenon: PMF in the drainage area above the site
  - Step 2:
    - estimate PMF using conservative assumptions: no precipitation loss, instantaneous translation of surface runoff to the site, no attenuation as flood peak passes through storage reservoirs; estimate coincident wind-wave effects consistent with ANSI/ANS-2.8-1992
    - let us say this conservative estimation resulted in inundation of site grade
  - Step 3:
    - use site specific data: route surface runoff using peaked unit hydrographs
    - flood level drops, but still presents hazards to some SSCs
    - use site specific data: precipitation loss rate consistent with US Army Corps
    - flood level drops more, only SSC still inundated is safety-related intake
    - no more site-specific data to use

An Example of HHA (cont.)

- PMF at a site
  - Step 4:
    - estimate flood hazards for the safety-related intake: hydrostatic forces (water levels), hydrodynamic forces (velocities), scouring potential, duration of inundation, and lead time for action

- HHA should be applied to all plausible flood causing phenomena
  - site flooding under local intense precipitation
  - flooding in rivers and streams; flooding from dam breaches and failures
  - storm surges, seiches, tsunamis, ice-induced events, channel diversions

Pacific Northwest
NATIONAL LABORATORY

Observations and Conclusion

- HHA provides a consistent framework for assessment of flood hazards

- HHA provides assurance that all plausible flood causing phenomena have been investigated
  - analysis of historical data and observations
  - documentation of implausible flood causing phenomena

- HHA documents the level of conservatism built into the flood hazard analyses
  - clear documentation of site specific data used in flood hazard analyses

- HHA documents the conditions under which safety margins are estimated

Draft Regulatory Guide 1290, *"Design-Basis Floods for Nuclear Power Plants"*

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
Regulatory Policies and Practices Subcommittee Meeting

JULY 10, 2012

Outline

- Background
- Overview of Technical Scope
- Topics Common to Most Flooding Mechanisms
  - Site Hydrologic Description
  - Design Storm Reports
  - Nonstationarity
  - Deterministic vs. Probabilistic Analyses
- Individual Flooding Mechanisms
  - Local Intense Precipitation
  - Riverine Flooding
  - Dam Failure
  - Surge, Seiche and Tsunami
  - Ice Effects
- Combined Events
- Status of Concurrence Reviews

Regulatory Basis

- 10 CFR Part 50, *"Domestic Licensing of Production and Utilization Facilities*", Appendix A, "*General Design Criteria for Nuclear Power Plants,*" General Design Criterion (GDC) 2, "*Design Bases for Protection Against Natural Phenomena*"
- 10 CFR Part 52, "*Licenses, Certifications, and Approvals for Nuclear Power Plants*"
- 10 CFR 100.20, "*Factors To Be Considered When Evaluating Sites*"
- 10 CFR 100.23, "*Geologic and Seismic Siting Criteria*"

Related NRC Guidance

- RG-1.70, Rev.3 "*Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)*"
- RG-1.206, "*Combined License Applications for Nuclear Power Plants (LWR Edition)*"
- NUREG-0800, "*Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)*"
- RG-1.102, "*Flood Protection for Nuclear Power Plants*"
- RG-1.200, "*An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities*"
- RG-4.7, "*General Site Suitability Criteria for Nuclear Power Stations*"

Related IAEA Guidance

- NS-R-1, "*Safety of Nuclear Power Plants: Design*"
- NS-R-3, "*Site Evaluation for Nuclear Installations*"
- GS-G-4.1, "*Format and Content of the Safety Analysis Report for Nuclear Power Plants*"
- NS-G-1.5, "*External Events Excluding Earthquakes in the Design of Nuclear Power Plants*"
- NS-G-3.5, "*Flood Hazard for Nuclear Power Plants on Coastal and River Sites*"
- NS-G-3.6, "*Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants*"
- SSG-18, "*Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations*"

Why Update This Guide?

- New data
  - Storm, precipitation and flood records
  - Topographical data
    - Digital Elevation Maps (DEMs), LIDAR
- Advances in analytical methods and tools
  - 2D and distributed hydrological models
  - Coupled wind-wave surge models
  - Geographical Information Systems
- Advances in computational resources
  - Dramatic increases in computer memory and data storage capacities
  - Dramatic increases in computational processing speed and affordability (e.g., PC Clusters)

Site Hydrologic Description

- Safety-related elevations, structures, exterior accesses, equipment and systems should be described from a hydrologic perspective
- Exisiting topography of the site as well as any proposed changes
- Location, size, and other hydrologic characteristics of water bodies that may influence flooding at the site
  - streams, lakes, estuaries, shore regions, man-made channels, etc.
- Existing or proposed water control structures
  - Dams, levees, diversions, channels, intake/discharge structures, etc.
  - Structures upstream and downstream of the plant site
- Flooding history of the site and region
  - Major historical flooding events should be described in detail
    - Water levels, discharges, duration, etc.
- Information from paleoflood studies (where available)

Dated Design Storm Reports

- Probable Maximum Precipitation (PMP)
  - NOAA/NWS Hydrometeorological Reports
  - Example: HMR-51 (1978)
    - Covers most of Eastern U.S.
    - Most recent storm analyzed: 1974
- Probable Maximum Hurricane Wind Fields
  - NOAA Technical Report NWS-23 (1979)
  - Many well-documented storms since NWS-23 PMH parameter ranges adopted
  - PMH concept replaced by more physically-based maximum potential intensity (MPI)
- Bottom line: valuable information, but dated
  - Due diligence required

Non-Stationarity

- Sea-Level Rise (Coastal Sites)
  - Historical trends
    - NOAA/NOS data
- Potential Climate Change Impacts
  - Potential for accelerated SLR rates (Coastal Sites)
    - USGCRP recommended approach
  - Potential for increases in storm intensity (Coastal Sites)
    - Ambiguous (model-predicted changes vs. observations)
  - Potential for Increased Precipitation (Inland Sites)
    - Ambiguous at region and site-scale (models differ)
  - Potential for Increases in stream discharge (Inland Sites)
    - Ambiguous (model-predicted changes vs. observations)

Deterministic vs. Probabilistic Analyses

- NRC staff has mainly relied on deterministic approaches to design-basis flood estimation: hierarchical hazard assessment (HHA)
  - progressively refined, stepwise estimation of site-specific hazards
  - most conservative plausible assumptions consistent with available data
  - NUREG/CR-7046 provides guidance and illustrative case studies for applying HHA to a variety of flooding mechanisms
- Probabilistic characterization of extreme floods by various mechanisms, or combinations of mechanisms will be accepted on a case-by-case basis
  - NRC staff does not provide specific guidance on probabilistic flood hazard analysis techniques at this time
  - NRC staff currently uses combined flooding event scenarios from ANS-2.8-1992
    - average annual probability of exceedance of less than 1E-6
  - Reasonable criterion to apply to design-basis flood estimates arrived at via probabilistic methods assuming that reasonable confidence limits can be established

Local Intense Precipitation

- Precipitation event occurring at the immediate plant site
  - Adequacy of site drainage systems (including drainage from roofs of structures) and adjacent drainage areas
  - Always examined irrespective of the plant grade elevation with respect to nearby rivers, lakes, or other water bodies
- Key elements
  - The site drainage system description
  - Design storm
    - Area, duration, and temporal distribution of rainfall intensities
    - Guidance provided by the National Weather Service (e.g. HMR-52)
  - Models and associated parameters used to estimate the generation of surface runoff from the design storm
  - Models and associated parameters used to estimate conveyance of the surface runoff away from the site
- Analysis should address potential for the site drainage system effectiveness to be compromised
  - Potential for blockage during storm events by water born-debris

Riverine Flooding

- Flooding hazards at the power plant site caused by severe hydrometeorological conditions occurring over watersheds that communicate with the site
- RG-1.59, Rev. 2, Appendix B (maps, tables from envelope curve formulas) no longer recommended for screening
- Deterministic analysis aimed at determining the most extreme credible flood, also known as the probable maximum flood (PMF)
  - Defined as the hypothetical flood (peak discharge, volume, and hydrograph shape) considered the most severe reasonably possible
  - Application of hypothetical extreme rainfall event (e.g., PMP) along with other hydrologic factors favorable for maximum flood runoff (combinations of processes occurring in the drainage basin above the site and at site)
  - Appropriate combinations to consider should be determined on a site-specific basis.
    - Sequential precipitation events
    - Timing, centering, and duration of precipitation
    - Seasonal variation of precipitation and antecedent moisture
    - Snowpack accumulation, snowmelt, and meteorological factors influencing snowmelt timing
    - Flood-caused dam failures
    - Reservoir elevations
    - Superimposed wind waves

Riverine Flooding: Key Elements

- Design Rainfall - Evaluate the precipitation flux over the watershed as a function of space and time
  - Developed from the hypothetical extreme rainfall event
    - Storm-centered, area-averaged PMP, in most cases
  - Optimal temporal distribution, optimal centering and orientation over the drainage basin
  - Movement of the storm along the basin axis
  - Procedures recommended by the National Weather Service
- Rainfall-Runoff Analysis – Evaluate effective precipitation flux as a function of space and time
  - Description of the watershed (area, topography, soil types, land cover)
  - Rainfall-runoff transformation function
    - unit or synthetic hydrograph
- Flood Routing - Route the precipitation excess to the plant site to determine flood hydrograph.
  - Description of the stream channel network
    - Reach lengths, cross sections, and cross-section locations
    - Channel roughness coefficients,
  - Flood routing method
  - Initial and boundary conditions
- Validation exercises - Apply the analysis to historical floods, if available

Dam Failure

- Dams to consider for potential failures
  - Dams upstream of the plant site
  - Dams not upstream of the plant, but whose failure may impact the plant because of backwater effects
  - Water-storage or water-control structures located at or above the grade of safety-related equipment
    - Onsite cooling or auxiliary water reservoirs, onsite levees
- Screening may identify some dams that can be eliminated from more detailed consideration
  - Low differential head, small water volume stored, distance from plant site, major intervening natural or reservoir detention capacity.
- Dam failure categories (predominant mode of failure)
  - Hydrologic dam failure
  - Seismic dam failure
  - Dam failure from other causes (sunny-day failures)
- Multiple dam failures and the domino failure of a series of dams
- Dynamic hydraulic models to route the flood wave resulting from dam failure to the plant
- Examine sensitivity of flood stage and water velocity estimates
  - Reservoir levels, reservoir inflow conditions
  - Tailwater conditions before and after dam failure
- Transport of sediment and debris by the flood waters

Coastal Flooding

- Coastal refers to the near-shore regions of any water body (e.g., ocean, lake, bay, estuary, etc.) where surge, seiche, or tsunami phenomena may occur, not just regions adjacent to the open ocean
- In coastal regions, flooding hazards result from storm surges, seiches, and tsunamis, along with coincident wave action caused by hydrometeorological activity
- Wind-generated wave activity that can occur independently of or coincidentally with storm surge or seiche should be included in surge and seiche flood hazard analyses
- Available records should be used to characterize the wave climate near the site using measures such as significant and maximum wave heights
- Wave setup, runup, splash, or overtopping, as appropriate, should be considered
- Potential impact of tides should also be included in surge and seiche flooding estimates

Storm Surge

- RG-1.59, Rev. 2, Appendix C maps, tables for screening no longer recommended
- Detailed analysis of historical storm events in the region, when available
- Historical record augmented by synthetic storms
  - Parameterized to account for conditions more severe than those in the historical record, but considered to be reasonably possible on the basis of meteorological reasoning.
- Each storm type appropriate for the region should be examined to determine estimates for extreme winds
  - tropical cyclones (hurricanes)
  - extratropical cyclones
  - squall lines and hybrid storms
- Simplified conservative methods may be used to screen out sites which clearly are not subject to significant storm-surge flooding
- When storm-surge flooding cannot be eliminated from consideration by simplified methods, detailed storm-surge modeling required
- Current state of the art in storm-surge modeling
  - Coupled hydrodynamic ocean circulation and wave models
  - Both models driven by a planetary boundary layer model that provides the atmospheric forcing.
- Models should be validated using historical storm information and data in the region of interest

Seiche

- The potential for seiche to impact the site should also be considered at coastal sites
- The oscillatory modes for the waterbody in question should be compared to forcing from a variety of potential sources
  - Local or regional forcing phenomena
    - Barometric pressure fluctuations
    - Strong winds, rapid changes in wind direction
    - Surge associated with passage of local storms
  - Distant but large forcing mechanisms
    - Distant storms, tsunami, or earthquake-generated seismic waves
- For waterbodies with simple geometries, modes of oscillation can be predicted from the shape of the basin using analytical formulas
- Most natural water bodies have variable bathymetry and irregular shorelines and may be driven by a combination of forcings
  - Seiche periods and water surface profiles should be determined through numerical long-wave modeling

Tsunami

- Tsunami hazard zones
  - Coastal sites : hazards from oceanic tsunamis
  - Inland sites: tsunami-like waves in water bodies in the region
    - Hill-slope failure or seismic sources
- Effects of tsunami or tsunami-like waves
  - Runup, flooding, erosion, and debris loads
  - Rundown or return flow of water (and debris)
- Screening
  - Regional or site specific survey and assessment of tsunamigenic sources
    - Potential near-field and far-field sources and mechanisms that could generate tsunamis
    - Any relevant paleo-tsunami evidence should be assessed
- Detailed assessment
  - Postulation of probable maximum tsunami (PMT) source mechanisms
    - Location, dimensions, orientation, and maximum displacement
  - Estimation of PMT source characteristics,
  - Initiation of the PMT wave,
  - Propagation of the PMT wave from the source toward the site
  - Estimation of tsunami effects at the site

Ice Effects

- Potential for ice-jam formation should be assessed based on regional hydroclimatic conditions
  - air temperature characteristics
    - NOAA's National Climatic Data Center (NCDC)
  - Regional ice accumulation and ice jam formation history
    - U.S. Army Corps of Engineer's Ice Jam Database
- When the potential for ice formation cannot be ruled out, or is not clearly bounded by other flooding mechanisms, flooding hazards due to ice effects should be examined quantitatively
  - Ice-jam formation on nearby streams
  - Ice accumulation on site facilities
- Because of the much higher flows that usually prevail during spring breakup, breakup jamming is usually identified as the ice-related event of main concern for flood-hazard assessment
  - Flooding due to backwater effects of ice-jam formation downstream of the plant
  - Flooding due to breach of an upstream ice jam
- Predicting precise location and severity of ice jams is generally infeasible
  - Analyze impact of hypothetical ice jams at critical locations

Combined Events

- Extremely large floods of interest for design basis seldom the result of a single event or process
- Consideration of reasonable sequences and combinations of processes and events, based on regional or site-specific information
- Maximum water-surface elevation and maximum hydrostatic force may result from different combinations.
- Many hydrometeorological flood-causing phenomena can occur sequentially or concurrently because they are not truly independent mechanisms
  - Floods from precipitation events may occur concurrently with snowmelt floods
  - In coastal regions, the precipitation event may be a result of a tropical or extratropical cyclone
    - Stream flooding could coincide with a storm surge and wind-induced waves
  - In general, the effects of coincident wind-generated wave activity on the water levels should always be considered
- Credible combinations and sequences of hydrometeorological and nonhydrometeorological events
  - Astronomical high tides may combine with hydrometeorological events (e.g., storm surge) or seismic events (e.g., tsunami).
- NRC staff currently uses ANS-2.8-1992 guidance (average annual probability of exceedance of less than 1E-6) as a metric to evaluate combined event scenarios
  - Guidance on formal probabilistic flood hazard assessment approaches providing consistent treatment of combined events is lacking
  - Reasonableness of qualitative and quantitative probability estimates for combined events assessed on a case-by-case basis, based on regional or site-specific information

Concurrence Reviews

Office	Division	Status
ACRS	---	In progress
NRO	Site Safety & Environmental Analysis	In progress
NRR	Operating Reactor Licensing	*Concurred*
	Risk Assessment	*Concurred*
	Engineering	In progress
NMSS	Fuel Cycle Safety & Safeguards	*Concurred*
Region I	Reactor Safety	In progress
Region II	Reactor Safety	In progress
Region III	Reactor Safety	*Concurred*
Region IV	Reactor Safety	*Concurred*

Thank You!

Questions?

RECLAMATION

Managing Water in the West

Research to Develop Guidance on PMP Estimates

Southeastern U.S.: North and South Carolina Pilot Project

NRC ACRS Summary – July 10, 2012

John England, Jason Caldwell, Victoria Sankovich

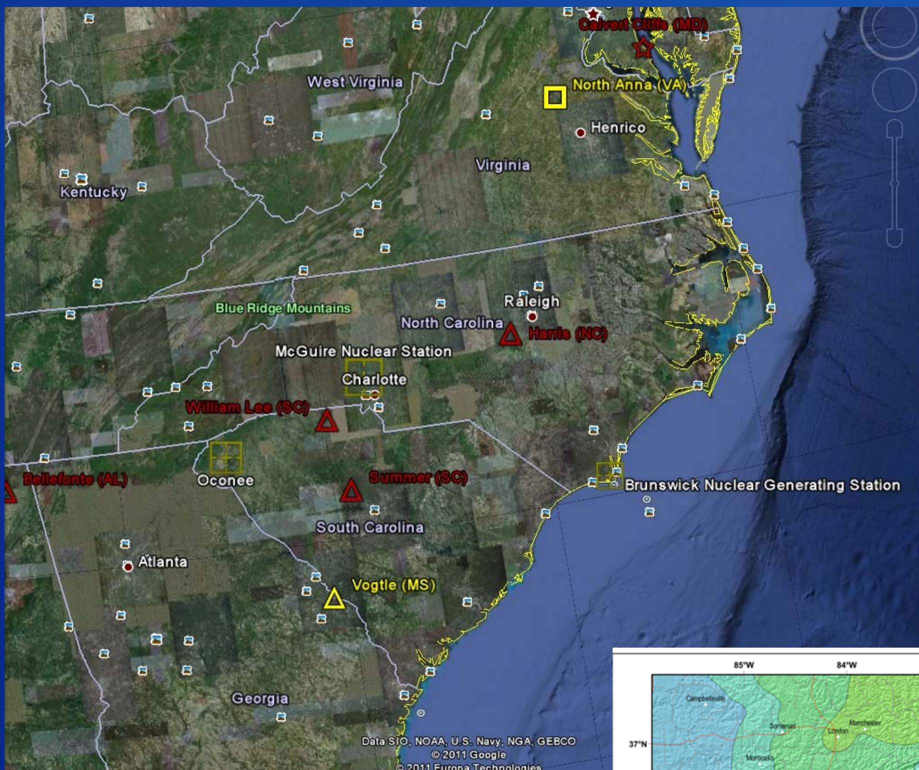
U.S. Department of the Interior
Bureau of Reclamation

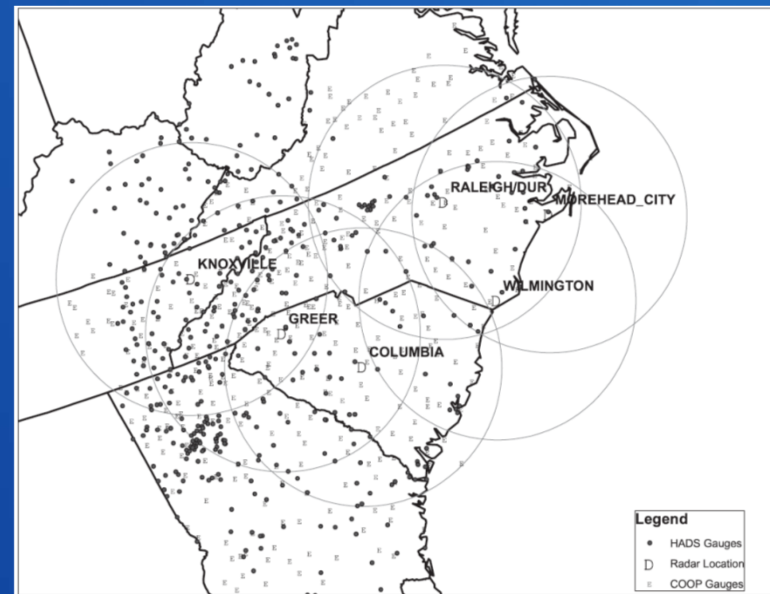
NRC PMP Research Objective

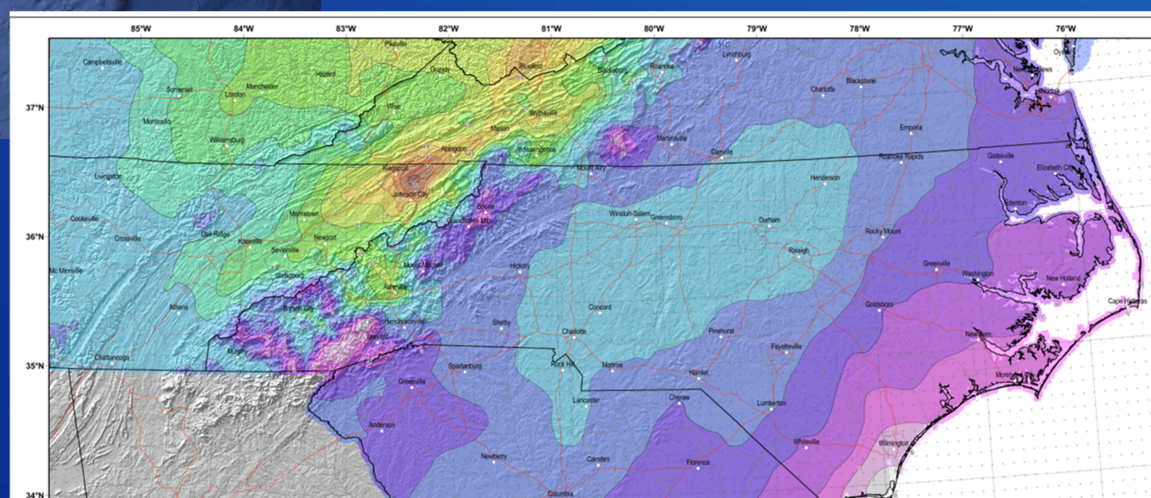
Main Objective: provide NRC staff with a supplement to the NWS HMRs 51 and 52 for estimating PMP for specified areas and durations within North and South Carolina (pilot area).

Supplement will provide the technical basis for developing and applying guidance to license applicants on acceptable methods and data sources for estimating and using PMP to calculate PMFs that the applicants need to consider in evaluating siting factors and in designing their facilities.

NC/SC Pilot Region







NRC locations
MPR
NOAA 14

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Major Deliverables - Reports

- Task 1: Review of PMP Methods report
- Task 2: Application of Radar Rainfall (new extreme storms) to PMP Estimates report
- Task 3: Synthesis of Extreme Storm Rainfall and PMP with Uncertainty

ftp://ftp.usbr.gov/jengland/NRC/reports/

Major Deliverables – Data and GIS

- D-A-D and Part II files for 20 major storms (1889-1972)
- D-A-D index (GIS) and D-A-D (spreadsheets) for 83 SE storms
- HMR 51 PMP Maps: shapefiles, grids
  ftp://ftp.usbr.gov/jengland/NRC/HMR51_PMP/
- HMR 51 storm index (GIS) and D-A-D (spreadsheets) for 55 storms in E US
- 10 new storms (MPR) hourly precip grids
- D-A-D for new storms and maximization factors
- All electronic files to reproduce analysis of new storms (raw MPR data, shell scripts, etc)

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Task 1 Review: Key Findings

- PMP methods have not changed in over 25 years
  - WMO (1986) = HMR 55A; WMO (2009) = WMO (1986)
- Old, outdated data: D-A-D, dewpoint climatologies
- Reports in eastern US – HMR 23, 33, 51 were continually updated/improved
- Big change from 33 to 51 was Yankeetown (1950) and larger transposition regions
- Relatively poor records/documentation in reports and files
- Subjective decisions; hard to reproduce
- Little research on fundamental PMP methods

HMR Evolution – Data, Methods, Documentation, Issues

- HMR 51 did not include orographic factors
- Orographic methods – storm separation – developed in HMR 55A
  - subsequently documented in WMO (1986)
  - used in HMR 57 and HMR 59
- Storm separation relies on precipitation frequency base maps (e.g. NOAA Atlas 2)
- Precip frequency methods now changed in NOAA 14 (regional frequency with L-Moments)

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HMR Evolution – Data, Methods, Documentation, Issues

PMP Probabilities and Climate Change

- Clear Probabilistic alternatives to PMP
  - regional precipitation frequency with L-Moments (e.g. NOAA 14) and Stochastic Storm Transposition
- Climate Change
  - very limited studies related to PMP; impacts unclear
  - Western US (1990s) – little impact (~10%)
  - Australia – potential increase in moisture availability, no increase in storm efficiency
  - impacts of new/recent storms and dewpoints easier to analyze/resolve

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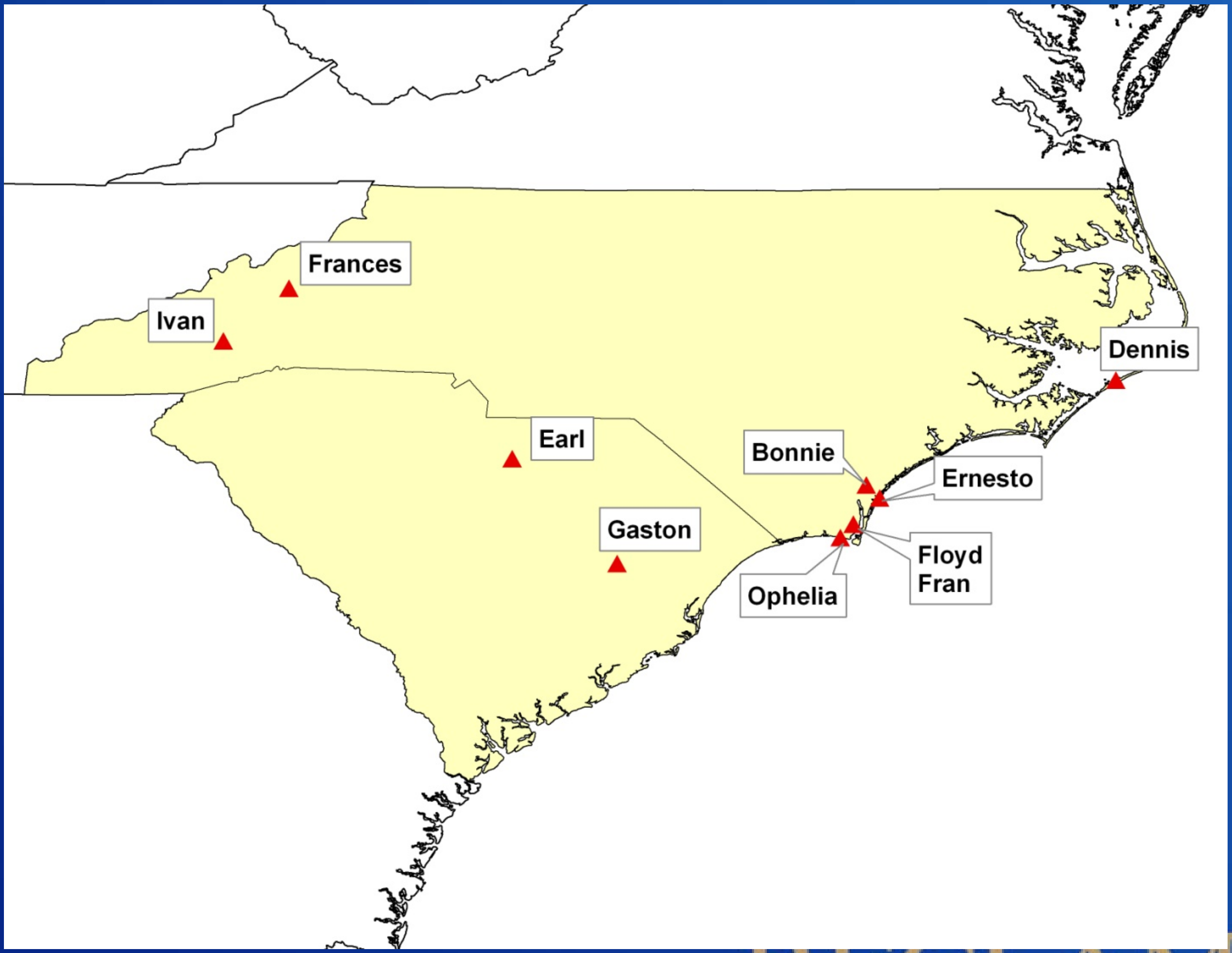
Task 2 New Data: Key Findings

Pilot project in NC/SC centering on **MPR** data

- New data analyses suggest ***HMR 51 PMP values too low*** for durations > 12 hrs and area sizes > 5,000 mi^2 along coastal Carolinas (Floyd and Fran)
- Other durations and area sizes unaffected in this location
- Storm maximized values somewhat sensitive to radar rainfall biases and use of maximized moisture
- Use of median moisture max ratio, Floyd still close to PMP

Max Rainfall Locations – Top 10

Sites concentrated near the coast for storms approaching from the Atlantic. Storms making landfall along the Gulf of Mexico produced highest rainfall totals in the piedmont and mountain regions.



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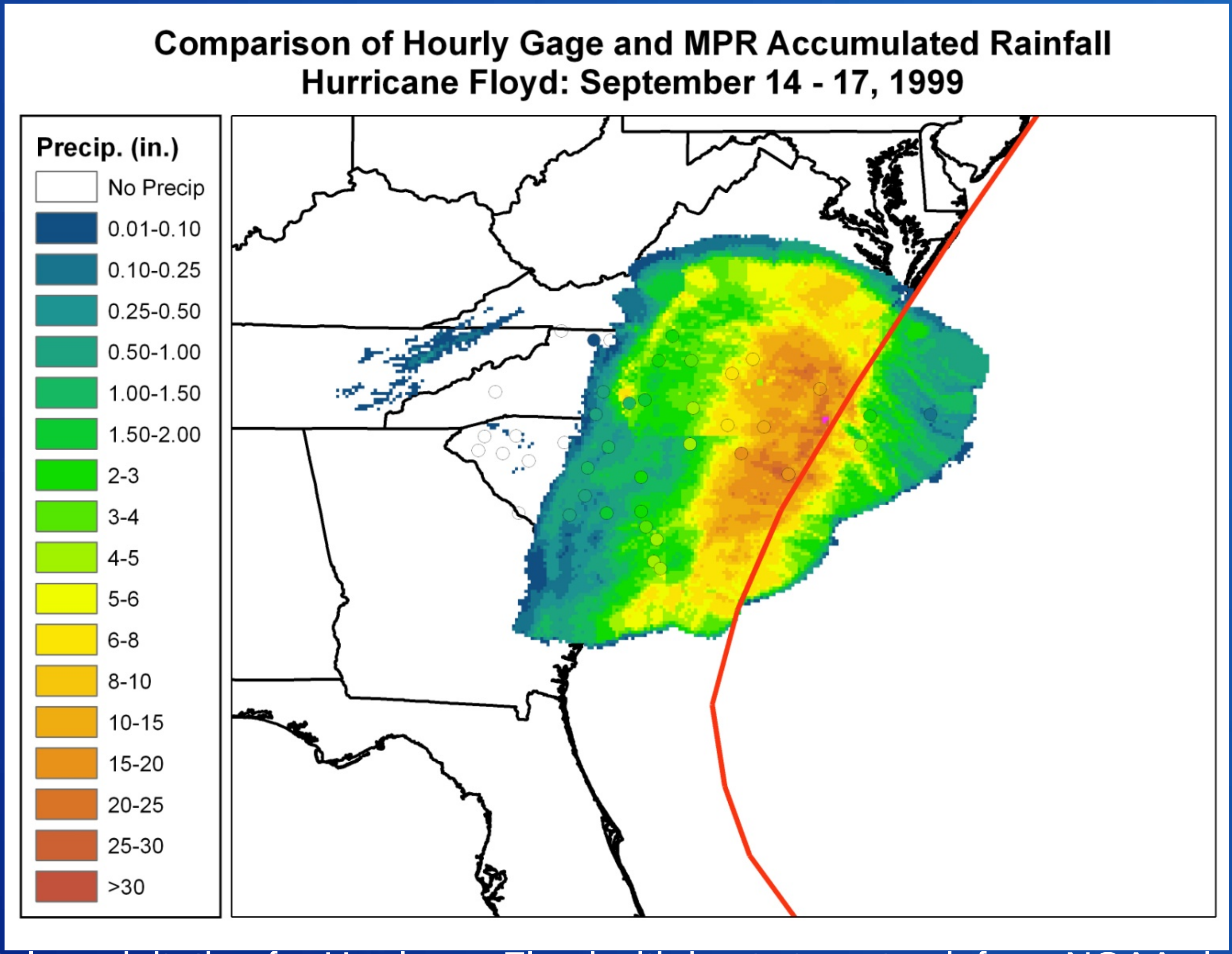
Results and Discussion

- 10 storms analyzed with MPR data
- 2 storms - Floyd and Fran - exceed HMR 51 PMP at their respective locations (in-place)
- Floyd and Fran appear to exceed HMR 51 major storms
- Excluded transposition and envelopment
- MPR data appear to compare well with gages

Individual Storm Analysis- Floyd



Storm total precipitation for Hurricane Floyd with best storm track from NOAA shown in red. Hourly precipitation gauge accumulations are overlaid to indicate differences between gauge and radar estimates.

Floyd – HMR 51 24 hour and 72 hr

Floyd1999		24h			72h		
Area (km^2)	Area (mi^2)	HMR51	MPR	% diff	HMR51	MPR	% diff
25.9	10	1084.59	755.40	-43.58	1279.64	1085.44	-17.89
51.8	20	840.78	675.41	-24.48	1046.30	906.62	-15.40
2589.99	1000	731.55	601.39	-21.64	873.40	779.99	-11.98
12949.94	5000	485.41	504.01	3.69	651.87	650.61	-0.19
25899.88	10000	388.75	443.13	12.27	567.97	578.20	1.77
51799.76	20000	309.86	357.37	13.29	462.52	467.33	1.03

Comparison of PMP values from HMR51 grids and 24-hour and 72-hour DADx from MPR for Floyd 1999.

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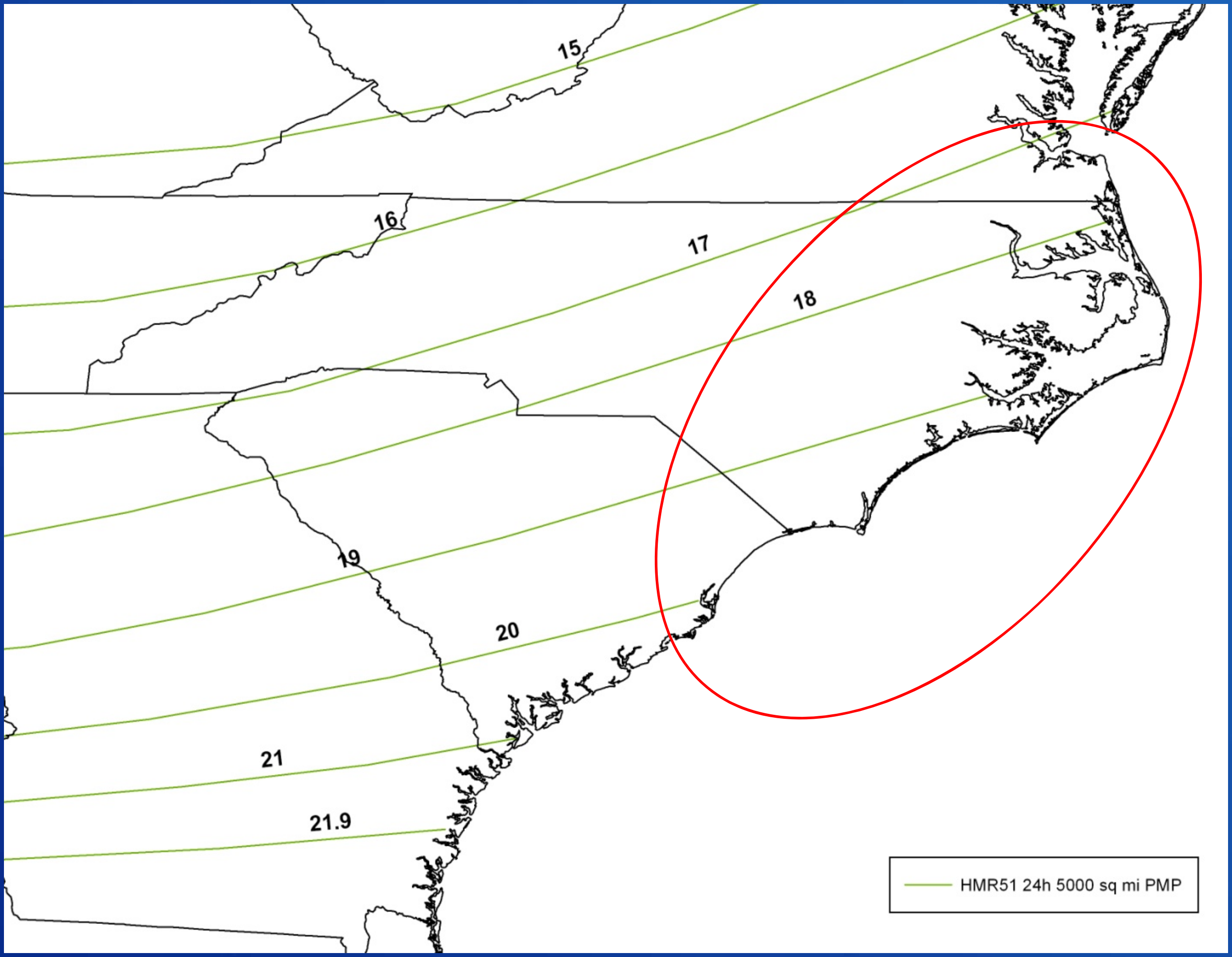
Comparisons with HMR 51 and Sensitivity of Methods

For each storm analyzed (10 MPR events)

- Comparison in-place with HMR 51 values
  - for Key durations
  - discrete values from HMR 51 for direct comparison, from HMR 51 grids (Task 1)
  - area sizes determined by storm, intersecting HMR 51 values
- Evaluation of Maximization Method
- Evaluation of Storm Clipping
- Comparisons with 3 TCs used in HMR 51
- Radar issues investigated

Potential PMP Increase Locations



Based on Floyd – approximate area affected at 24hr duration and 5000 mi^2

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Task 3 Uncertainty/Synthesis: Key Findings

- No significant trends found in SST and Td grids; suggests stationary series for maximization
- Potential for increased temporal clustering of TC events in August-September (1999, 2004, 2011)
- Longer-duration rainfalls (> 72 hr) and soil moisture for runoff may be changing factors
- PMP ratios to 1/1000 AEP 24hr rainfall range from 2 to 6x
- PMP 24hr, $10mi^2$ return periods range from 10^{-5} to $> 10^{-7}$
- Additional efforts needed to address orographics and piedmont

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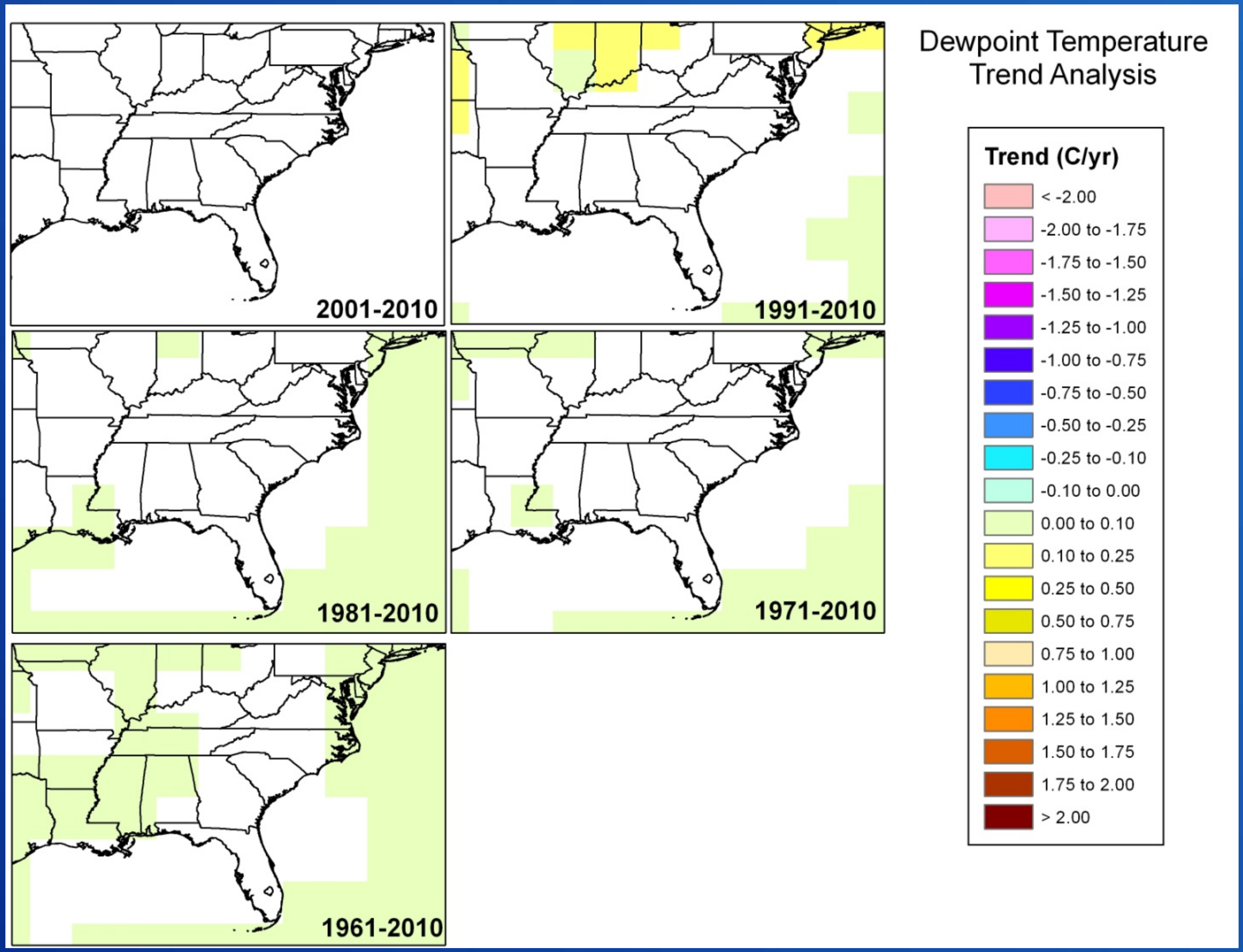
Maximum Moisture Trends

No significant trends in Td over land

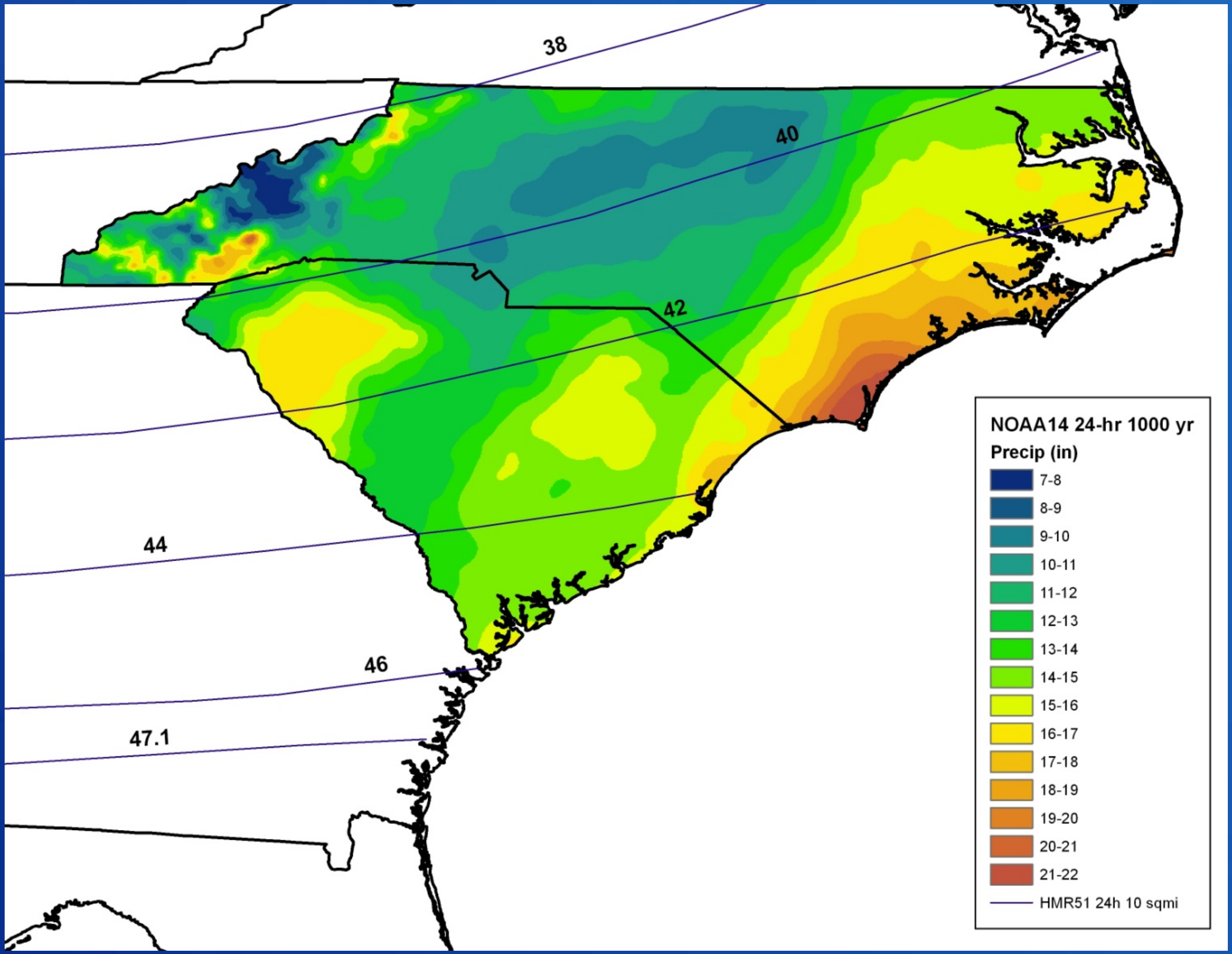
Small increase over ocean – NC coast

Pw approximately stationary



Trend analysis for Td for the month of September for each decade during the period of record for NCEP/NCAR (1948-2010). Only significant trends (alpha > 0.10) are shown. Similar results found using ICOADS (1960-2010).

Precipitation Frequency Ratios



NOAA 14 high spatial detail compared to PMP isolines

high points along coast, Appalachians

low in Piedmont

NOAA 14 24-hour, 1000-year precipitation with 24-hour, 10 mi^2 PMP contours from HMR 51.

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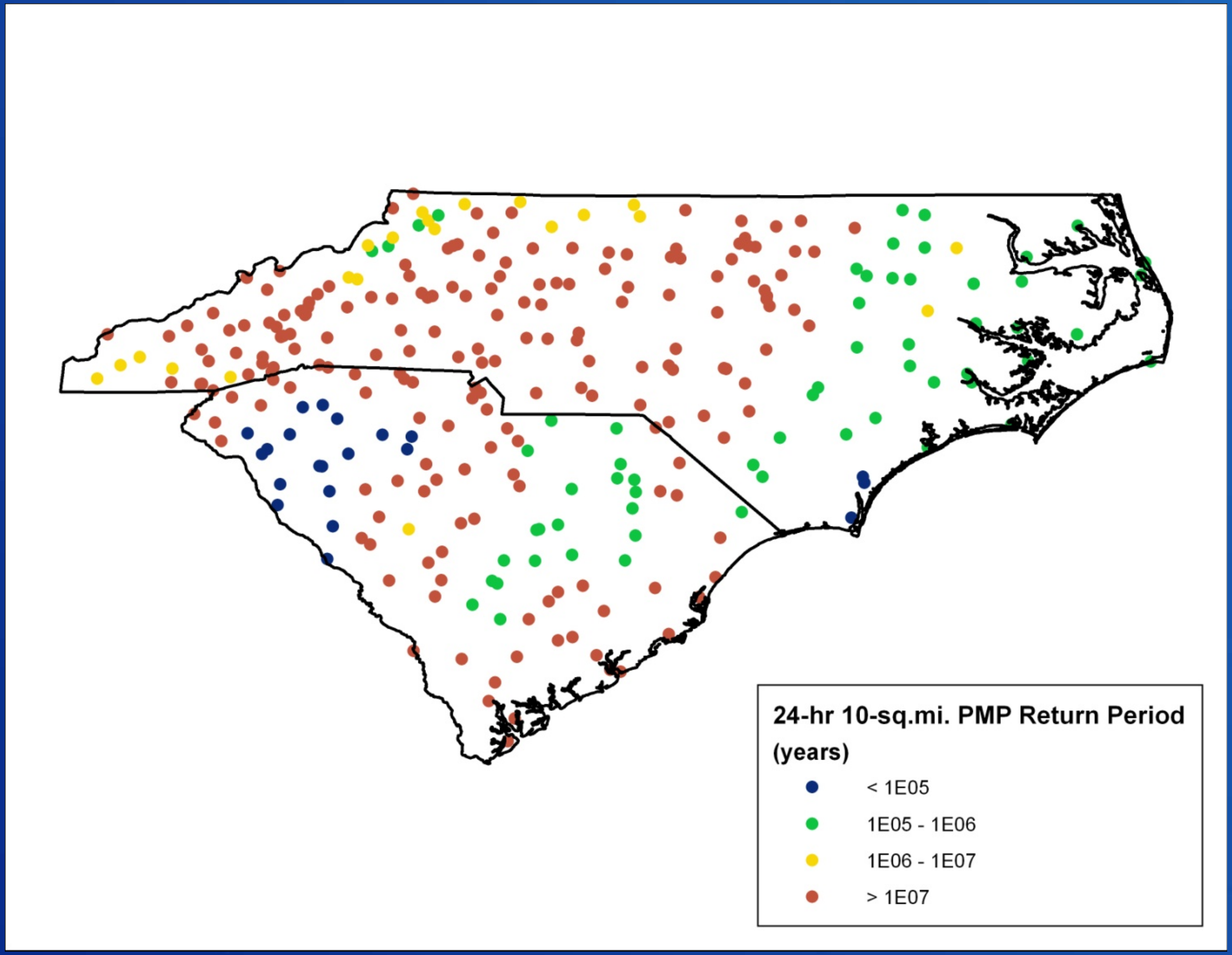
PMP Frequency Estimates



Return periods of the 24-hour, 10 mi^2 PMP using regional frequency distributions.

Discussion, Implications, Future Work

Investigation of 10 storms in-place for NC/SC (MPR)

- HMR 51 may need to be updated for coastal areas in Carolinas
- Unknown impacts in Carolinas considering transposition (e.g. Fay in FL; Fran center in VA) or envelopment
- Orographic effects unclear due to limited sample
- HMR 51 PMP estimates might be high in Piedmont based on NOAA 14 point frequency

Discussion, Implications, Future Work

Risk perspective:

- NOAA 14 extrapolations suggests PMP point values may be exceeded at 10^{-5} along coast and less frequent inland
  - problems with use of different distributions in space and extrapolations, especially GLO in W SC
- Point frequency estimate confidence intervals need to be utilized (e.g. observed events)
- PMP amounts are ESTIMATES and can be exceeded
- Uncertainties of PMP estimates can be quantified for point values
- Further work needed for areal estimate uncertainties

RECLAMATION

Discussion, Implications, Future Work

Design/maximum perspective:

- Database behind HMR 51 severely outdated and needs to be comprehensively updated
- Use of recent gridded data sets extremely valuable
- Resolution of recent products (NOAA 14) superior to HMR 51 smoothed estimates
- NRC could consider a coastal multiplier for HMR 51 PMP estimates
- Open question: focus on specific locations versus generalized or regional PMP estimates

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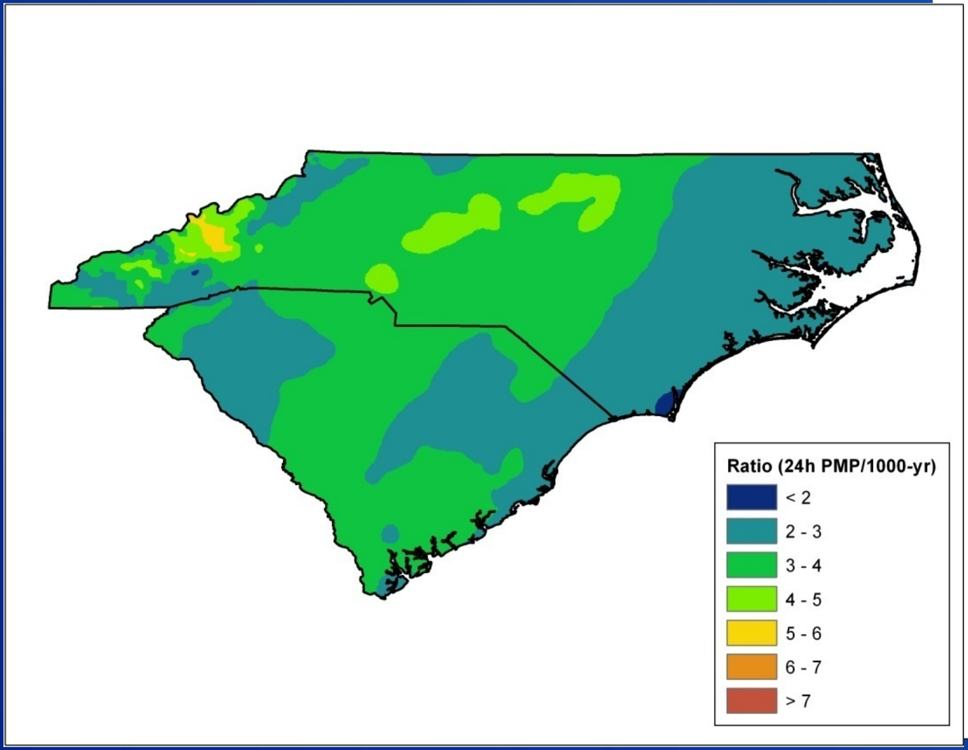
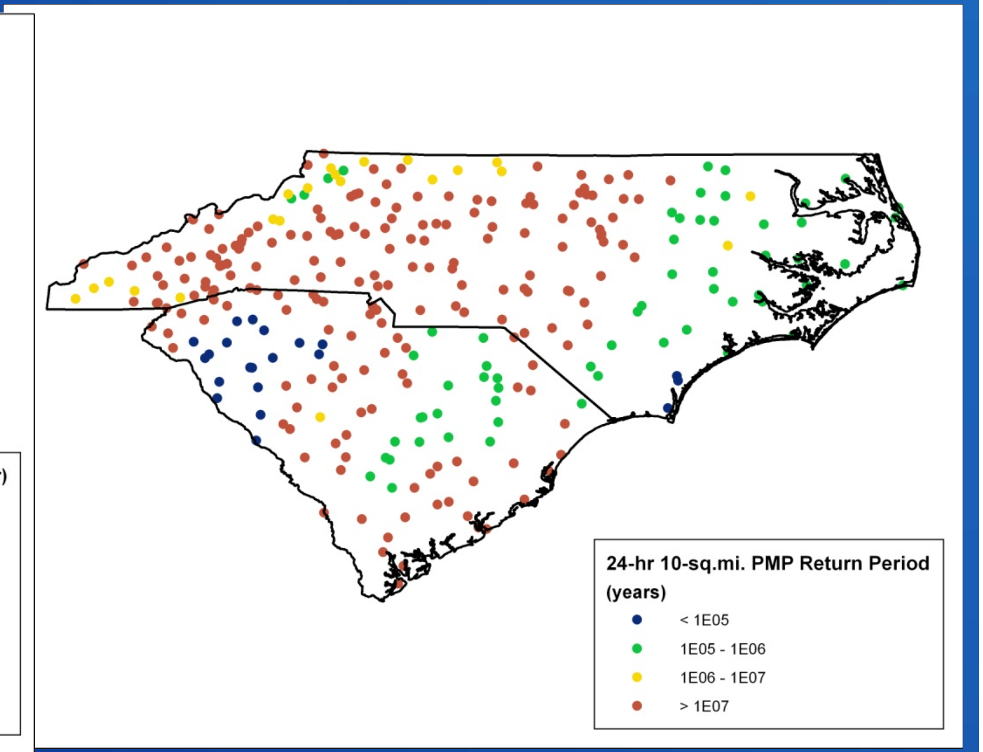
Discussion, Implications, Future Work

Path Forward:

- Larger region spatial data set (GA, TN, FL, VA) can be enhanced with MPE and analyzed
- Examine Orographic effects with WRF experiments (place-based analysis)
- Transposition and Envelopment evaluation may require focus based on tracks and larger-scale synoptic effects, e.g. Coastal, Direct, Appalachians…
- Community efforts needed on extreme storm database

Questions/Discussion?





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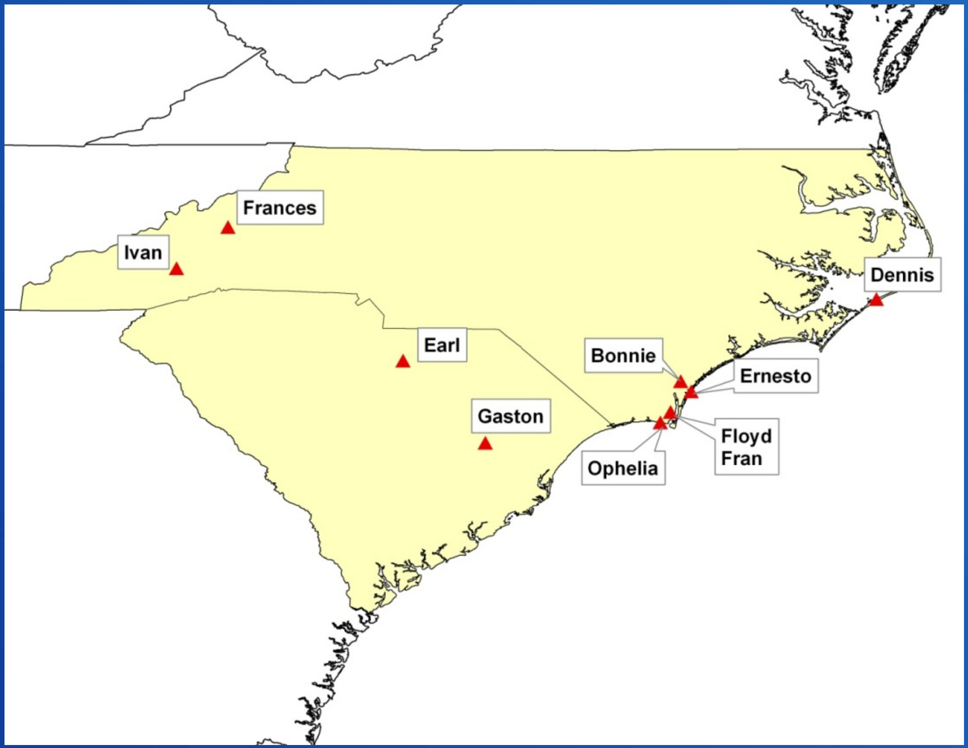
Additional Technical Details

- As time permits, or to facilitate discussions

Potential New Data Impacts – PMP Unresolved Issues

- Area sizes < 5000 mi^2?
- Durations < 12 hr and < 6 hr?
- Orographics – western areas not fully resolved
- Potential reductions in Piedmont and PMP spatial resolution compared to newer data sets/analyses (NOAA 14)
- Temporal clustering of TC events in August-September (1999, 2004, 2011)



- Longer-duration rainfalls (> 72 hr) and soil moisture for runoff may be changing factors

RECLAMATION

HMR Evolution – Data, Methods, Documentation, Issues

- EPRI (1993) MI/WI regional PMP study
  - highlighted issues on max persisting dewpoints (frequency and duration issues); unresolved
- NRC (1994) examined PMP methods
  - recommended current methods for operations
  - WSR-88D into PMP catalog
  - major research for scientific understanding of extreme rainfalls, storm rainfall studies and extreme rainfall probabilities
- WMO (2009) updated WMO (1986) PMP manual; No major changes to methodology

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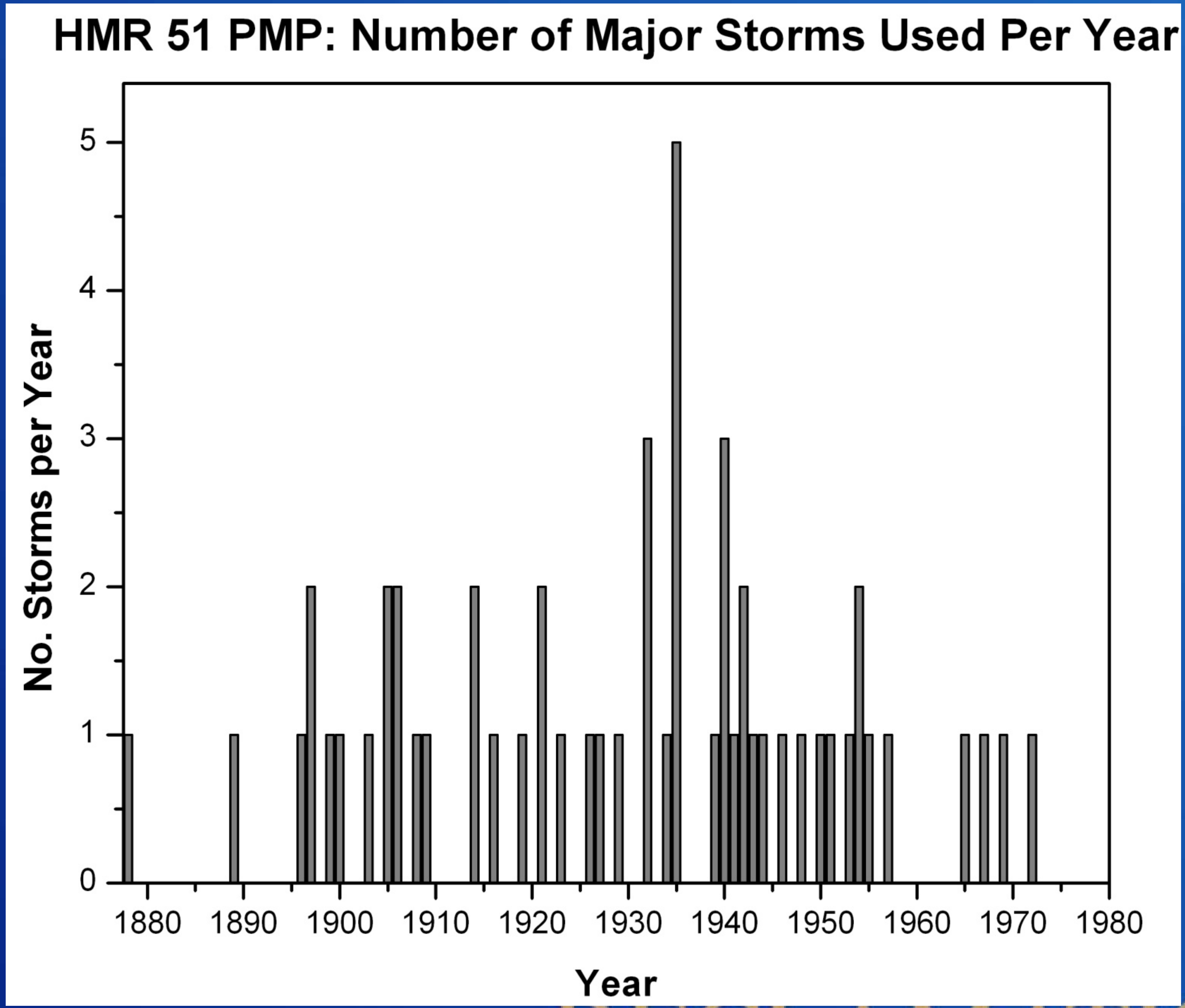
SE US Pilot: HMR 51 Update Critical Issues

- OLD D-A-D Data
- Poor temporal resolution
- Poor spatial resolution
- Lack of storm data collection, archival, retrieval
- Dewpoints need updating
- Consideration of orographics
- Lack of research on underlying methods
- Lost of new data and opportunities for improvement
  - Task 2 report

Basic Problem: Temporal Limitations



HMR51:

53 Major Storms used for PMP in Eastern US

also spatial limitations!

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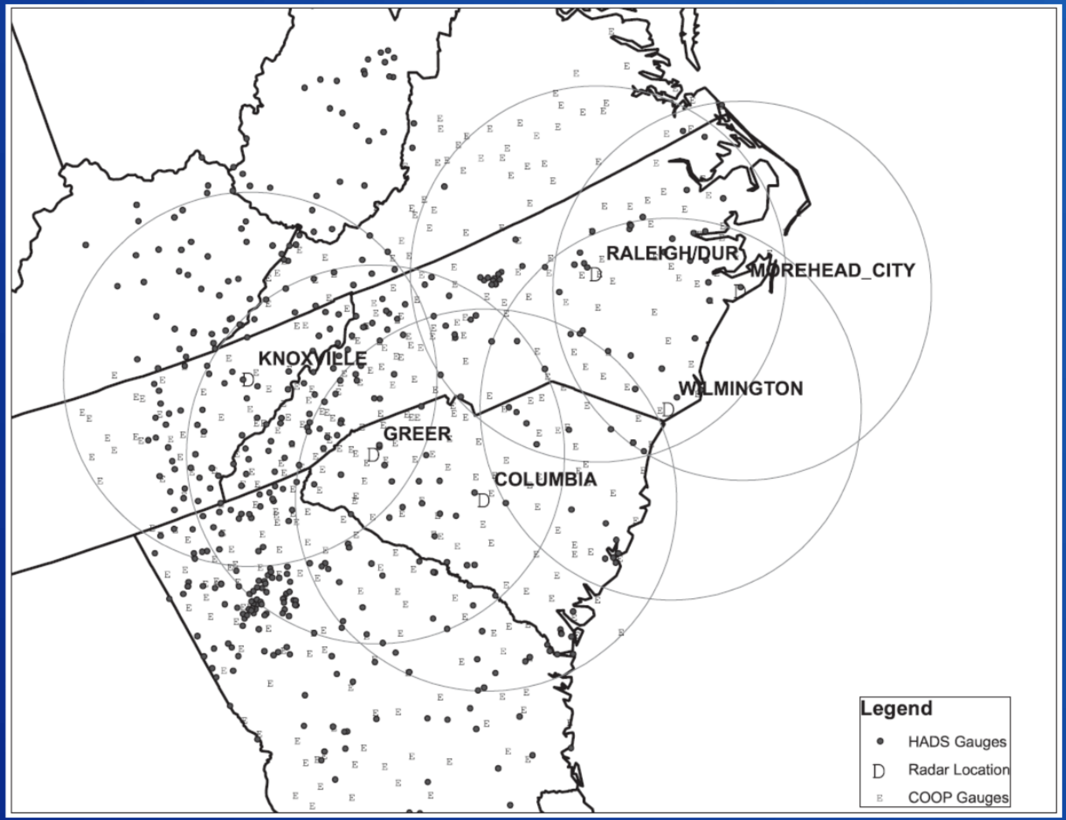
Key Data Set: MPR from NCDC

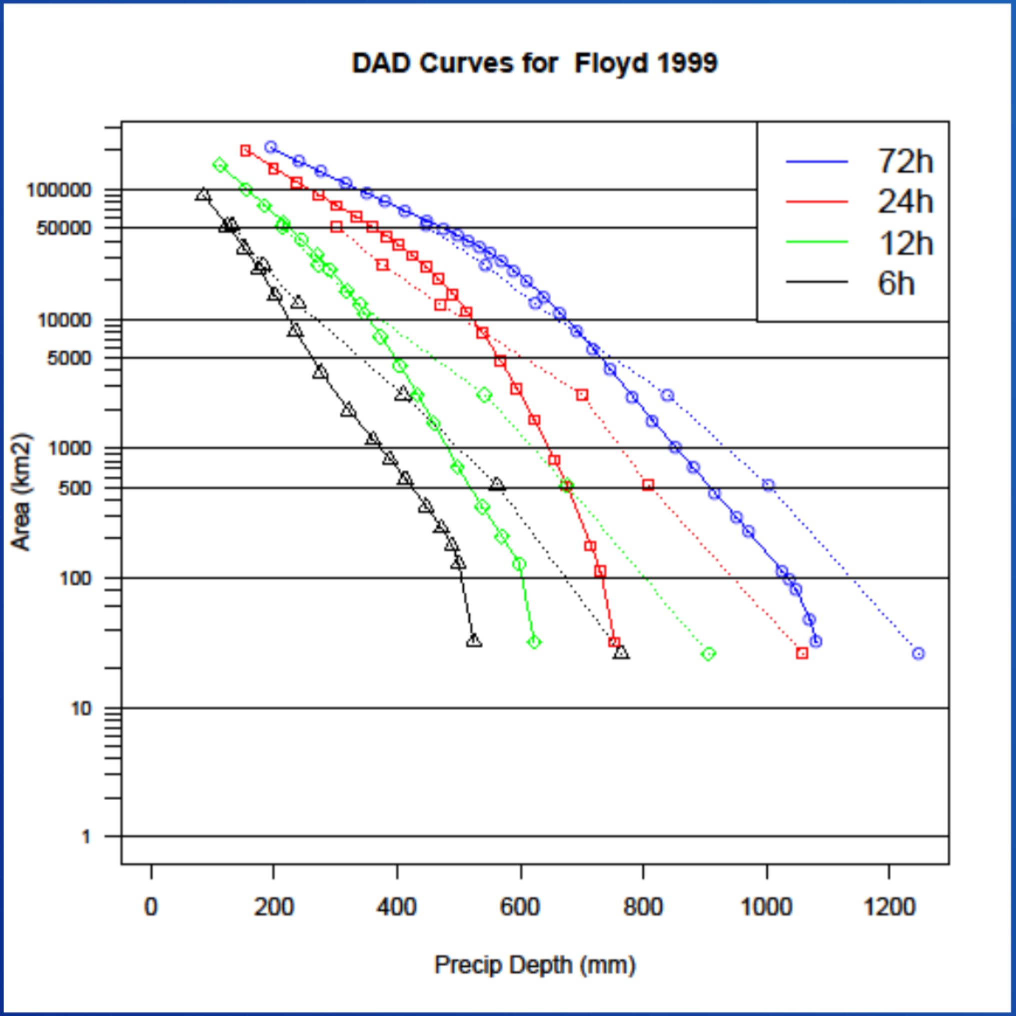
- Radar WSR-88 Digital Precip Array
- Hourly and daily rain gage data (HADS, COOP)
- Combined data set 1 hour, ~4x4 km2
- Builds on NWS operational Multisensor Precip Estimation (MPE)



details: Nelson et al. (2010) JHM

RECLAMATION

Floyd – HMR 51 PMP Comparison

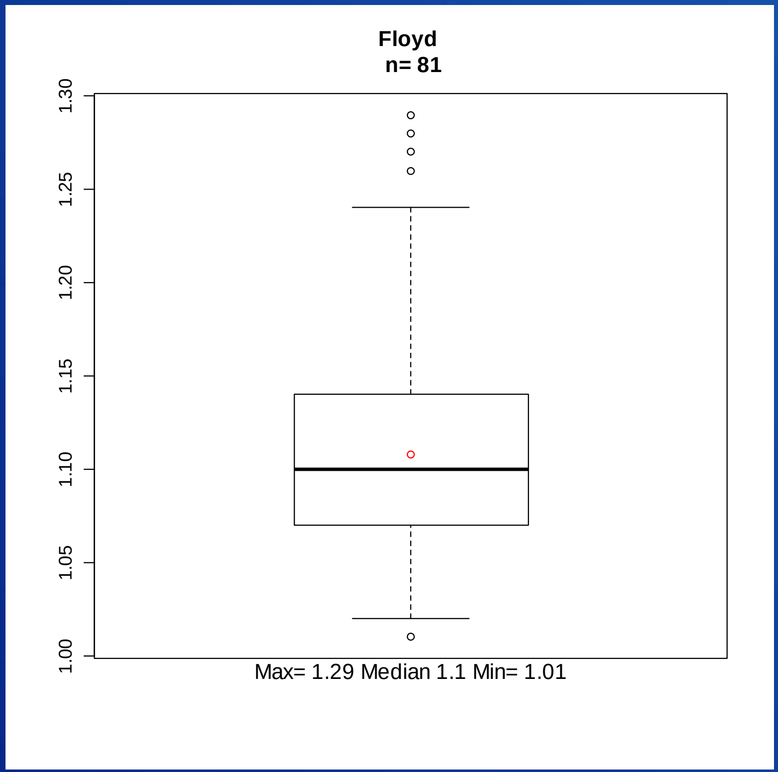


Comparison of DADx curves from MPR (solid) and HMR51 (dashed) for Floyd 1999. Exceedance of HMR51 PMP values are evident where solid lines cross dashed lines of the same color.

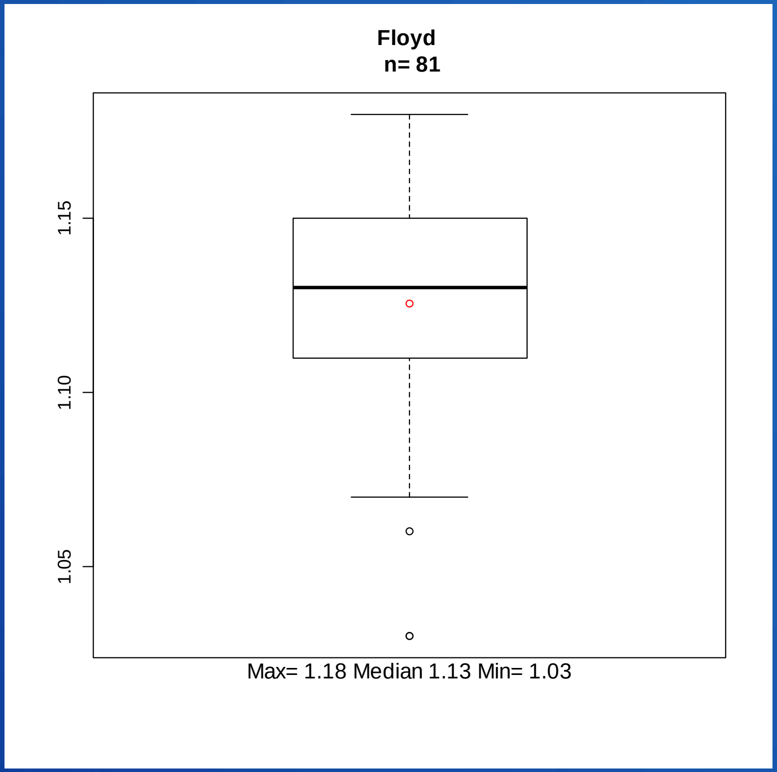
RECLAMATION

Moisture Maximization Factors

gridded SST



gridded Pw



Boxplots of IPMFs for Floyd using gridded SST (left) and gridded PW (right). The value of n represents the number of combinations from HYSPLIT back-trajectories. ***BIG difference in Max; Median is similar***

Floyd DAD – Maximization Sensitivity

Floyd1999		24h				
Area (km^2)	Area (mi^2)	HMR51	MPR (max)	MPR (median)	% diff (max)	% diff (median)
25.9	10	1084.59	755.40	644.14	-43.58	-68.38
51.8	20	840.78	675.41	575.93	-24.48	-45.99
2589.99	1000	731.55	601.39	512.81	-21.64	-42.66
12949.94	5000	485.41	504.01	429.78	3.69	-12.95
25899.88	10000	388.75	443.13	377.86	12.27	-2.88
51799.76	20000	309.86	357.37	304.73	13.29	-1.68

Comparison of computed DADx using the median and maximum and HMR 51 PMP.

PMP Sensitivity

Examined Key Factors

- Maximum Moisture trends – ***Climate Change Impacts?***
- Frequency Estimates of PMP
  - NOAA COOP, NOAA 14 and Regional Frequency
  - Precipitation Frequency Ratios
  - PMP Frequency Estimates
  - Point Frequency Estimates
- See H44E-08 Thurs for related work

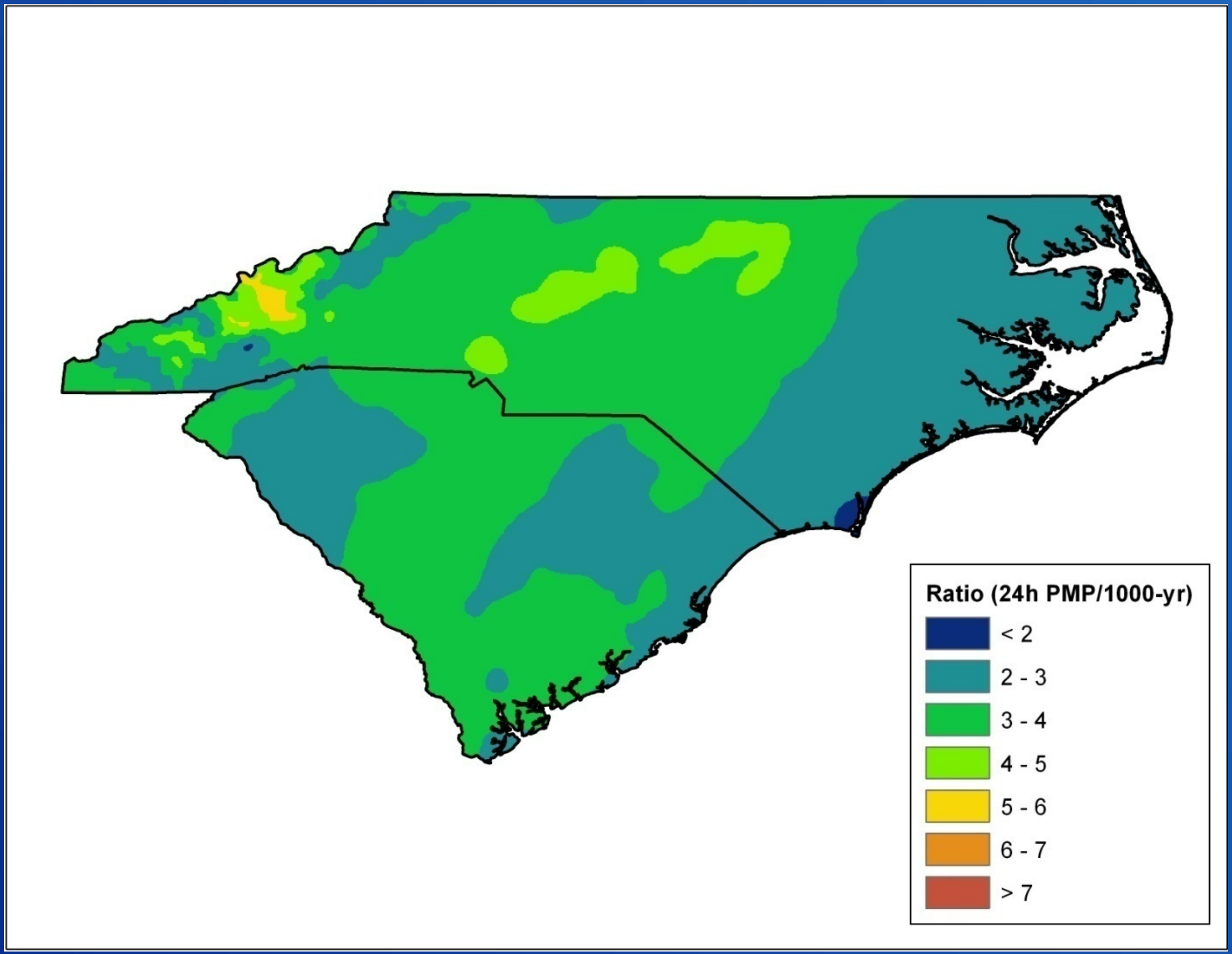
RECLAMATION

Precipitation Frequency Ratios

NOAA 14 underlying spatial detail responsible for the ratio pattern

low ratios along coast, Appalachian upslope areas

W SC anomaly-GLO



Ratios of 24-hour, 10 mi^2 PMP from HMR 51 and NOAA 14 24-hour, 1000-yr precipitation

RECLAMATION

Key New Steps: Hydrologic Hazard

- Need Flood RISK Estimates
  - EXTREME Flood Probabilities > 1 in 10,000!!!
  - Design Rainfalls and Floods Estimates CHANGE!
- Data and Observations from EXTREMES within Watershed and Region are Required
  - Fine-Scale Spatial and Temporal Rainfall
  - Flood Hydrographs and Paleofloods
  - Integrated Hydrometeorology, Flood Hydrology and Paleofloods
- Consider Climate Change in Context of Specific Data and Problem
  - Moisture Maximization factors, trends
  - Frequency Estimates up to PMP; quantify uncertainty

Risk Perspectives on Flood Hazard Assessment:
Current and Planned RES Activities

Dr. Joseph Kanney
Hydrogeologist
RES/DRA/ETB

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
Regulatory Policies and Practices Subcommittee Meeting

JULY 10, 2012

Motivation

- Ongoing discussions among staff in RES, NRO, NRR, and Regions have identified several areas that may benefit from a more risk-informed approach with respect to external flooding events
  - Review of Safety Analysis Reports for COLA and ESP Applications
  - Risk Assessment Standardization Project
  - SPAR Model Development Program
  - Significance Determination Process
  - Accident Sequence Precursor Program

Motivation (Cont.)

- Reviews by NRC Contractors, NRC/ACRS, GAO have made similar observations
  - *"Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America", NUREG/CR-7046 (NRC/PNNL, 2011)*
  - *"NRC Natural Hazard Assessments Could Be More Risk-Informed"*, GAO-12-465 (GAO, 2012)
  - "*Review and Evaluation of the NRC Safety Research Program*", NUREG-1635, Volume 10 (ACRS, 2012)

Current Activities

- 2011 Long-term Research Plan Item *"Assessing Climate Variability Contribution to Risk at Nuclear Facilities"*
  - Originally scheduled for FY13 funding
  - Partially funded by NRR User Need (FY12-14)
    - Enhance treatment of external flood events in EE SPAR models
      - Probabilistic rainfall modeling
      - Flood frequency analysis
      - Continuous simulation approaches for flood frequency
    - "Data and Methodology for Probabilistic Rainfall Modeling" (Oak Ridge National Laboratory and Northeastern University)
      - Assess databases and probabilistic rainfall models
  - Remainder funded in FY12-13
    - "Using Paleflood Information to Assess Climate Variability Contribution to Flooding Risks at Nuclear Power Plants" (U.S. Geological Survey)
      - Assess potential for paleoflood information to improve flood risk assessment at nuclear power plant sites

Proposed Near-Term Activities (FY12-14)

- Regional Frequency Analysis for Extreme Precipitation (U.S. Bureau of Reclamation)
  - Proposed follow-on work from Carolinas PMP pilot study (NRO RG-1.59 Support User Need)
  - Evaluate, modify (as needed), and apply precipitation frequency approaches to extreme precipitation (e.g., up to PMP) in an orographic region (Tennessee River Basin, TRB)
  - Scope includes: review of existing methods and databases for extreme storm precipitation in orographic regions, collection and analysis of storm information for TRB, orographic storm analysis methodology, extreme precipitation frequency and uncertainty for TRB
- PFHA Technical Basis Document for Riverine Flooding (Pacific Northwest National Laboratory)
  - Proposed for emergent issue funding
  - Riverine PFHA including extreme events and combined events (antecedent conditions)
  - Scope includes: data sources, analysis approaches, mathematical models, model parameterization, uncertainty analysis, sensitivity analysis, modeling software
  - Out of scope: Dam failure, ice effects, channel diversion

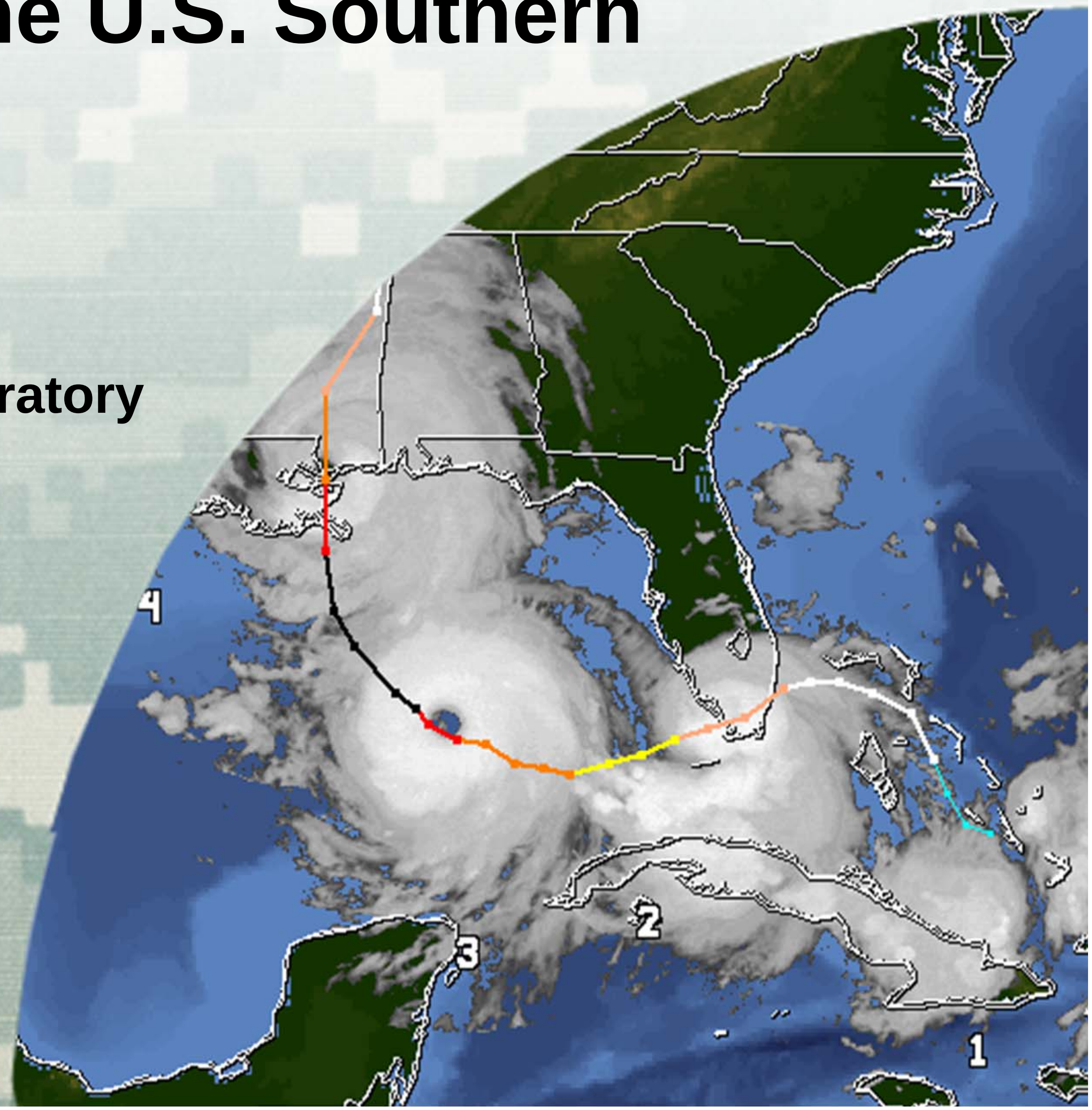
Proposed Near-Term Activities (Cont.)

- Multi-Agency PFHA Workshop
  - Joint NRO/NRR User Need Letter
  - Hosted by RES (tentative date: Jan 29-31, 2013)
    - Organizing Committee Co-Chairs:
      - Thomas Nicholson (RES/DRA)
      - Richard Raione (NRO/DSEA on rotation to RES/DRA)
  - Potential Co-Sponsors: NOAA, USGS, USBR, USACE, DOE
  - Proposed Topics:
    - Probabilistic modeling of local intense precipitation, riverine flooding, dam failure, storm surge, tsunami
    - Treatment of combined events
    - Interface with PRA models

Longer-Term Activities

- Coordinate with User Offices to evaluate options for addressing gaps identified by PFHA Workshop
  - User Offices draft additional User Need Letters
  - RES Develops Research Plan
- Evaluate options for PFHA Guidance
  - Develop NRC guidance
  - Adopting industry consensus standards
    - ANS-2.31 (currently under revision)
    - ANS-2.8 (currently under revision)

Research to Develop Guidance on Probable Maximum Storm Surge Flood Estimates along the U.S. Southern Coast



Engineer Research and Development Center

Coastal and Hydraulics Laboratory

Don Resio and Ty Wamsley

US Army Corps of Engineers
BUILDING STRONG®

Primary Tasks

1. Review existing guidance and document recommendations for updating.
2. Develop screening method for estimating surges.
3. Develop and demonstrate an approach for estimating very-low probability hurricane storm surges.
4. Tech transfer.

Review of Existing Guidance

- Regulatory Guide 1.59 and supporting documents (focus on storm surge)
  - ► Bathystrophic Storm Surge model is extremely limited by restrictions and over-simplifications made in order to make the problem computationally tractable given the computer resources available in the early to mid 1970's.
  - ► Acceptable modern approach requires numerical models that *properly define the physical system* and include an *appropriate non-linear coupling of the relevant processes*.

Review of NWS 23

- Assumptions regarding the Probable Maximum Hurricane (PMH) defined in NWS 23 (Schwerdt et al.1979) are now known to be invalid.
- PMH concept for NRC application must be updated in accordance with new theoretical concepts and data. In particular,
  - Allow the Maximum Possible Intensity to attain a lower central pressure than the NWS 23 suggested values
  - Estimate storm size as a conditional probability function of storm intensity in simulations

Uncertainty

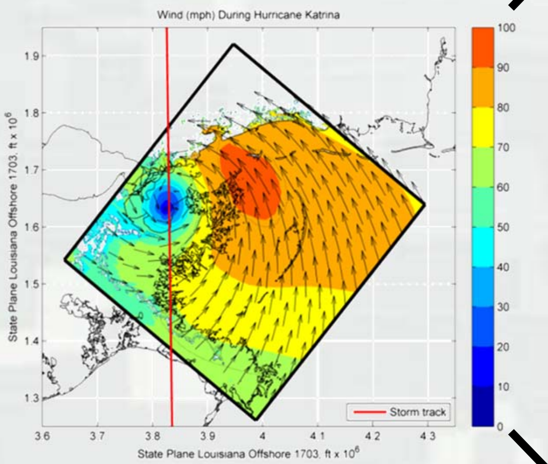
- Uncertainty was not appropriately considered in the existing guidelines and supporting documents.
- It is important that the range of uncertainty inherent in the storm wind fields and the resulting modeling representation of these wind fields be considered and quantified.

Recommendations

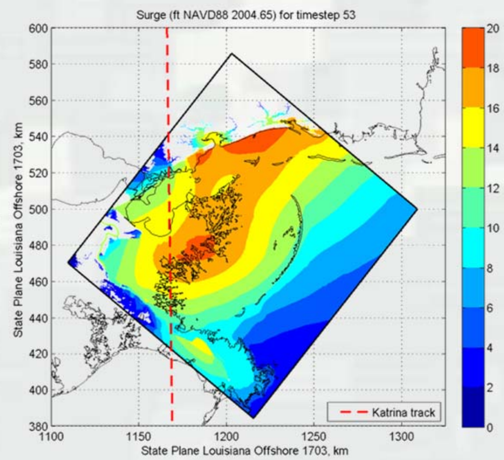
1. Apply coupled numerical model system that properly define the physical system and includes all relevant processes.
2. Allow for MPI storm central pressure and estimate size as a conditional probability
3. Consider uncertainty.

Modeling System

CSTORM-MS

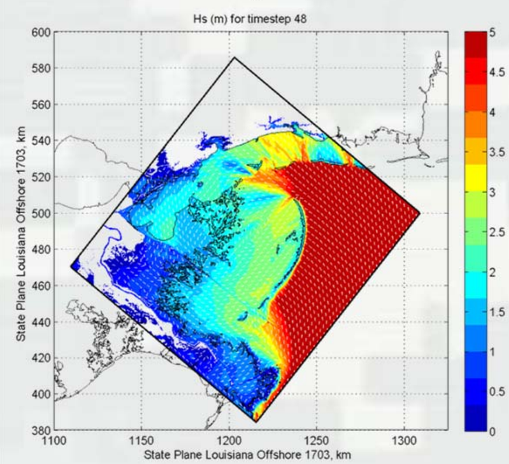


PBL Model
Wind fields &
Wind stresses



Surge model:
ADCIRC

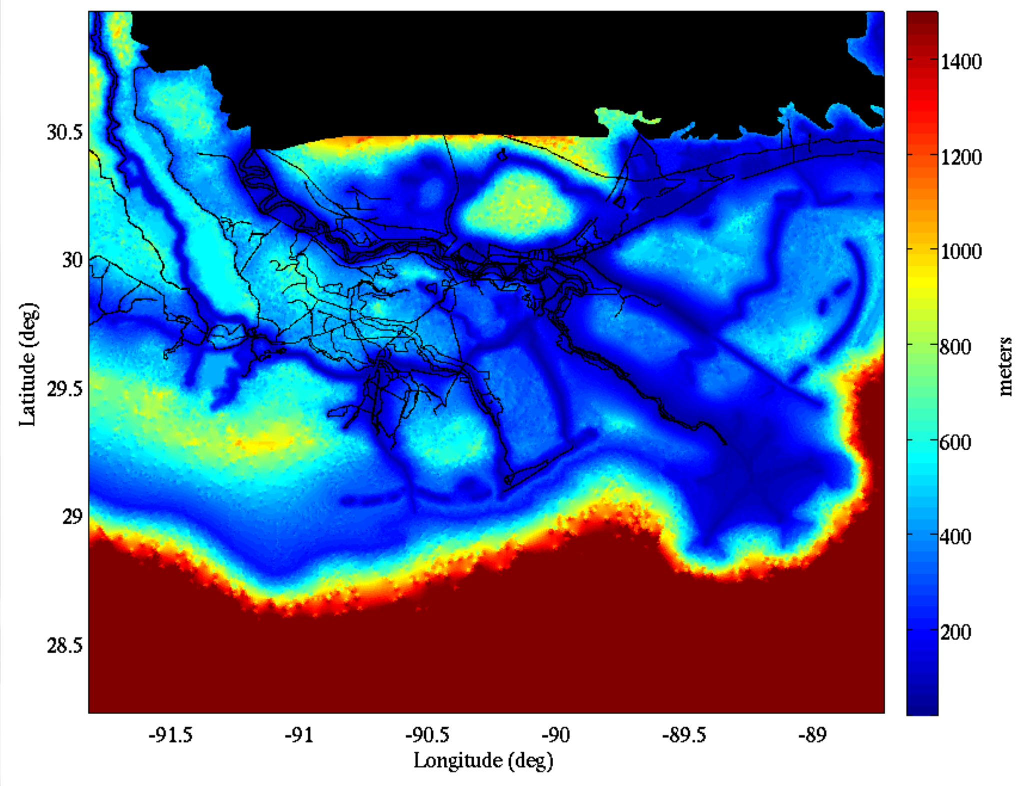
Coupling



Offshore waves:
WAM
Nearshore waves:
STWAVE-FP

Modeling System

- Appropriate definition of physical system while maintaining reasonable computational efficiency is facilitated through the application of unstructured surge meshes.



Problems with Deterministic Approach

- Implies:
  - 1) The precise set of forcing conditions that can create the maximum (or at least a given fixed very-low probability) surge at a given location is known.
  - 2) There is no uncertainty in either the predictive models utilized or the limiting estimates of the inputs to the predictive model.

- **Since neither of these conditions is met, a strictly deterministic approach may not represent the actual maximum condition (or very-low-probability event) expected at a given location.**

Problems with Probablistic Approach

- There are three problems in the estimation of the very-low-probability events using a strictly probabilistic approach:
  - ► 1) The large error associated with extrapolations based on a relatively small number of years to very large return periods and
  - ► 2) Problems with including non-stationarity into the error bands.
  - ► 3) Lack of a strong probabilistic basis for selecting a level of risk appropriate for a surge to exceed a design level.

Hybrid Approach

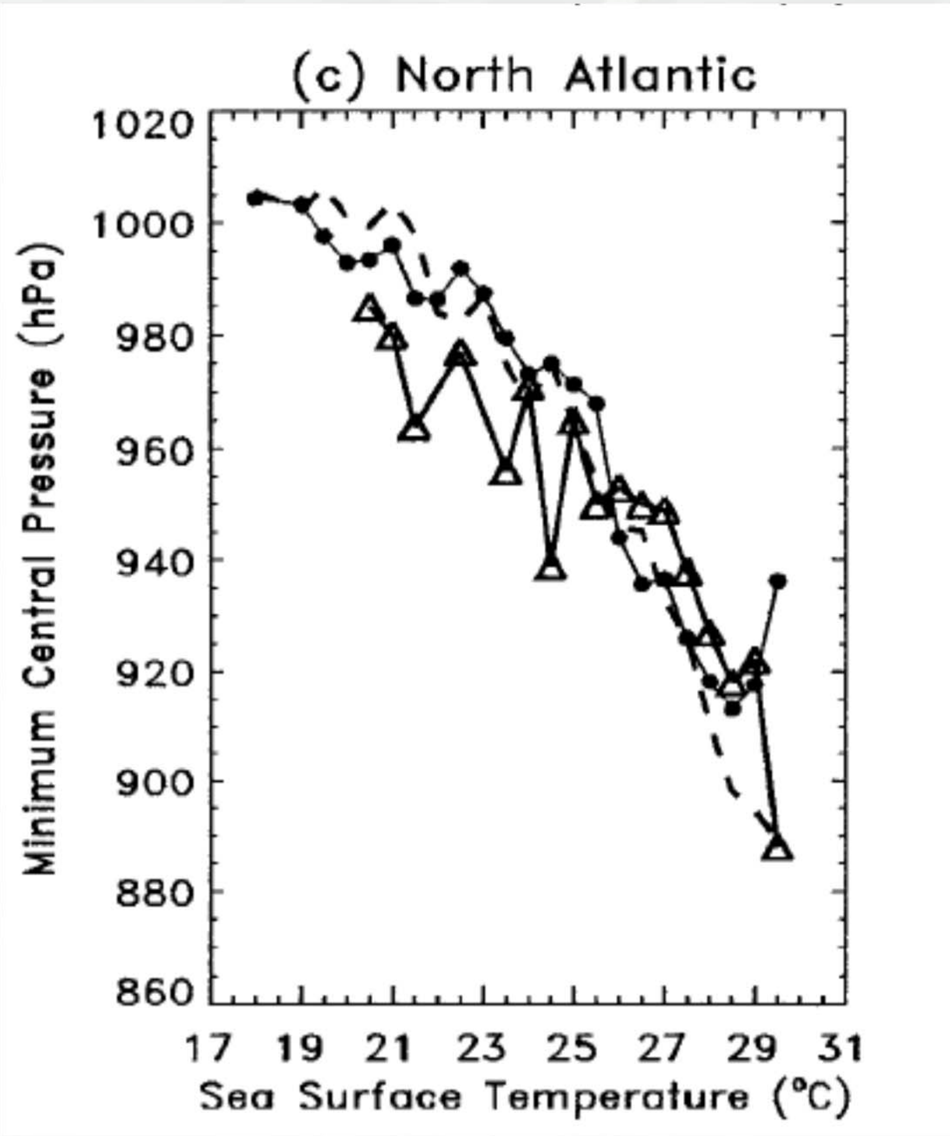
- Attempts to determine which factors affecting hurricane surges can be shown to have asymptotic upper limits and which factors still have to be treated within a context that allows for natural uncertainty in estimating an upper limit for surges at a specified site.

Hurricane Parameters with Asymptotic Limits

$$\eta_{max} = \Phi_1(\Delta p)\Phi_2(R_{max})\Phi_3(x - x_0)\Phi_4(v_f)\Phi_5(\theta_f)$$

- Storm Size (R_{max})
- Landfall location
- Forward speed
- Landfall Angle

MPI Concept



The lowest North Atlantic Values appear to support a value around 880mb as the lowest central pressure for the range of water temperatures in the Gulf of Mexico Tonkin (2000)

Synopsis of Simulation Approach

- Use near MPI values for central pressure (800 and 870 mb) and large R_{max} values (30,45 nm)
- Set track to correspond to expected position of maximum surge
- Allow speed and track angle to vary in a manner consistent with expected large, intense storms
- Use state of the art modeling system with good resolution and physics to simulate the storm set – including inland propagation of surge

In Addition to Deterministic Information, Uncertainty Should Be Considered

- Modeling errors (winds, bathymetry, topography)
- Selection of upper limits
- Climate variation
- Tides
- Sea Level Rise

Synopsis of Statistical Interpretation

- Examine uncertainty in all terms that significantly affect estimated surge levels
  - Modeling errors (surges and MPI value)
  - Climatic variability
  - Tides
  - Sea Level Rise
- Add all terms together for PMSS estimate plus measure of sensitivity to uncertainty
- Compare to 10^{-6} annual probability with uncertainty added to distribution estimates

Screening Method

- Since a limit to the influence of coastal hurricane surges exists, it is advantageous to consider a conservative screening filter to avoid requiring detailed computations in areas where they are clearly unnecessary.

- Screening Method is an efficient approach that it makes use of a surge modeling system applied on a mesh that does not resolve the coastal floodplain. It provides a simplified, conservative approximation to coast storm flood risk which should be considered before detailed computations are performed.

Conclusions

- PMSS estimates appear to be consistent with or lower than the 10^{-6} annual probability levels at the 2 Florida sites examined
- It is very important to consider uncertainty in extreme distribution CDFs when estimating 10^{-6} annual probabilities
- The combination of risk-based estimates with natural physical constraints seems to offer a good option for estimation of very-low probability surges

End

Questions?