

# **Official Transcript of Proceedings**

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1 UNITED STATES OF AMERICA

2 NUCLEAR REGULATORY COMMISSION

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4 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

5 (ACRS)

6 + + + + +

7 REGULATORY POLICIES AND PRACTICES SUBCOMMITTEE

8 + + + + +

9 TUESDAY

10 JULY 10, 2012

11 + + + + +

12 ROCKVILLE, MARYLAND

13 + + + + +

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

18 COMMITTEE MEMBERS PRESENT:

19 JOHN W. STETKAR, Acting Chairman

20 CHARLES H. BROWN, JR.

21 HAROLD B. RAY

22

23

24

25

1 NRC STAFF PRESENT:

2 DEREK WIDMAYER, Designated Federal Official

3 WILLIAM OTT

4 JOSEPH KANNEY

5 NILESH CHOKSHI

6 HOSUNG AHN

7 JILL CAVERLY

8 THOMAS NICHOLSON

9  
10 ALSO PRESENT:

11 RAJIV PRASAD, Pacific Northwestern National\*

12 JOHN ENGLAND, U.S. Bureau of Reclamation\*

13 DON RESIO, University of Florida\*

14 VICTORIA SANKOVICH, U.S. Bureau of

15 Reclamation\*

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

17  
18 \*Present via telephone

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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.

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

8           Derek Widmayer is the Designated Federal  
9 Official for this meeting.

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

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

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

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

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

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

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

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

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

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

25                 We directly involved contractors in these



1 discussions through conference calls and technology  
2 transfer seminars here at headquarters.

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

8 We are also aware of domestic --

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

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

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

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

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1 CHAIR STETKAR: Well since you brought it  
2 up and Harold followed up, how does the staff view  
3 this update of the Reg Guide interfacing with the  
4 activities under Near-Term Task Force Recommendation  
5 2.1 to essentially reconfirming or reevaluating the  
6 design-basis floods for all sites in the U.S.?

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

10 CHAIR STETKAR: Okay, thanks.

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

14 CHAIR STETKAR: Okay, thanks.

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

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

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

7           And Joe, take it away.

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

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

24          As probably most of you are well aware,  
25          the regulatory basis for the guidance on design-basis

1 flood comes from 10 CFR Part 50 and 10 CFR Part 52,  
2 Part 50 of Appendix A, the General Design Criteria,  
3 specifically GDC-2 on Design Bases for Protection  
4 Against Natural Phenomena.

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

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

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

18 In addition, there is a separate Reg Guide  
19 1.102 on Flood Protection for Nuclear Power Plants.  
20 One of the things that you may have noticed in going  
21 through DG 1290 is that the old guide, Rev. 2 of 1.59  
22 sort of blended in a little bit of things of guidance  
23 regarding flood protection. And since Reg Guide 1.102  
24 is being updated right now, we thought it would be  
25 better to move the things which are flood protection

1 guidance into the new 1.102 and have Reg Guide 1.59  
2 deal just with the hazard estimation. We think it is  
3 a cleaner way to divide it.

4 MR. WIDMAYER: So Joe, excuse me.

5 MR. KANNEY: Yes.

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

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

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

16 MR. WIDMAYER: Okay, thanks.

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

19 MR. KANNEY: And in addition, I'm going to  
20 skip over the next to the last bullet and go to the  
21 last bullet. Reg Guide 4.7, General Site Suitability,  
22 which is also under revision right now, actually the  
23 revised version is out for public comment right now.  
24 And just as the title implies, it does address the  
25 flooding issues but from a general site suitability

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1 standpoint, not in detailed guidance on methodologies  
2 for estimation and things like that.

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

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

20 Why update the guide? I think Bill and  
21 others talked a little bit about it in a little bit  
22 more detail reasons to update this guide. We have new  
23 data. Bill mentioned the age of the previous revision  
24 in the intervening almost 40 years we have new data on  
25 storms, on precipitation, on floods. And as you will

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1 see as you have gone through the guide and some of the  
2 background material, the estimation process is, in  
3 some cases, very much sort of a data-driven process so  
4 that the estimate you are going to come up with for a  
5 particular flooding phenomenon may depend a lot upon  
6 the historical record that you are starting with. And  
7 we have a longer historical record than we had before.

8 In addition --

9 CHAIR STETKAR: Joe?

10 MR. KANNEY: Yes.

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

14 MR. KANNEY: Yes.

15 CHAIR STETKAR: Okay.

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

23 CHAIR STETKAR: Thanks.

24 MR. KANNEY: Okay. There is a lot of  
25 higher resolution topographical data that is now

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

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

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

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

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

24           Of course water bodies that may influence  
25 flooding at the sites; streams, lakes, estuaries, man-

1 made channels or natural channels, these things have  
2 to be described in an adequate way that you can do an  
3 engineering analysis. So that means location, size,  
4 and various hydrologic characteristics.

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

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

1 are using.

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

15 CHAIR STETKAR: Before you get to that --

16 MR. KANNEY: Yes.

17 CHAIR STETKAR: -- and I am going to come  
18 back to this probably two or three times during the  
19 afternoon but one topic that intrigues me is this  
20 notion of using historical flooding data, historical  
21 meteorologic data to support this assessment,  
22 recognizing the fact that the whole list of criteria  
23 are that we are trying to estimate the severity of  
24 floods that have a return period, if you want to think  
25 of it that way, of once in a million years. Not once

1 in a hundred years or a thousand years, once in a  
2 million years. There is ten to the minus six numbers  
3 there. These are floods that we have never seen  
4 because if we had seen them, for example, they would  
5 have a return period much, much more frequent than  
6 once in a million years.

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

16 MEMBER RAY: That is the point I would  
17 make.

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

20 MEMBER RAY: Go ahead.

21 CHAIR STETKAR: There is this notion that  
22 probabilistic analyses are uncertain because there is  
23 not enough data. I maintain that deterministic  
24 analyses are even more uncertain because they rely on  
25 data that don't even exist and they rely on it as if

1 it is fact. So I would like to kind of address you  
2 and perhaps some of the contractors out there who have  
3 thought about this more strongly that notion. Because  
4 indeed, according to the guidance, we are trying to  
5 predict floods of a severity such that they occur only  
6 once in a million years or less frequently. And that  
7 is a real challenge.

8 MR. KANNEY: Yes. Yes, it is.

9 CHAIR STETKAR: I'm sorry.

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

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

20 One of the questions that I have and I  
21 didn't look through the slides that perhaps will  
22 address it but let me just lay it on the table, is  
23 this notion. In the Agency's regulatory guidance  
24 there are not written requirements, to my knowledge  
25 unless Harold knows that they are written down

1 somewhere, but in a sense we define a design-basis  
2 seismic event as an event that has an expected  
3 frequency on the order of roughly once in 10,000 to  
4 roughly once in a 100,000 years. Ten to the minus  
5 four to kind of ten to the minus five range.  
6 Typically, ten to the minus four is used. That says  
7 that that is the level of seismic acceleration at  
8 which we design our plants, once in 10,000 years.

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

21 So I am interested in the rationale of why  
22 are we designing the plants to ten to the minus six  
23 events? And given the fact that we have to design  
24 them to ten to the minus six events, what kind of  
25 confidence do we have in our estimation of design-

1 basis floods at that frequency?

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

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

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

15 Yes, I think Nilesh wants to add  
16 something.

17 CHAIR STETKAR: Hi, Nilesh.

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

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1     you tried to compute maybe the total risk, it may be  
2     --

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

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

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

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

18                  MR. CHOKSHI: But that is a good question.

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



1 frequencies that are consistent.

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

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

8 CHAIR STETKAR: Well that is part of the  
9 problem. Having grown up in the risk business, over  
10 the last 30 years, I will tell you that back in the  
11 1970s was the first time people started to throw these  
12 numbers around but they didn't understand those  
13 numbers.

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

23 There was not an appreciation of what  
24 these frequencies really mean when you start to look  
25 at the types of events that we are actually talking

1 about here. You know, the tsunami event, for example,  
2 in Japan was not a ten to the minus six tsunami. A  
3 ten to the minus six tsunami in Japan is a heck of a  
4 lot bigger. It's not much but it is a check of a lot  
5 bigger than what hit Fukushima. And yet, we are  
6 saying we need to design a plant to that event  
7 deterministically.

8 That's enough.

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

21 In regard to the hurricane, maximum  
22 hurricane wind fields, there is sort of an analogous  
23 technical report, NOAA Technical Report NWS-23. And  
24 in all of these cases, there is a great deal of data  
25 and hydrometeorological knowledge and judgment that

1       went into these reports. These reports were  
2       technically the best available at the time.

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

21              CHAIR STETKAR: One of the things that has  
22      bothered me, quite honestly, as I started to read more  
23      of the regulatory guidance in the entire area of  
24      external events, is the fact that I believe the  
25      Agency, this is my own personal belief. It is a

1 subcommittee meeting. So it is me. It is not ACRS,  
2 nor is it the subcommittee.

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

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

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

22 CHAIR STETKAR: Okay.

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

1 design.

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

7 MR. KANNEY: Well but the way that you use  
8 the hurricane wind fields, the way that would flow  
9 into a surge analysis is different than if you were  
10 just merely doing a structural analysis. If you are  
11 doing a structural analysis for a building, you are  
12 only really worried about certain sustained gust  
13 speed. For a surge, there are basically about five  
14 different parameters with regard to the storm that you  
15 are going to need to worry about. You know, there is  
16 obviously going to be like the central pressure or  
17 central pressure deficit, the radius to maximum winds.  
18 Because you know the surge is going to be created by  
19 a wind field over a very large area. And so the angle  
20 that the storm makes as it comes into the coast,  
21 whether it is coming along the coast or straight in,  
22 and then the actual distribution of pressure within  
23 the storm is also going to be important for the surge.  
24 And then you have the bathymetry and the  
25 topography. So you know, in my -- I'm not a wind

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1 engineer. Let me put that out there. But in the way  
2 I look at it, the structural design input that you  
3 need from the storm is a heck of a lot simpler than  
4 what you would use for the surge.

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

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

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

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

8           MR. KANNEY: Yes. And --

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

16          CHAIR STETKAR: Absolutely.

17          MR. AHN: So that is the difference.

18          CHAIR STETKAR: Absolutely. My only point  
19          is that information that is point that information  
20          that is published by this agency in 2011 that derives  
21          from current thoughts about how to model the behavior  
22          of hurricanes, and there is a lot of good stuff in the  
23          background of this Reg Guide, it strikes me that that  
24          same information ought to at least be referenced or  
25          acknowledged when we are talking about hurricane-

1 driven storm surges, recognizing that we are talking  
2 about different dynamics of the particular wind field,  
3 if you want to call it that, gusts versus more  
4 sustained. But if we have learned stuff about  
5 modeling hurricanes and we are using that information  
6 to inform one of our regulatory guides for structural  
7 wind-loading, there just might be something in there  
8 that we could use to inform these efforts also, rather  
9 than relying on things that are 1974 or 1979-related.

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

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

20 Okay, the other topic is broad topics of  
21 what I call non-stationarity. And I sort of identify  
22 two flavors. Some other folks I think could probably  
23 come up with other flavors but for coastal sites we do  
24 have sea-level rise. Actually in some cases you have  
25 sea-level decline. But in most cases we are worried

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1 about the sea-level rise and there are historical  
2 trends due to rebound from the glaciers. And what we  
3 point out in the guidance is basically where you can  
4 go to get this information. You know, this sort of  
5 information, the NOAA's National Ocean Service, one of  
6 their key responsibilities is tracking this sort of  
7 information and so they there is very good information  
8 about historical trends that one can use as input to  
9 your analysis.

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

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

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

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

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

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

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

21           Okay, deterministic versus probabilistic  
22 analyses. As you are well-aware, the Staff has relied  
23 mainly on deterministic approaches to the design-basis  
24 flood estimation. And in NUREG/CR-7046 that our  
25 contractor at PNNL put together, they put a nice

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1 package around this and sort of made a nice systematic  
2 description of it, the phrase they use is a  
3 hierarchical hazard assessment. Other people look at  
4 it and they say it is a progressive step-wise  
5 screening approach. But the key is when doing an  
6 analysis, start out with the most conservative,  
7 plausible assumptions consistent with the data that is  
8 available. And then if you can live with the flood  
9 that that sort of analysis gives you, then you are  
10 pretty much done with the analysis.

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

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

18 MR. KANNEY: That is the problem.

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

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1 about competence.

2 CHAIR STETKAR: The way I look at this,  
3 and by the way I was going to bring this up when PNNL  
4 comes up but we are going to run short on time so I  
5 might as well get it on the table. It is relevant to  
6 what you just said, Harold. This HHA concept is not  
7 novel. It is not new and it doesn't at all address  
8 the recurrence interval of the hazard, regardless of  
9 what people say. It is directly analogous to the  
10 process that is followed in NUREG/CR-6850, write it  
11 down, look it up, for the valuation of internal fires.  
12 You start with a fire whose frequency you derive from  
13 data. In the case of fires we do have data. You  
14 presume that that fire burns everything in this room  
15 the worst way possible and see what the risk is from  
16 that fire. Then, if you cannot survive that level of  
17 risk, you start to apply refinements to the analysis.  
18 In many cases, those refinements deal with modeling  
19 the physics of a fire, which is the same level of  
20 refinement in terms of modeling the local hydrology  
21 modeling, perhaps. If it is a seismically-induced dam  
22 failure, the fragility of that dam, it doesn't  
23 necessarily address the initial frequency of the fire,  
24 it refines your understanding of the consequences of  
25 that fire. This HHA process is exactly analogous to

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1 that. Now, within the construct of CR-6850 we have a  
2 framework to systematically examine the consequences  
3 of events for which in fire analysis we have guidance  
4 to develop frequency. We also have guidance about how  
5 to evaluate uncertainties in the models for physics of  
6 fires, which we could evaluate, for example, in the  
7 models for hydrology, they are directly analogous from  
8 a modeling perspective.

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

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

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

21 MEMBER RAY: You have got to spend 16 to  
22 100 million dollars doing a seismic source  
23 characterization. You know, you spend \$250,000 doing  
24 this. The two things just don't seem to make -- they  
25 don't line up for whatever reason I don't understand.

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

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

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

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

19 MR. KANNEY: Then so with regard to  
20 probabilistic characterization, what we have put in  
21 the new draft guide, and in fact this actually isn't  
22 new. This was actually in ANS-2.8, you know, we don't  
23 provide any specific guidance on probabilistic hazard  
24 assessment in this guide. It certainly doesn't rule  
25 out any applicant doing such an analysis. Such an

1 analysis would be reviewed on a case-by-case basis.  
2 If you look in the existing guide and in the new  
3 guide, the only really specific guidance there is  
4 really in terms of the target for combined events.  
5 You know, when you look at different combined events  
6 to come up with your design-based flood, you have to  
7 have in mind some idea really of some level of  
8 probability.

9 What was proposed in ANS-2.8 was 1E to the  
10 minus six. I have it here in this -- I have less than  
11 1E to the minus six. That's not really true. I'm not  
12 sure why I wrote that. They have a target of 1E to  
13 the minus six.

14 CHAIR STETKAR: That means if I am 1.0001  
15 E to the minus six, I fail the test. And if I am  
16 9.9997 E to the minus seven, I pass the test?

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

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

24 MR. KANNEY: I would agree so.

25 CHAIR STETKAR: Okay.



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

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

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

11 CHAIR STETKAR: And we are cheating  
12 ourselves.

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

15 CHAIR STETKAR: Okay.

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

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

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

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

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

19 It just seems anomalous.

20 MR. KANNEY: To my knowledge, that exact  
21 same process has not been applied in too many flooding  
22 analyses, with the exception of that type of process  
23 has been applied to dam failure. There have been  
24 instances where committees have been put together and  
25 they have tried to come up with some sort of generic

1 dam failure probabilities. Those are the only things  
2 that I am aware of.

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

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

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

25 MR. KANNEY: The advantage of doing the

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

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

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

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

21 CHAIR STETKAR: You are absolutely correct  
22 in that.

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

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

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

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

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

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

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

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

22 With regard to local intense  
23 precipitation, the key ideas here are this is an  
24 analysis which you need to do, regardless of where  
25 your plant is sited. Your plant can be sited very far

1 from the ocean, very high above a river, very far from  
2 a lake or high above a lake. It is basically what you  
3 are looking at here is the hazard from an intense  
4 local storm that could overwhelm the site drainage or  
5 the grading. That is what you are looking for here.

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

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1       there.

2                   CHAIR STETKAR:   Joe?

3                   MR. KANNEY:    Yes.

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

8                   MEMBER BROWN:   On the next page.

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

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

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

24                  What I am struggling with is I would like  
25      to understand what that concept means.   Because as I

1 read through the guidance I see sort of three sets of  
2 terms that are used that are, to me anyway, different  
3 notions. I see terms, and these are just excerpts  
4 that I wrote down, the physical limit of a natural  
5 event thought to be meteorologically possible. The  
6 greatest depth of precipitation for a given duration  
7 that is physically possible. That to me is a notion  
8 of there is some physical constraint such that the  
9 event cannot be worse than this; cannot by physics.  
10 So that is one notion.

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

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



1 couple hundred years? Is it a couple of millennia?

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

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

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

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

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

24 MR. KANNEY: Okay.

25 CHAIR STETKAR: That tsunami for which the

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

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

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

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

25 CHAIR STETKAR: Okay.

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

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

12 MR. KANNEY: Right but --

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

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

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

22 There is one -- philosophically, the basis  
23 for this is that at the time this stuff was developed,  
24 you know, meteorologists, hydrologists thought that  
25 there were physical limitations. Now, do we know what

1       they are? The answer is not really.

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

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

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

24              MEMBER RAY: Well I don't think that --  
25      that being true without a question, to me the larger

1 question is how do we go about -- do we limit  
2 ourselves in terms of the record that you referred to  
3 that we can access or do we attempt other means of  
4 hazard characterization such as modeling?

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

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

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

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

24 MR. CHOKSHI: Dr. Ray, I think you said --  
25 the problem with the flood is that physical models you

1 can only take compared to seismic. We are forced to  
2 assume stationary process. So you have like the  
3 seismic source characterization things and the  
4 attenuation you can model and assume that those are  
5 reflected in the time frame.

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

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

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

25 (Laughter.)

1                   MEMBER RAY: That is the explanation,  
2                   period.

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

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

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

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

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

22                  CHAIR STETKAR: I think one of the things  
23                  I think that bothers probably Harold as much as I is  
24                  that it is seems as though the Reg Guide says until we  
25                  have the unified theory about how to probabilistically

1 address every single flooding mechanism that we can  
2 think about, we rely on the old deterministic ways.  
3 That is the message that I get anyway.

4 MR. KANNEY: I guess --

5 CHAIR STETKAR: And there are --

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

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

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

23 On the other hand, the current state of  
24 the practice methods for dealing with others of the  
25 flooding hazards, I wouldn't call them necessarily



1 mature but they have been fairly well applied. And  
2 the notion that we can't do any of it until we  
3 understand how to perfectly do everything basically  
4 begs the question of just well it is just the status  
5 quo until we have the ultimate solution. And by the  
6 time we all are retired, we won't have to worry about  
7 that.

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

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

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

21 CHAIR STETKAR: Deterministic methods in  
22 the context of --

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

1 of it.

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

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

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

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

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

21 MR. KANNEY: But.

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

24 MR. KANNEY: Okay, so moving on to  
25 riverine flooding, there is a couple slides here. You

1 know, the key points, I guess.

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

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

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

22 And the thing is those were put together  
23 to make it easy for folks to do the analysis because  
24 the analysis at that time was much more intractable  
25 than it is today. We have better models, faster

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1 computers. You can do the site-specific analysis much  
2 easier than you could do it back then. So the need  
3 for going to this sort of cookbook approach really has  
4 been overtaken by our capabilities in terms of data  
5 processing and new models. We just don't need to do  
6 it anymore. We can do a better job.

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

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

1 considered.

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

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

21 Dam failure. Again the idea is that you  
22 can either consider dams both upstream and downstream  
23 of the site because of backwater effects. And also  
24 when we talk about dams in this guide really what we  
25 mean is basically any of these water control

1 structures. It could be a classic dam but it still  
2 you could also be talking about levees either on or  
3 off-site or some sort of water-control structure. We  
4 have sort of lumped them into the idea of dams.

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

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

19 CHAIR STETKAR: One quick one.

20 MR. KANNEY: Yes.

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

1 of the site.

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

16 Where do we integrate those notions of dam  
17 failures that not only inundate the site which are  
18 clearly addressed in the context of this NUREG but dam  
19 failures that take away a site's water supply, which  
20 may have the same causes, seismic events, other  
21 upstream dam failures, a sequential hydrologic loading  
22 or severe precipitation, are those other types of  
23 effects of dam failures -- where are those addressed?  
24 And are they addressed consistently so that if I am a  
25 plant owner and have to look at dam failures I don't

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1 look at them different from dam failures that drown me  
2 versus dam failures that make me dry?

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

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

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

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

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

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

22 So I will just throw that out. As I said,  
23 it is a focus question. I did stumble across the  
24 notion of degraded plant water supply in a couple of  
25 places but it was a minor secondary notion. That is



1       why I wanted to bring it up.

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

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

9                       CHAIR STETKAR: Sure.

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

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

18                      I understand a flood wave coming and  
19 taking away, for example, my intake structure. I can  
20 handle that, taking away my service water pumps.  
21 Fukushima can understand that. What I am talking  
22 about is either a precipitation-related or a cascading  
23 dam failure such that I have something coming down now  
24 through my, let's call it a river stream, that could  
25 result in flooding of my site. It may or may not,

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1 depending on the elevation of that water. It could  
2 also take out my downstream dam that is impounding my  
3 cooling water system.

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

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

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

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

1 address that element.

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

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

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

14 MR. CHOKSHI: Absolutely. Right.

15 CHAIR STETKAR: The phenomena aren't any  
16 different.

17 MR. CHOKSHI: Or you could cross-  
18 reference.

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

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

24 MR. KANNEY: I will --

25 CHAIR STETKAR: It is part of this

1 integration thing.

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

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

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

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

20 With respect to storm surge itself, here  
21 we sort of call out again an appendix from the Rev. 2,  
22 which again had maps and tables for the purposes of  
23 screening sites which are no longer applicable again,  
24 based upon old data. In this case for the storm  
25 surge, based upon some very, very old and simplified

1 models, essentially 1-D models which really didn't  
2 take into account the bathymetry or the topography of  
3 the site, very simplified. They were meant to be  
4 conservative but there is actually I think there is no  
5 reason to do this anymore.

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

19 Within storm surge there can be different  
20 varieties. For your region, you need to look at the  
21 types that you may see. Everyone thinks of hurricanes  
22 or tropical cyclones. But extratropical cyclones can  
23 produce flooding, which is much more extensive in  
24 terms of the spatial extent and its duration. And  
25 that is not often thought about too much. Also in

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1 certain areas squall lines can produce significant  
2 storm surge. The Great Lakes would be a good example  
3 of that.

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

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

22 For seiche, I don't want to say too much  
23 about this. At any coastal site it should be  
24 considered. And the idea is that there can be local  
25 phenomena that are forcing that seiche due to storms

1 particularly, barometric pressure fluctuations, strong  
2 winds that may change in direction, passage of local  
3 storms, these are very important, especially for  
4 enclosed bodies like lakes, bays, things like that.

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

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

21 For tsunami, much of this is just taking  
22 -- I should call out there is a separate -- I didn't  
23 put it here unfortunately. It is referenced in the  
24 guide, there is a separate NUREG/CR report, CR-6966  
25 that the folks at PNNL put together for NRO. And that

1 was actually before much of this work got underway and  
2 the stuff that you see here about the different  
3 tsunami hazard zones, the tsunami assessment, the  
4 screening and detailed assessment is all from that  
5 particular NUREG, CR.

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

20 Now one of the key aspects of the ice-jams  
21 is that it is really not possible to predict precisely  
22 where one is going to occur. So again, you have to  
23 come up with a synthetic, a hypothetical ice-jam and  
24 then look at its consequences. And ice-jams both  
25 upstream and downstream can be important. If there is



1 an ice-jam that forms downstream, you would have  
2 backwater effects. If you had an ice-jam that forms  
3 upstream when that dam then breaks, you can have  
4 inundation of the site.

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

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

20 Now when looking at probabilities, again  
21 you need to account for the fact that many of these  
22 mechanisms are not independent. So that you may have  
23 say a frequency of one event and a frequency of  
24 another event. But if they are not truly independent,  
25 they are common cause from a hydrometeorologic

1 perspective, you can't treat them as independent  
2 events and that needs to be taken into account.

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

9 But again, the combination or sequences  
10 that you are going to have to consider are going to be  
11 on a site-specific basis. And the guide outlines a  
12 number of candidate combinations for various sites,  
13 whether you are beside a lake or river or at a coastal  
14 site. These were basically adopted from ANS on 2.8  
15 and these combinations were put together again with  
16 the target, qualitative target I guess is probably the  
17 best way to describe it, of having exceedance of about  
18 1E to the minus six.

19 CHAIR STETKAR: The question I have, and  
20 again we are running short on time so I will try to  
21 keep this short, is that as I read through that list,  
22 that is Appendix H, there all kinds of caveats in the  
23 introduction that says look, this is not a cookbook  
24 list. Don't treat it as a cookbook list. It is  
25 examples of things you ought to think about. And then

1 it degrades into a cookbook list. It says you take a  
2 two-year wind event with a maximum precipitation. And  
3 the notion is that you don't want to take necessarily  
4 the worst possible combination of two things and infer  
5 that they could occur coincidentally. It is an  
6 attempt to be some sort of compromise without being  
7 too quantitative about any basis for anything. I  
8 understand the intent at that level.

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

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

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

24 So I just throw that out as something as  
25 I was reading. Believe me, I understand your intent

1 but I am worried about how it will be used in practice  
2 and how those examples are actually interpreted by  
3 people.

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

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

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

18 CHAIR STETKAR: Okay.

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

21 CHAIR STETKAR: Okay.

22 MR. KANNEY: Yes. I guess I would just  
23 add to that that for many of these I would look at the  
24 sensitivity. If there is, for example, the 24-month  
25 versus the 19-month, are we sensitive to that? Are

1 the results sensitive to that? Then yes, you would  
2 have to dig deeper and look for a real rationale, a  
3 basis for that.

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

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

14 Otherwise, when I combine a 0.5 event per  
15 year with a number I get something greater than 1E to  
16 the minus six. So why am I only looking at a 0.5  
17 times a two times ten to the minus -- why am I not  
18 looking at a once in a thousand year wind speed in  
19 combination with a once in a thousand year stillwater  
20 elevation? Much more likely to have that elevation.  
21 Much less likely to have that wind speed, perhaps.  
22 You know, why am I stylized that I use a 0.5  
23 exceedance frequency for a wind speed with some guess  
24 about what some elevation might be at some exceedance  
25 frequency and infer that if I am okay for that I need

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1 my ten to the minus six per year exceedance frequency  
2 for a design-basis flood? I don't understand why that  
3 is the case.

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

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

16 MR. KANNEY: Okay.

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

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

22 Okay, very quickly concurrence reviews.  
23 The draft guide is concurrence right now. We actually  
24 have the Reg Guide development branch handles this  
25 very nicely, all the mechanics of shipping this out to

1 the various offices for us. And all I wanted to show  
2 you here is so you guys here have a sense of all of  
3 the different offices and divisions who use this guide  
4 and have an interest and that they are in fact being  
5 consulted in the process.

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

10 I guess one point we had a discussion in  
11 terms of scheduling with you and I believe Dr. Ray a  
12 few weeks back about how the concurrence reviews may  
13 interface with the activities for the recommendation  
14 2.1 implementation, the flooding reevaluations. And  
15 our colleagues in NRO came to us and said well we have  
16 this process going on. We are actually going to be  
17 reevaluating or the licensees are going to be  
18 reevaluating their flooding hazard for all of these  
19 sites which hasn't been done in years, and years, and  
20 years. We certainly have an expectation or they have  
21 an expectation that we are going to learn a lot as we  
22 go through that process. And they would like to fold  
23 the lessons learned from that process into their  
24 concurrence on this guide. And that has been  
25 discussed with the Reg Guide development branch and

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1 with my branch. And we think it probably won't result  
2 in large delays in getting the guide out but that is  
3 the current plan is for us to work several months  
4 through the 2.1 process.

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

12 CHAIR STETKAR: Joe let me just make sure  
13 I understand. Is your plan then to not issue the Reg  
14 Guide until you have this interchange with not only  
15 internally but with external stakeholders regarding  
16 the analyses that are being done under recommendation  
17 2.1 or is your plan to issue the Reg Guide as it  
18 exists today and then have people use this Reg Guide  
19 as a basis for those evaluations? Because I wasn't  
20 quite sure.

21 MR. KANNEY: The Reg Guide as it stands is  
22 meant to incorporate the lessons that the Staff has  
23 learned in reviewing the Early Site Permits and the  
24 Combined Operation License Applications that we have  
25 done to this point in time. And that is also the



1 basis that Staff is using to provide guidance. That  
2 is the guidance that the Staff has given to the  
3 licensees regarding evaluations they are doing under  
4 2.1. But everyone recognizes that there is a  
5 potential to learn some new things as we go through  
6 the process.

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

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

20 Let's talk a long-needed break here.

21 MEMBER BROWN: I don't need it.

22 (Laughter.)

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

25 (Whereupon, the above-entitled matter

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

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

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

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

25                  CHAIR STETKAR: Yes, I think that would be

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

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

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

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

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

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

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

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

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1 need to be considered in this assessment approach.

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

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

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

25 CHAIR STETKAR: Rajiv, before we flip to

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

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

25           And if I can't live with that, I now start

1 looking at both the damage that could be caused by the  
2 fire and my understanding of a particular fire from a  
3 particular fire source, which to me sounds very  
4 similar to the type of process in HHA. Am I  
5 mischaracterizing the HHA approach?

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

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

22 Now what we don't do is that we don't use  
23 any probabilistic notions to make those refinements.  
24 We don't have any consideration saying that we would  
25 knock down a particular conservatism by assuming say

1 a probabilistic or a PDF for that particular plan  
2 because of that particular assumption and we will  
3 scale it back from its bounding level to say 90  
4 percent exceedance.

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

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

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

24 Now there is a caveat to that. If you  
25 look at how the probable maximum precipitation were



1 derived, there is an underlying probabilistic concept  
2 behind it. They have taken a set of extreme events  
3 and then those extreme events were described in a  
4 probabilistic fashion. But by the time they applied  
5 the maximization approach, the transposition approach  
6 to that concept what we get out of this particular  
7 approach is one number for a PMP for a particular  
8 location and a particular duration.

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

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

24 MEMBER RAY: Okay, all right.

25 MR. KANNEY: -- that is what they were

1       trying to do.

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

5                   Now you earlier said used the term maximum  
6       credible. I licensed a plant back in 1970, which is  
7       forever ago. And maximum credible was what we used,  
8       referred to in terms of seismology. We now we don't  
9       do that anymore. But at least it had the attribute  
10      that you could say well anything bigger than that is  
11      not credible. But when you use probable maximum, then  
12      people say well you mean it is not likely in the next  
13      40 years is what you mean. Well, no, I mean it is not  
14      likely in the next hundred years or thousand years, or  
15      two thousand years. I have no clue. I don't know  
16      what you are talking about.

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

22                  And so we are into a dilemma in that  
23      regard but this isn't the meeting to talk about  
24      semantics, even though that is what I have been doing.  
25      The problem that we have, I think, that we have got to

1 grapple with is although this is where we are today  
2 and you guys are describing it in a lot of detail and  
3 I think we appreciate that and largely understand it.  
4 The question is when are we going to move off of this  
5 position. And if the answer is never, okay, then we  
6 will process that. But if the answer is we are going  
7 to move on to something that does address things  
8 greater than the design-basis, which let's face it  
9 that is the world we are in now, right, we are having  
10 to deal with things that are beyond the design basis,  
11 not just pick a design basis that we are satisfied  
12 with.

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

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

24 MEMBER RAY: Maybe.

25 CHAIR STETKAR: And that is really our

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

3 MEMBER RAY: Yes, if you look at --

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

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

10 CHAIR STETKAR: Yes.

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

20 CHAIR STETKAR: Rajiv, go on with these  
21 slides and I, as I said, semantics are semantics.  
22 Sometimes they do make a difference and I will still  
23 float the notion that as much as you defend the HHA as  
24 being a completely deterministic and you never will  
25 characterize it as a probabilistic approach, I believe

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1       that it could equally be applied in a probabilistic  
2       assessment, the basic thought process.

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

5               CHAIR STETKAR: I understand.

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

9               CHAIR STETKAR: Right.

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

14              MR. KANNEY: Okay, slide three?

15              MR. PRASAD: Slide three, yes.

16              MR. KANNEY: Okay we are there.

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

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

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

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

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

1 particular hazard.

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

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

22 But then in that routing approach you need  
23 to apply a particular routing model. A routing model  
24 would come with its own sets of parameters that you  
25 can still pick conservatively. But you have backed

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1 off from the initial assumption, which may have been  
2 even more conservative.

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

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

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

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1 site.

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

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

11 MR. PRASAD: Yes.

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

21 MR. PRASAD: Yes, I --

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

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

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

6 MR. KANNEY: Okay, we are there.

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

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

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

1 event.

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

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

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

22 The second thing, when water falls in a  
23 catchment and this catchment is I don't about five  
24 thousand to six thousand square miles, when you have  
25 that big a catchment, water moving from the upstream

1 end to the downstream end takes a little while to get  
2 out there. Maybe today, maybe it is couple of days.  
3 What if we were to assume that water falling anyplace  
4 in that catchment would instantaneously appear at the  
5 downstream end? That is demonstrably a physically  
6 bounding assumption. If we do that, then we are not  
7 only maximizing the volume by the first assumption,  
8 but we are also maximizing how quickly this volume  
9 gets to the outlet where my site is located and I have  
10 to estimate the bounding flood.

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

24 Now, suppose we come up with this estimate  
25 of the PMF and we see that at my site there is nothing

1 that is inundated, no safety-related structures that  
2 are exposed to this flood hazard. Then they are free  
3 and I am done. There is no SSC anymore that I need to  
4 care about. So I need to go to Step 4 and say that  
5 well the site is dry and it would never have any  
6 problem with flooding, at least for this particular  
7 mechanism, which is a marine flooding and the PMP.  
8 And that PMP is the only assumption then that I have  
9 to be worried about, whether that is actually a  
10 critical maximum amount. Does that make sense?

11 CHAIR STETKAR: Yes, it does.

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

24 And then when I do the routing model, then  
25 I have to come up with okay, what sort of stream that

1     what we are talking about. What are the properties of  
2     those streams? What model do I use? How do I  
3     characterize the channel? How do I characterize the  
4     delay, the run-off delays in those channels? And then  
5     you start building up the model that is more detailed,  
6     more refined than the first analysis which basically  
7     said everything is a conduit dropping out right at the  
8     outlet.

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

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

24             And at the end of that model run, I will  
25     come up with another set of flood scenarios for

1 flooding and then I will compare it with the  
2 elevations of the SSC or the properties of the SSC  
3 that they should be designed to to try to see if that  
4 flood, which is less conservative than my first flood  
5 scenario but still conservative because when I am  
6 putting together this channel network model, I will  
7 make sure that each of the parameters that I come up  
8 with I have a basis with the available data to make  
9 those parameter choices conservative. And principal  
10 among those is the roughness for the channel network  
11 that we use.

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

19 But this is how HHA would work. At the  
20 end you may have to become even more realistic and say  
21 that okay, I have to now do an accounting for rainfall  
22 losses also or I have to do a more dynamic modeling  
23 rather than just a one dimensional modeling. Maybe I  
24 need to do a three-dimensional modeling in terms of  
25 watershed areas like below the dam, if there is one

1 dam, or maybe you have to take into account of two-  
2 dimensional flooding in the flood plains.

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

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

13 CHAIR STETKAR: Thank you.

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

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

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

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

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

22           And that notion, if we are applying that  
23 same basic type of process to floods in the context of  
24 this HHA, those basic notions, I think, ought to be  
25 done in parallel. We ought not to be reinventing the

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1 wheel. We ought not to be saying you think about  
2 models for flooding or refinements of a flooding  
3 analysis differently than we think about models for  
4 fires or methods to refine a fire analysis. Because  
5 that again it says that for some reason this agency  
6 needs to think about flooding as fundamentally  
7 different than fires. Granted, it is a different  
8 topic but we ought not necessarily think about how we  
9 address that topic differently simply because it is  
10 water or flames, if you follow my notion.

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

17 I like this process. It works really  
18 well. You characterized it as a deterministic  
19 process. Well the fire guys five years ago  
20 characterized theirs as a totally deterministic  
21 process. And there is a lot -- I mean there are  
22 fundamentally deterministic models. I mean we have  
23 already said this. So I would suggest talking to them  
24 because I think what you have here makes a lot of  
25 sense and it is indeed fundamentally consistent with

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1        what is being done in the Agency to address other  
2        types of hazards, in this case internal fires but  
3        there is sort of this physics involved phenomena.  
4        Their process also, by the way, does not address the  
5        fundamental forcing function, which is the frequency  
6        of that fire. It does address, for example,  
7        distribution of that fire in this room. So it looks  
8        at different hazards but that is analogous to you  
9        looking at different parts of a drainage basin instead  
10       of treating it all as one single lump parameter.

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

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

19                CHAIR STETKAR: I think some of the basic  
20        concepts, you know, obviously the details are  
21        different. There is a lot of good stuff in that NUREG  
22        about what to think about in the context of flooding,  
23        obviously. But sort of the basic thought process in  
24        what needs to be considered on how it can be addressed  
25        could then, regardless of the way we treat the

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1 fundamental hazard, which in this case is that  
2 mystical PMP, we would then at least have a process of  
3 dealing with that hazard in terms of its progressive  
4 refinements or going from what we consider to be a  
5 bounding case to a more realistic best estimate case  
6 and ways of treating and documenting the uncertainty,  
7 at least in that part of the process, that refinement  
8 part of the process. It doesn't address what a PM,  
9 whatever it is, is. But certainly at least that part  
10 of the analysis would, I think, make a lot of sense  
11 and could then equally be applied in the context of  
12 something that somebody might use the dreaded  
13 probabilistic method in terms of characterizing the  
14 exceedence frequency of the hazard.

15 Rajiv, do you have anything more?

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

19 CHAIR STETKAR: Yes.

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

23 CHAIR STETKAR: Okay, good.

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

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

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

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

20 Okay and my perception of the flooding  
21 would be you pick the various phenomena, whether it is  
22 rain, whether it is ice-jams, whatever it is, you take  
23 what is the historical data you have over the last  
24 hundred years and that data is there and you say it  
25 occurs over this period of time during calendar years

1 or what have you then say okay, the maximum is this.  
2 I would multiply it by three and say okay, that is the  
3 number I am going to use.

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

20 And that would have been my suggestion,  
21 based on the discussions. I know you all have already  
22 done all of this and you are ready to go but I think  
23 you are missing something by not having -- and I'm not  
24 saying this is the exact process. It is just so open  
25 and the words are so general. And the probable

1 maximum, what does that mean? And all that other kind  
2 of stuff just creates angst. So I will stop now.

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

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

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

8 MEMBER BROWN: I'm the electrical guide.

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

11 MEMBER BROWN: Okay.

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

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

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

21 MEMBER BROWN: Is it described in the Reg  
22 Guide?

23 CHAIR STETKAR: No.

24 MEMBER BROWN: Is it described in the  
25 NUREG?

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

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

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



1 making maximization based upon meteorological  
2 criteria.

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

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

25 But you don't leave it up to all these

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

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

12 MEMBER BROWN: Well, I'm done.

13 CHAIR STETKAR: -- you know, screaming.

14 MR. ENGLAND: I can speak up now?

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

17 There are -- this is not an easy problem  
18 to solve, obviously. And the reason it is not easy is  
19 that there are a number of different flood-causing  
20 mechanisms, if I can call it that, precipitation is  
21 one. There are different types of precipitation. You  
22 know, if I can characterize large intense storms  
23 versus longer, less-intense but the longer duration  
24 events, dam breaks, seismically-induced dam breaks,  
25 dam breaks just sunny-day dam breaks, seiches,

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1        tsunamis, you know. All the list that Joe went  
2        through initially are different problems that need to  
3        be addressed to characterize the input hazard for a  
4        particular site. And I always think of the input  
5        hazard in terms of a set of exceedance curves. Each  
6        one of those hazards could have a different set of  
7        exceedance curves.

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

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

23               And I think it is important to sort of  
24       think about that. And as I said, there are analogies  
25       in both the seismic world, there are analogies in the

1 fire world to thinking about the problem in that sort  
2 of three-step process.

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

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

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

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

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

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

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

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

1 sound?

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

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

9 MR. KANNEY: Okay.

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

15 And a bit of background. I don't want to  
16 pejorative here but Reclamation has been working on  
17 probabilistic flood hazards for 15 years. We  
18 essentially threw out PMP in the late in the late  
19 1990s because we had to go to probabilistic 401(b).

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

25 If I speak too fast and you guys can't

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

3 CHAIR STETKAR: John, --

4 MEMBER RAY: You are creating a  
5 transcript.

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

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

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

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

23 So the particular last question was when  
24 are we going to move off this position? My view is it  
25 can be done now. Reclamation is doing it. We are

1 sizing modifications to our existing dams based on PRA  
2 using probabilistic flood hazards for existing dams  
3 and we are looking at modifying dams according to  
4 these things. We call these hydrologic hazard  
5 analysis, as we wrote down in about 2004, so we have  
6 a slightly different acronym for HHA.

7 Point number three is you turn to page A1  
8 in the draft of DG-1290, our approach is summarized in  
9 references 28, 29, and 30 in Appendix A and reference  
10 22 in Appendix B. Reference 22 is an American  
11 Geophysical Union monograph that I have a chapter in,  
12 as well as my coworkers have written on paleofloods.  
13 We spent a substantial amount of time in the field on  
14 paleo data. But essentially we have got guidelines  
15 and standards on how to do the technical methods  
16 behind our HHAs. They have been sort of superseded  
17 and we are trying to catch up. But those references  
18 I honestly provided those to the NRC in 2008 in July  
19 in technical update lectures. So I could do that  
20 again. I am hoping to come out in January with Tom  
21 Nicholson and Richard Raione.

22 Point number four, in our view, PSHAs,  
23 PRAs, and probabilistic flood hazard assessments  
24 require full distributions because we don't want to  
25 focus on the single maximum points. You know, PMS can



1 limit these things if we choose to, but with  
2 uncertainty we could define what we want. Maybe we  
3 need the one in a thousand, one in two thousand and we  
4 can do this with hydrologic hazard exceedance curves.

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

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

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

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

21 MR. ENGLAND: This is extemporaneous here.

22 MR. KANNEY: Okay.

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

25 MR. KANNEY: Oh, okay.

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

4                   MR. KANNEY: Okay.

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

8                   (Laughter.)

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

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

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

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

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

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

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

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

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

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

6                   Thanks for the opportunity, Joe.

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

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

17                  CHAIR STETKAR: Yes.

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

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

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1 and that you also address uncertainties.

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

9 MR. ENGLAND: The short answer is it  
10 varies.

11 CHAIR STETKAR: Okay.

12 MR. ENGLAND: So the long answer is just  
13 akin to PSAJ we have peak flow frequency curves that  
14 are done in a classical sense so the magnitude of the  
15 variable is the flood peak versus AEP. And we used  
16 various models to do that; some Bayesian maximum  
17 likelihood, some moments-based things that would give  
18 95 percent confidence limits. So they are basically  
19 data-driven from historical and paleoflood data and  
20 streamflow records.

21 That is one particular technique. We try  
22 to combine that with rainfall runoff models. Because  
23 the problem for our runoff reservoirs and the same  
24 thing for nuclear facilities is that the multivariate  
25 hazards. So the same thing with PSHA. Is the problem

1 peak dominant? Is acceleration the deal? Is it the  
2 ground motions for the time histories at the site of  
3 interest? Our parallel in floods like Rajiv mentioned  
4 is the duration of the flood and the coincidence of  
5 the flood against the big volume. So we in some cases  
6 do families of hazard curves based on volume as well.

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

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

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

14 CHAIR STETKAR: Okay, thank you.

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

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

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

22 MR. ENGLAND: I think the most thing you  
23 are interested in, that is why I ditched the slides,  
24 frankly, is because Joe put together some other ones  
25 that he hasn't presented yet on their near-term

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1 activities and we are trying to fit in with that.

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

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

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

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

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

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

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

23 Let me first answer there was one question  
24 early on about the difference between wind hazards  
25 that are used for structural -- by structural people

1 and wind hazards and the winds that were used to drive  
2 hydrodynamic models. And we have actually looked  
3 quite a bit at both of these classes. And what we  
4 have found is that their fundamentals are very  
5 similar. The parameters that they feed them probably  
6 fit the people, Peter Vickery as an example, his work  
7 on the land winds certainly seems to fit the on-land  
8 winds better than the people who do the meteorological  
9 work offshore. But they, the people who do the  
10 offshore work actually fit better right there. And it  
11 is more the parameters they drive them with than the  
12 differences in the models, however.

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

19 I would like also to go back to some of  
20 the questions that started. What we were trying to do  
21 was very much along the lines of what the subcommittee  
22 was discussing, which is to try to look at the  
23 uncertainty that is inherent in a lot of this data and  
24 see where we could work in to determinism where we  
25 could. But even when we would work in the

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1       determinism, a good example is if you model the  
2       maximum, what they now call the maximum possible  
3       intensity which is a little variation on a theme  
4       there, but it is still somewhat of a random variable.  
5       But if we look at all of these things, they still have  
6       randomness about them and we actually think that that  
7       randomness should not be thrown out with the wash but  
8       should be considered in a lot of the work that is  
9       done.

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

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

23               So but on the other hand, there was some,  
24       such as the storm intensity that even though there is  
25       a stated quasi-empirical, quasi-theoretical argument

1 for in existence of a maximum potential heat engine  
2 rate of extraction of energy and this sort of thing  
3 and it has been debated, I'm not sure how finely tuned  
4 that estimate is at the moment.

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

19 And that actually turned out to be a  
20 fairly smaller term than we expected; whereas the  
21 modeling errors just the fact that surge models are  
22 sort of all hydrologic models are fairly crude when  
23 they come down to it because roughness, topography,  
24 and changes in the middle of the run and we don't know  
25 exactly how or why. There is just a lot of

1       uncertainty in the situation. So when you start  
2       putting all that in together, some of the things kind  
3       of dropped out.

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

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

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

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

23              You mentioned something that caught my interest.  
24       you have dealt with characterizing and quantifying  
25       uncertainties in the models themselves. Did I

1 understand that correctly?

2 MR. RESIO: That is correct.

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

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

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

1 MEMBER RAY: No.

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

5 MEMBER RAY: One more --

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

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

20 You know, where a lot of the uncertainties  
21 come in of course you are just trying to represent a  
22 very complex thing with a numerical model, which is  
23 difficult. And then really a lot of where we found  
24 when we were more often in places than others has to  
25 do with how well you actually are resolving the

1 physical system. Do you have the right bathymetric  
2 and topographic features in there. And so it is  
3 really important to try and resolve and get as good a  
4 representation of that coastal flood plain as you  
5 possibly can to try to minimize what that uncertainty  
6 is associated with the model. And so that is the  
7 approach that we presented in the report.

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

10 MEMBER RAY: No.

11 CHAIR STETKAR: Thanks, Ty.

12 MR. WAMSLEY: All right.

13 CHAIR STETKAR: I guess, Joe --

14 MR. KANNEY: Back to me?

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

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

24 Over the last several years since, I think  
25 certainly since I have joined the Agency three years

1 ago and I think discussions were going on before that  
2 between Staff and Research and NRO and NRR and the  
3 Regions, there are several areas which have been  
4 identified which really can benefit from a more risk-  
5 informed approach with respect to the external  
6 flooding events. Some of the items which have been  
7 flagged, of course, you know, the review of the SARs  
8 for COLAs and ESPs but also the risk assessment  
9 standardization project within research, the SPAR  
10 model development program. There is an external  
11 events SPAR model that you are probably aware of. You  
12 are probably aware that they are not very well  
13 developed with regard to external flooding.

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

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

1 CHAIR STETKAR: Right.

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

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

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

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

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

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

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

25 And then the other two bullets are bullets

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

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

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

21 And then also earlier on we talked a  
22 little bit about paleoflood information. And we have  
23 a project that we are putting in place right now, the  
24 actual work hasn't started, with the U.S. Geological  
25 Survey to help us better assess how useful paleoflood

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1 information might be with regard to flood risk  
2 assessment at power plants.

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

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

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

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1 CHAIR STETKAR: Not characterizing the  
2 sources.

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

6 CHAIR STETKAR: Right, regardless of where  
7 --

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

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

19 Okay, then some proposed near-term  
20 activities. These are like late, very late FY12  
21 through next year and the following year. As a  
22 follow-on to the work that the Bureau of Reclamation  
23 did in support of Reg Guide 1.59 update, the work that  
24 John and his colleagues did taking the existing PMP  
25 methodology, looking at the impact of including newer

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1 storms. What does that do to the estimate? As John  
2 mentioned, for certain area sizes and certain  
3 durations, you basically break the PMP in the  
4 Carolinas is what they found. Okay?

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

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

18 The other things is we didn't really --  
19 John would have mentioned this had we gone through his  
20 full presentation but the work that he and his  
21 colleagues did in the Carolinas did not look at  
22 orographic regions. They looked essentially, the  
23 impact they studied was mainly the impact of like an  
24 additional ten tropical cyclones that impacted sort of  
25 the coastal areas of North Carolina. Now as you get

1 into the more mountainous areas of the Carolinas, then  
2 orographic influences will come into the precipitation  
3 estimates. And that wasn't looked at in that study.

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

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

23 And really just because of sort of the  
24 amount of funding that we think we might have  
25 available, there are certain things which I have

1 listed that we are not going to treat, not because  
2 they are not important. That is actually the last  
3 bullet, like the dam failure ice effects and channel  
4 diversion, they are out of scope for this project just  
5 because of the amount of funding we think we are going  
6 to have for it. It is not because we don't think  
7 those are important or that they don't need to be  
8 treated but we are going to have to treat that in some  
9 other project or in some other way.

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

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

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

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

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

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

18                 MR. KANNEY: Sure.

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

25                 We have gotten verbal agreements from



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

6 MR. KANNEY: Thank you, Tom.

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

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

18 And then further along then we would  
19 evaluate what the options for NRC have in terms of  
20 providing guidance. Sort of at a ten thousand foot  
21 level the two options are, do we develop NRC specific  
22 guidance or perhaps adopt industry consensus standards  
23 because we are aware and we are participating at a  
24 certain level in these industry consensus standards  
25 development. Certainly two that are of most relevance

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1 are ANS-2.8 for design or flooding hazards for nuclear  
2 power plants and that is currently under revision.  
3 And the working group is driving at a probabilistic  
4 standard. ANS-2.31, which includes precipitation is  
5 also under revision right now and that is also driving  
6 towards a probabilistic standard.

7 And that is all I have on that.

8 CHAIR STETKAR: Well thank you.

9 MR. KANNEY: Do you have any questions?

10 CHAIR STETKAR: Charlie? Harold?

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

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

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

24 For the full committee presentation, I  
25 think one area of interest, and I am not sure whether

1 it is addressed in the material that we have today,  
2 but something that kind of came out of the last 45  
3 minutes or so of discussion would be some appreciation  
4 of which areas, for example Joe you started with the  
5 different flooding mechanisms, out of those areas, if  
6 I consider those different sources of a flooding  
7 hazard, where do we have better or lesser capabilities  
8 to address them probabilistically? For example, if we  
9 heard from the Bureau who obviously has a certain  
10 mindset about their experience addressing things. We  
11 heard from the Corps. There are other areas where  
12 perhaps we are on the fringes of where are we in terms  
13 of the state of the practice. I think that would be  
14 valuable information to kind of set a perspective for  
15 the full committee in terms of not necessarily the  
16 need to holistically solve the entire problem of how  
17 do you address a probabilistic flooding hazard  
18 analysis but where are we. Are there certain parts of  
19 the problem where we are fairly close and others where  
20 we are less close?

21 I think that the HHA is worthy of  
22 discussion only because of its parallels at least in  
23 my mind of things that are already done. So this  
24 notion that there is a methodology for dealing with  
25 however the hazard is specified, dealing with its

1 progressive refinement and how one might do that, I  
2 think that is useful information. And to make sure  
3 that the committee understand that at least in my  
4 interpretation the NUREG/CR-7046 is focused at that  
5 part of the problem, primarily, although it does talk  
6 about other parts.

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

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

15 (Laughter.)

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

19 CHAIR STETKAR: Okay.

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

23 CHAIR STETKAR: Yes.

24 MR. OTT: And I sort of backed off from  
25 saying anything directly. I discussed it with NRO and

1 we were actually anticipating that we probably would  
2 get a letter out. But apparently that is still up in  
3 the air whether we do or not.

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

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

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

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

24 MEMBER RAY: Well in that regard, given  
25 that schedule that I am sure will result, I can tell

1 you that the impression is going to be in the industry  
2 that well now it is settled for the next generation.  
3 I'm telling you that is what it is going to be.

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

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

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

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

22 (Laughter.)

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

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

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

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

24 And I wanted to make one observation about  
25 John England's enthusiasm for what the bureau has

1 done. And that is one of our problems. One of the  
2 problems we face with other federal agencies is the  
3 recurrence intervals that they are concerned with is  
4 those are the recurrence intervals that you are  
5 concerned with.

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

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

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

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

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

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

6                   MEMBER BROWN: Oh, okay.

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

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

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

13                  MEMBER BROWN: Yes.

14                  MEMBER RAY: But that is another story.

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

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

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

22

23

24

25

CERTIFICATE

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# **ADVISORY COMMITTEE ON REACTOR SAFEGUARDS**

## **Regulatory Policies and Practices**

### **Subcommittee Meeting**

## **Hierarchical Flood Hazard Assessment**

**Rajiv Prasad**

Pacific Northwest National Laboratory

July 10, 2012

# Hierarchical Hazard Assessment Approach

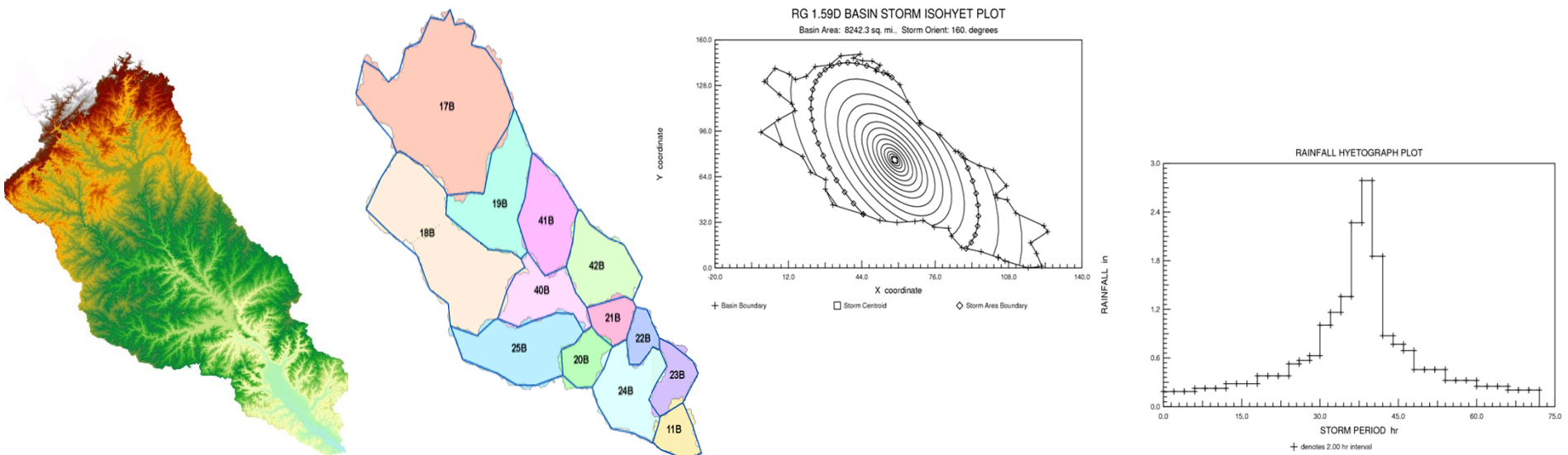
- Objective of Flood Hazard Assessment
  - provide reasonable assurance that plant SSCs would be safe
  - account for worst historical flood hazard
  - account for limited datasets
  - demonstrate sufficient margin
- How do we meet these objectives?
  - analysis of historical data and observations
  - 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



# 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”***

**Dr. Joseph Kanney  
Hydrogeologist  
RES/DRA/ETB**

**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
- Existing 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          | <i>Concurred</i> |
|            | Risk Assessment                      | <i>Concurred</i> |
|            | Engineering                          | In progress      |
| NMSS       | Fuel Cycle Safety & Safeguards       | <i>Concurred</i> |
| Region I   | Reactor Safety                       | In progress      |
| Region II  | Reactor Safety                       | In progress      |
| Region III | Reactor Safety                       | <i>Concurred</i> |
| Region IV  | Reactor Safety                       | <i>Concurred</i> |

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

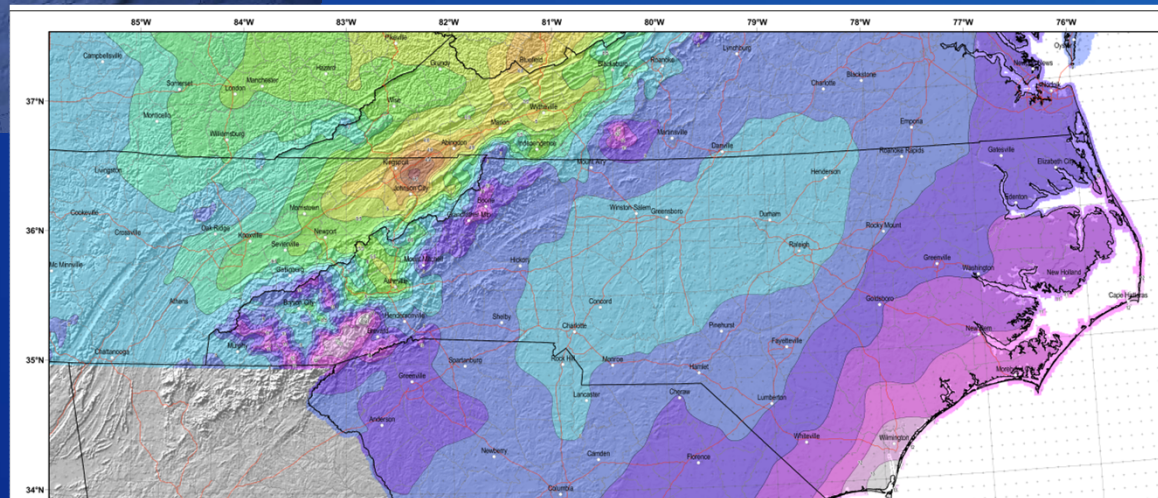
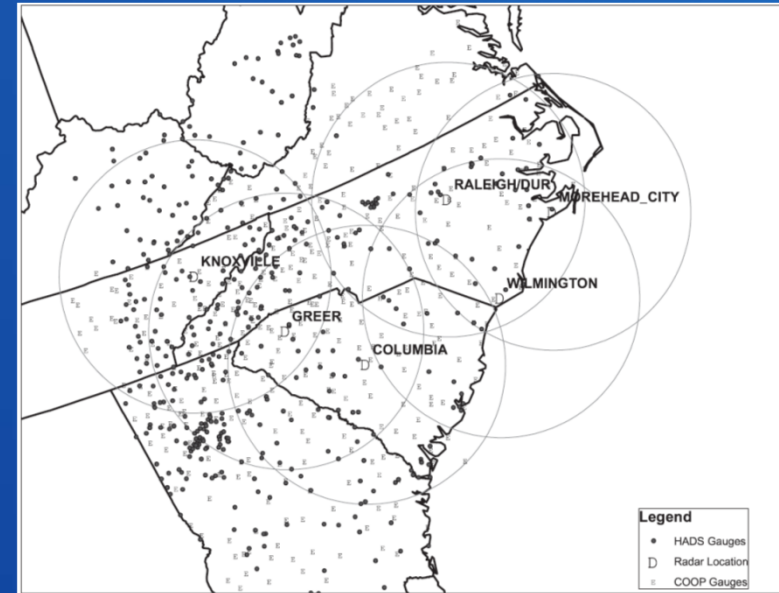
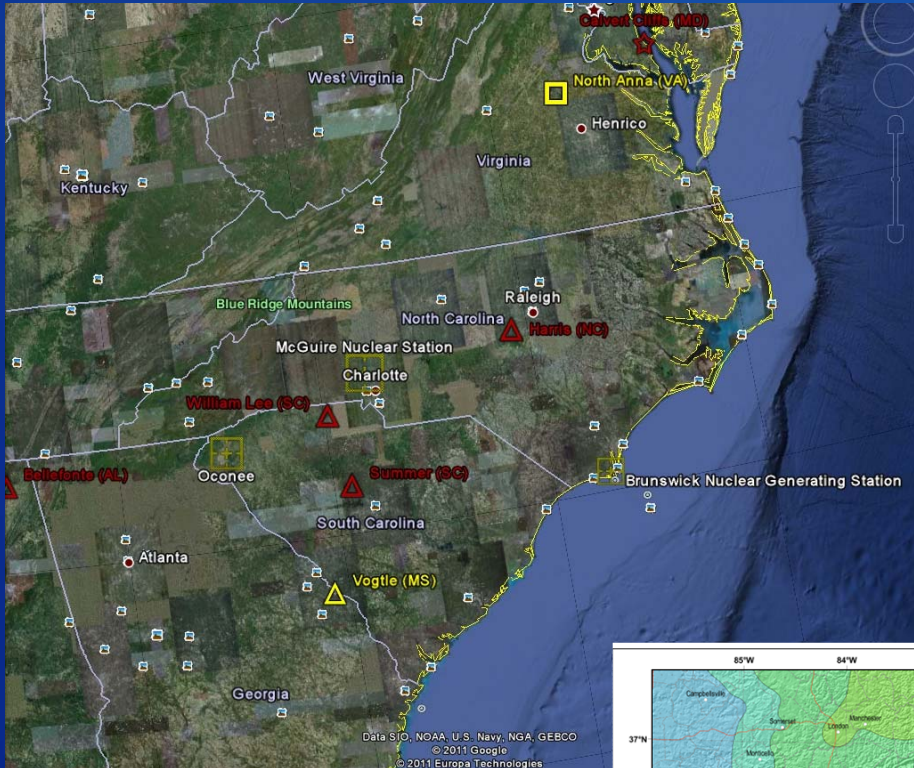


# NRC PMP Research Objective

**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

# 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/](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)



# 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)

# 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

# Task 2 New Data: Key Findings

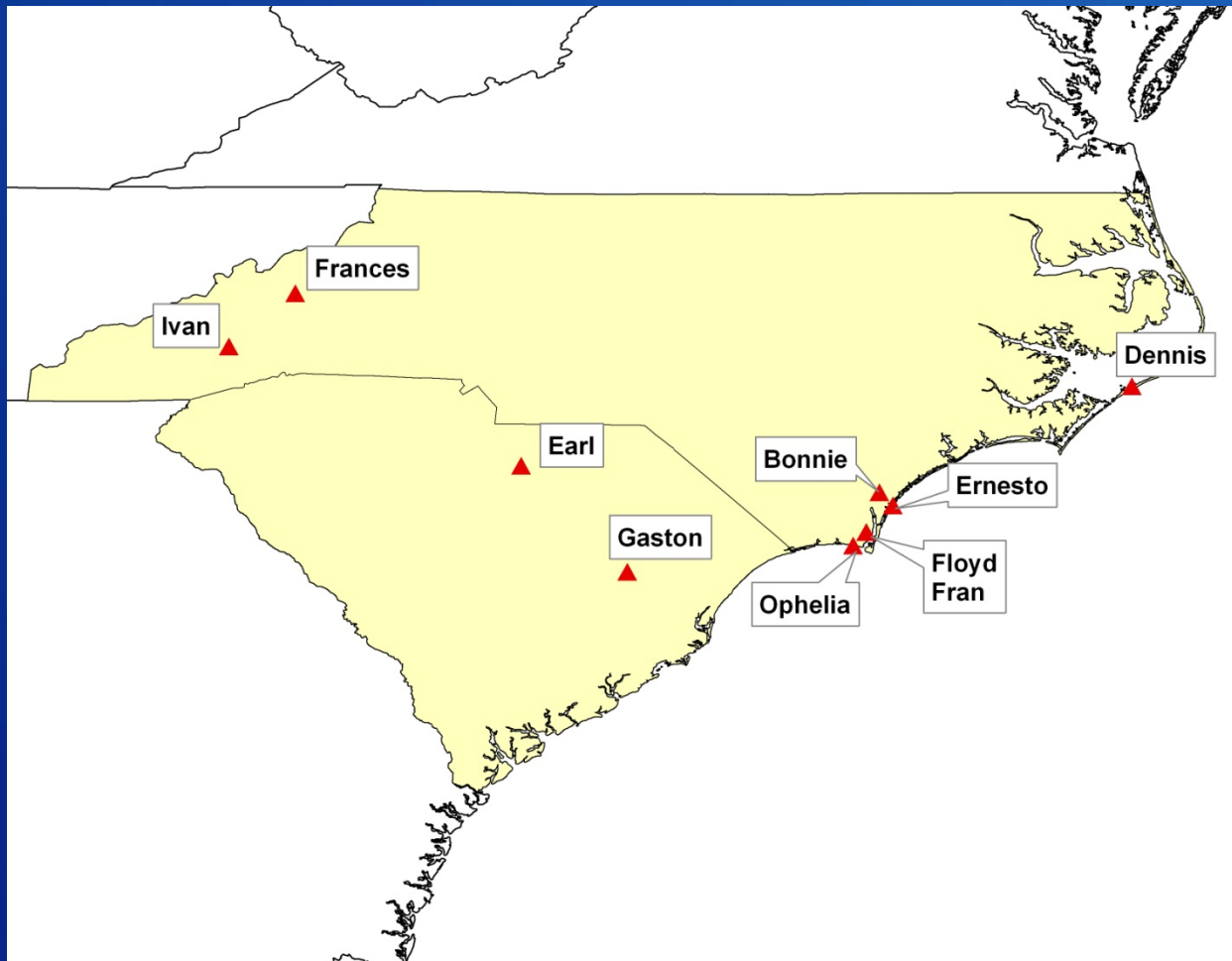
Pilot project in NC/SC centering on **MPR** data

- New data analyses suggest ***HMR 51 PMP values too low*** for durations  $> 12$  hrs and area sizes  $> 5,000$  mi<sup>2</sup> 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

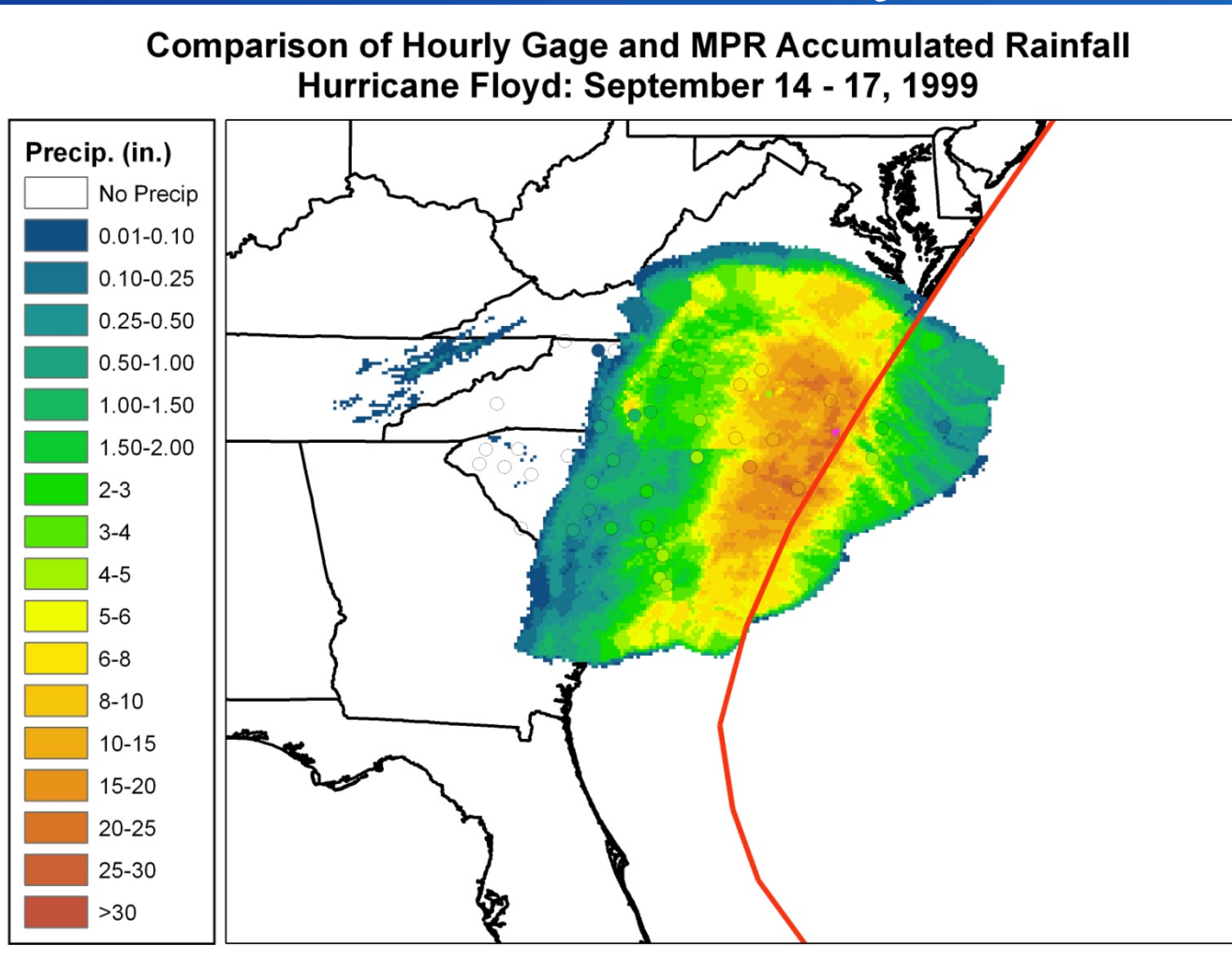
Sites concentrated near the coast for storms approaching from the Atlantic.  
Storms making landfall along the Gulf of Mexico produced highest rainfall totals in the piedmont and mountain regions.



# 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 <sup>2</sup> ) | Area (mi <sup>2</sup> ) | 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   |

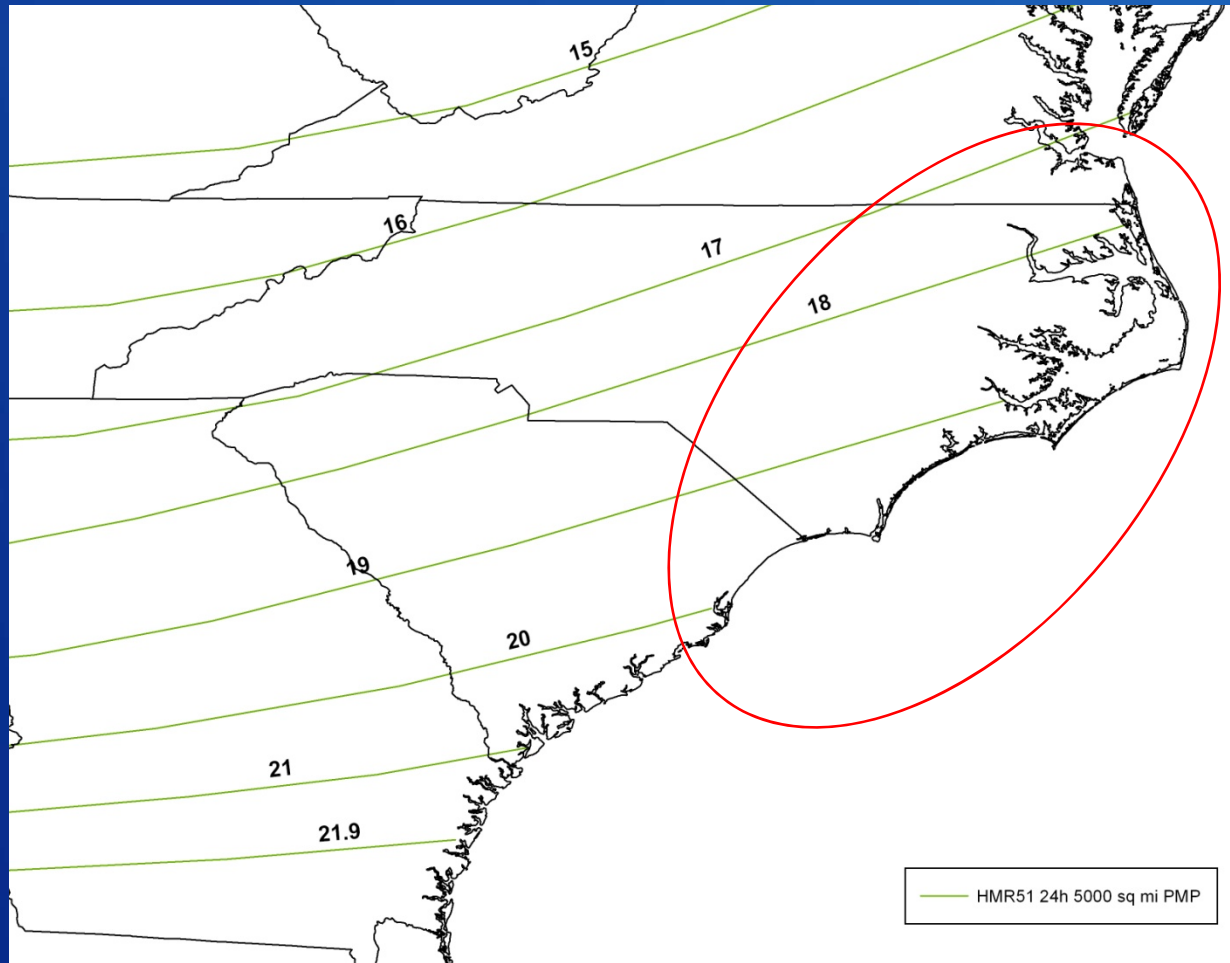
Comparison of PMP values from HMR51 grids and 24-hour and 72-hour DADx from MPR for Floyd 1999.

# 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<sup>2</sup>



# Task 3 Uncertainty/Synthesis: Key Findings

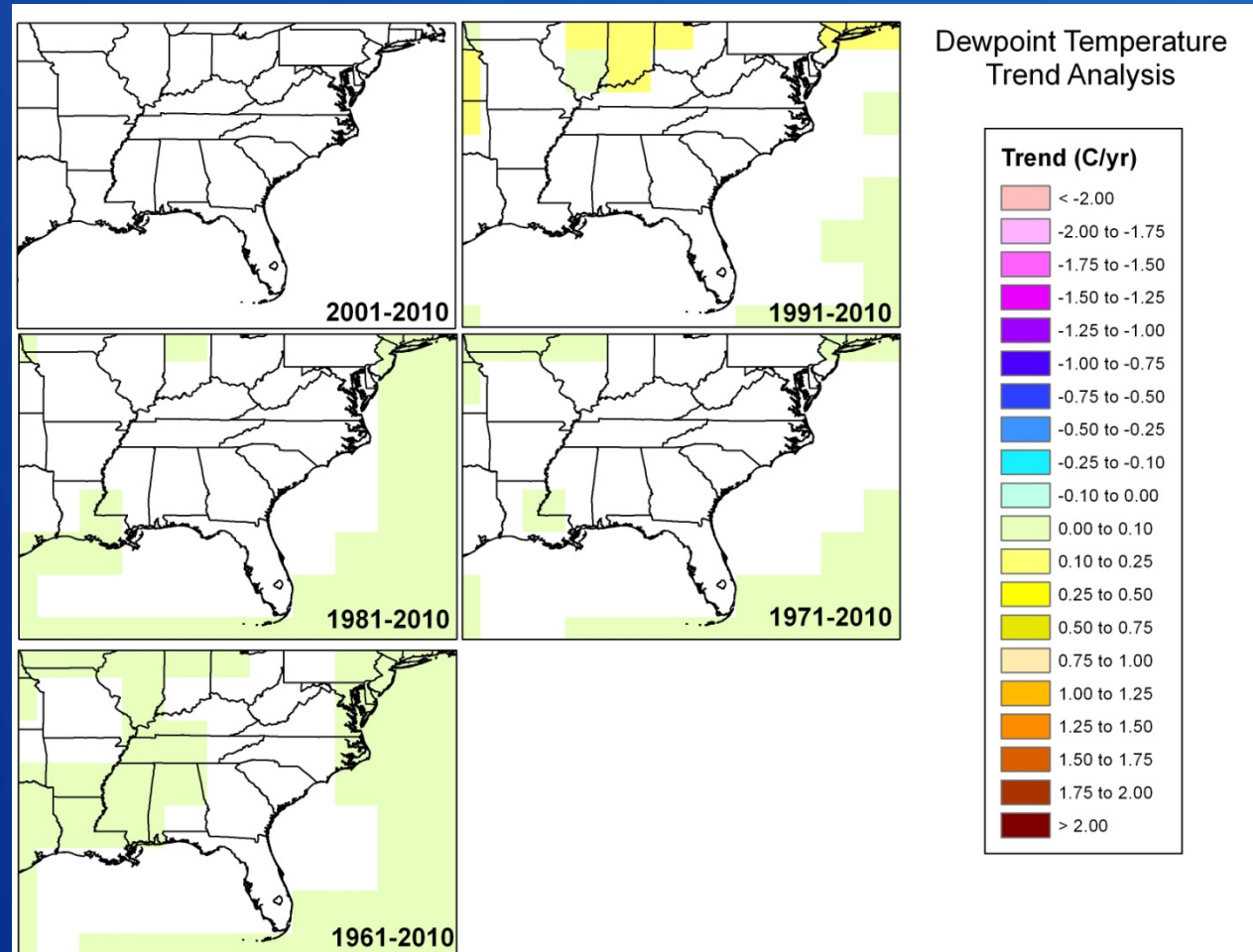
- No significant trends found in SST and Td grids; suggests stationary series for maximization
- Potential for increased temporal clustering of TC events in August-September (1999, 2004, 2011)
- Longer-duration rainfalls ( $> 72$  hr) and soil moisture for runoff may be changing factors
- PMP ratios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

# 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).

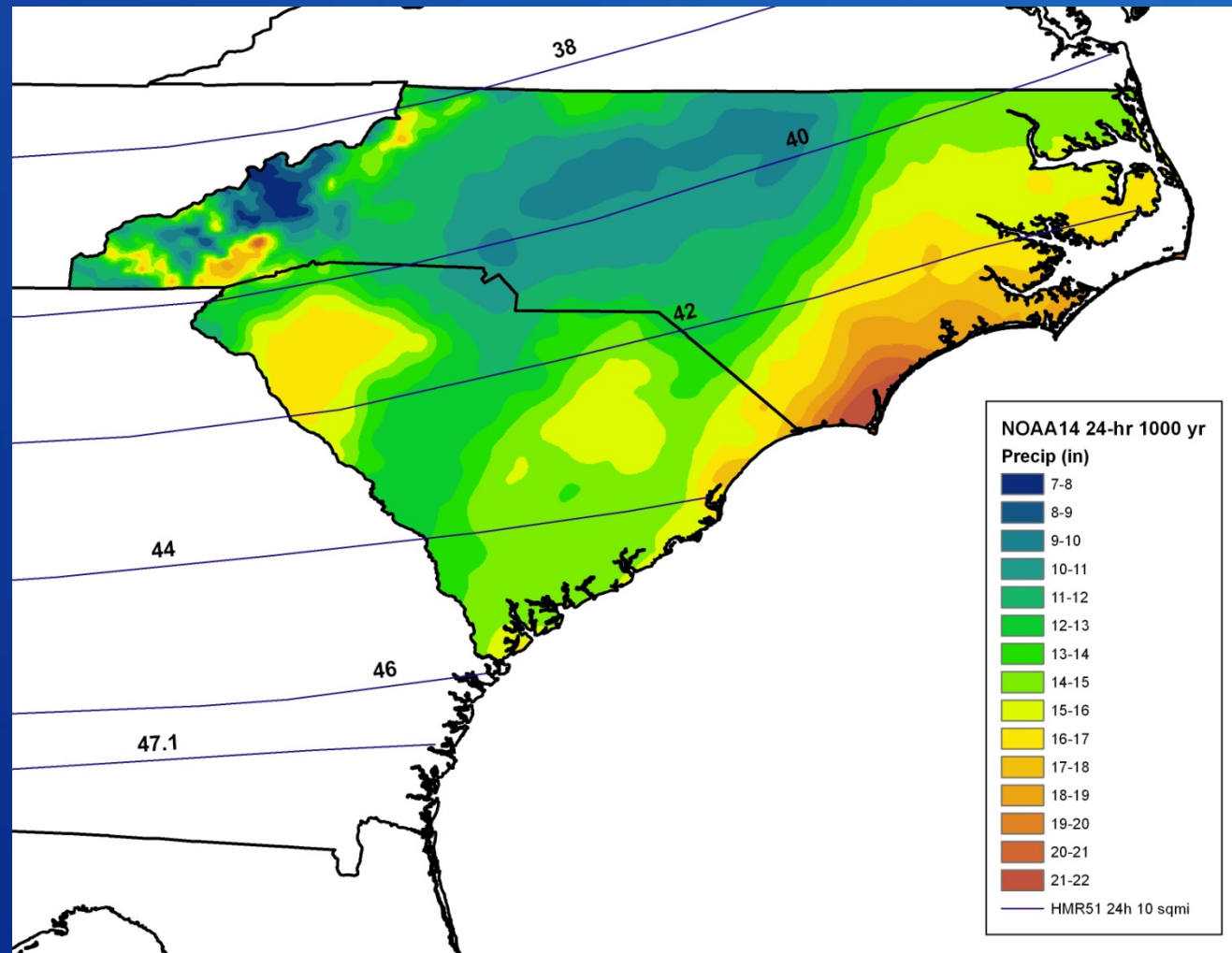


# Precipitation Frequency Ratios

NOAA 14 high  
spatial detail  
compared to  
PMP isolines

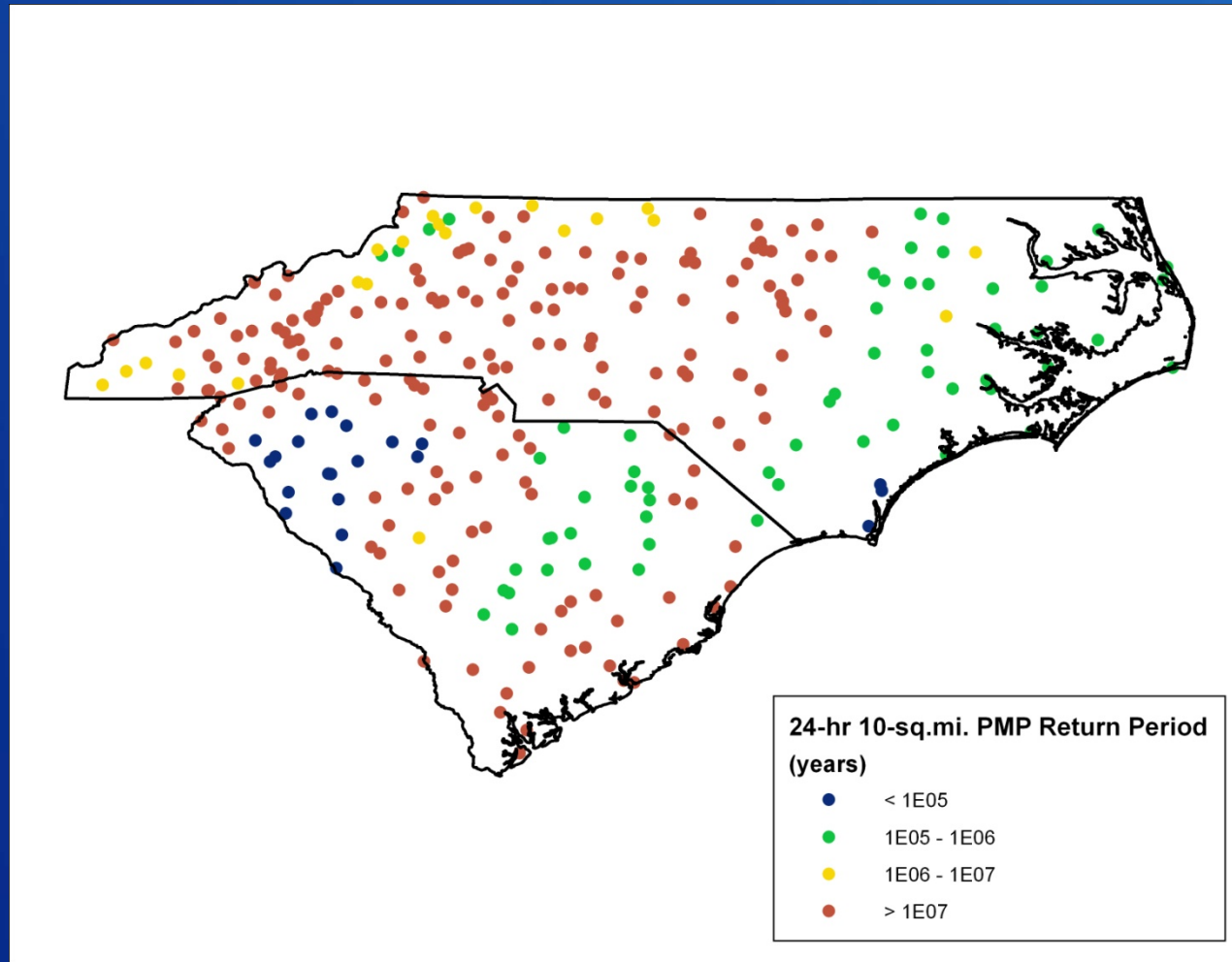
high points  
along coast,  
Appalachians

low in Piedmont



NOAA 14 24-hour, 1000-year precipitation with 24-hour, 10 mi<sup>2</sup> PMP contours from HMR 51.

# PMP Frequency Estimates



Return periods of the 24-hour, 10 mi<sup>2</sup> 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

# 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

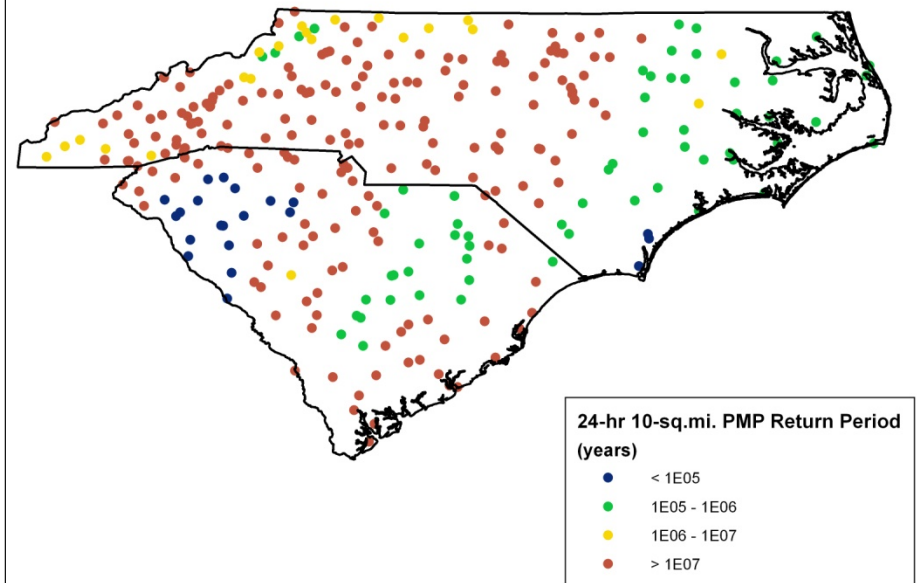
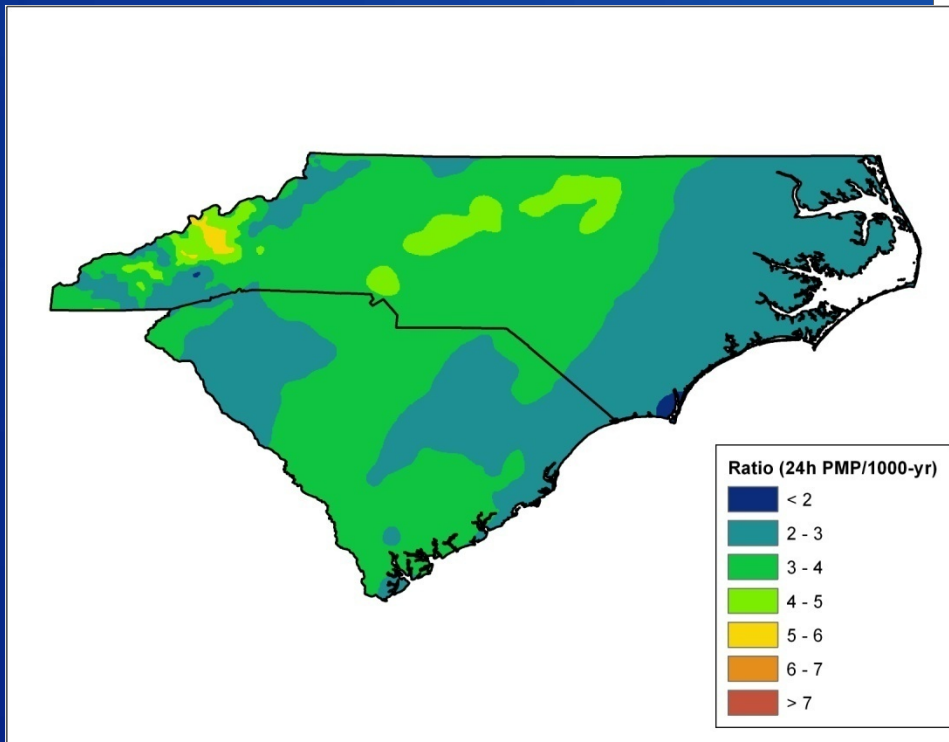
# Discussion, Implications, Future Work

## *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?



# Additional Technical Details

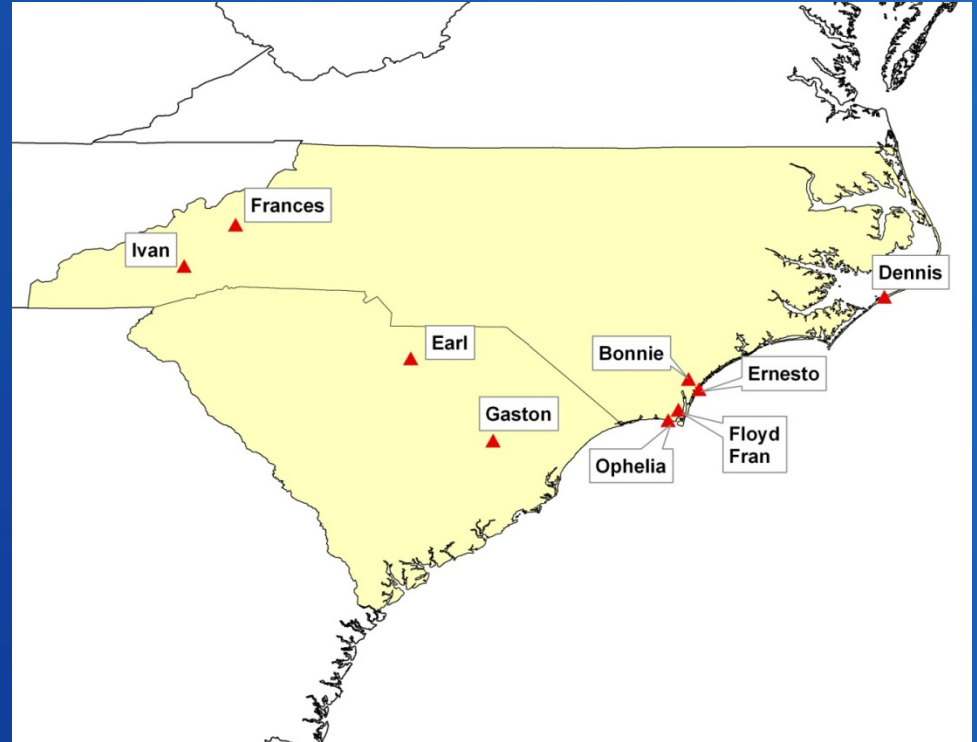
- As time permits, or to facilitate discussions



# Potential New Data Impacts – PMP

## Unresolved Issues

- Area sizes  $< 5000 \text{ mi}^2$ ?
- Durations  $< 12 \text{ hr}$  and  $< 6 \text{ hr}$ ?
- 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 ( $> 72 \text{ hr}$ ) and soil moisture for runoff may be changing factors

# 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

# 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

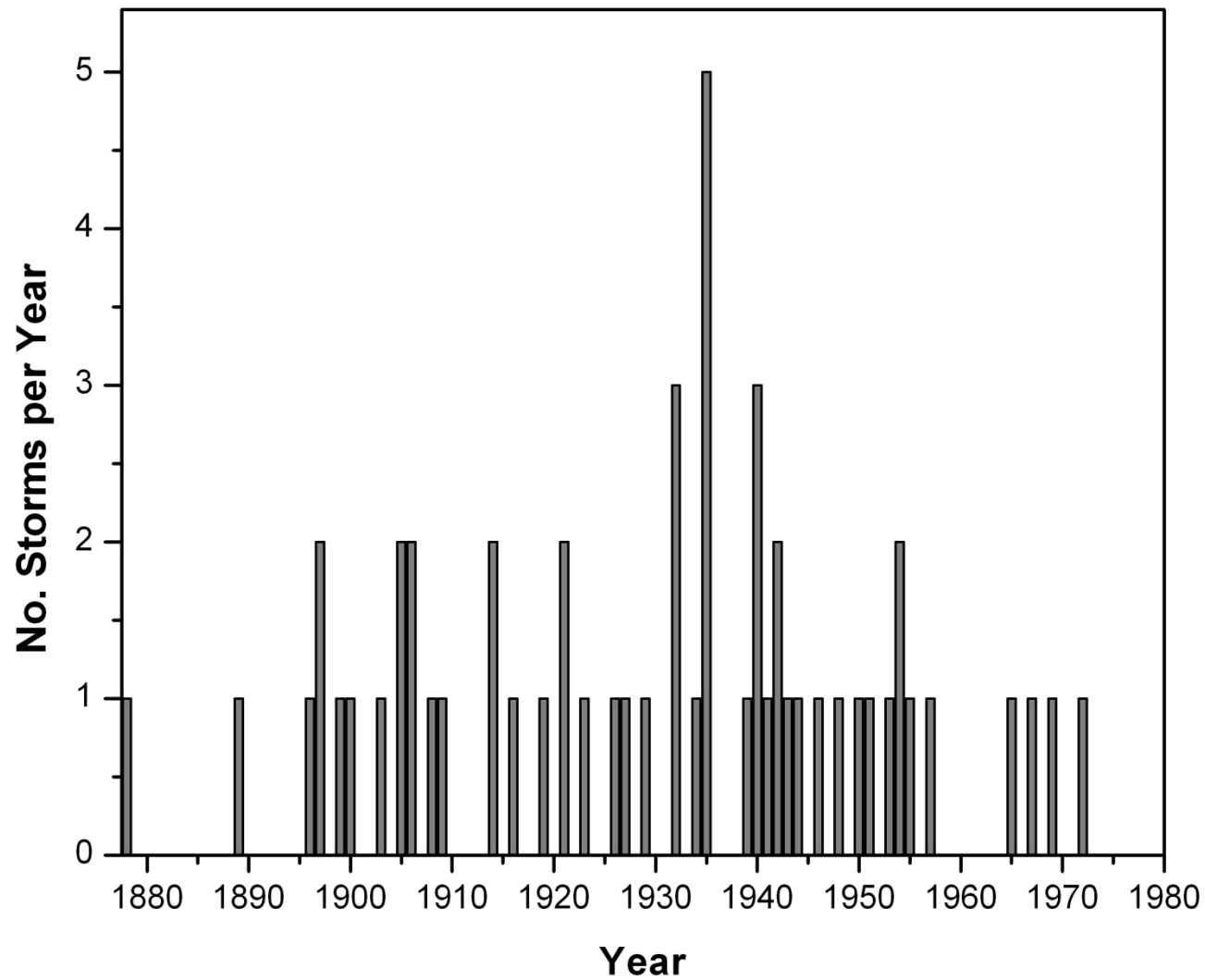
# Basic Problem: Temporal Limitations

HMR51:

53 Major  
Storms  
used for  
PMP in  
Eastern  
US

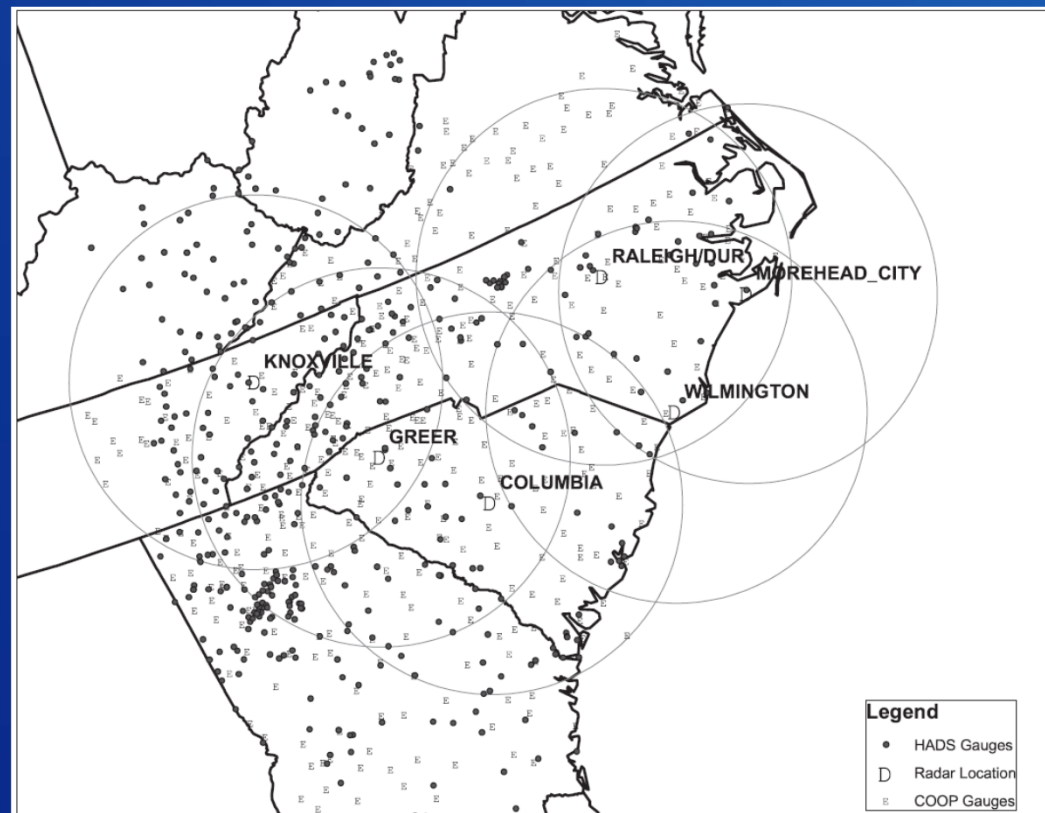
*also spatial  
limitations!*

HMR 51 PMP: Number of Major Storms Used Per Year



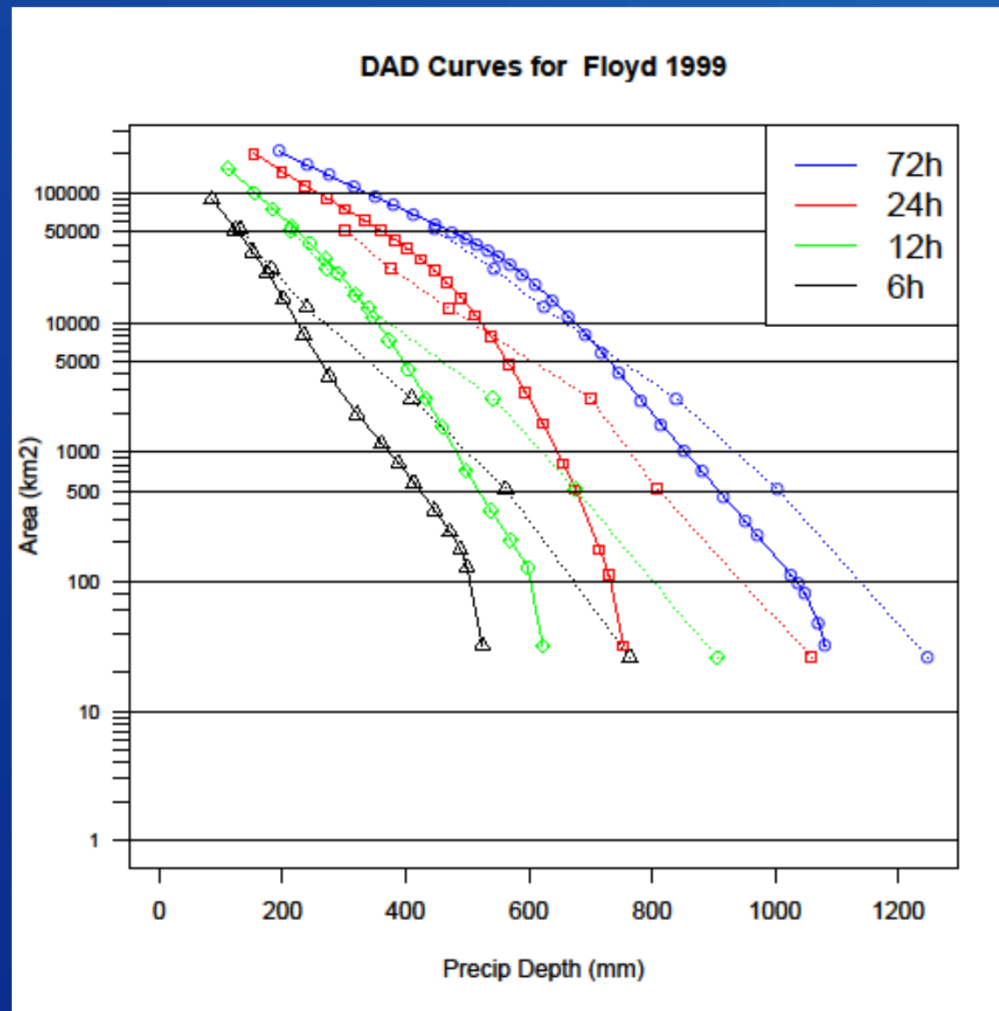
# Key Data Set: MPR from NCDC

- Radar WSR-88 Digital Precip Array
- Hourly and daily rain gage data (HADS, COOP)
- Combined data set 1 hour,  $\sim 4 \times 4$  km<sup>2</sup>
- Builds on NWS operational Multisensor Precip Estimation (MPE)



details: Nelson et al. (2010) JHM

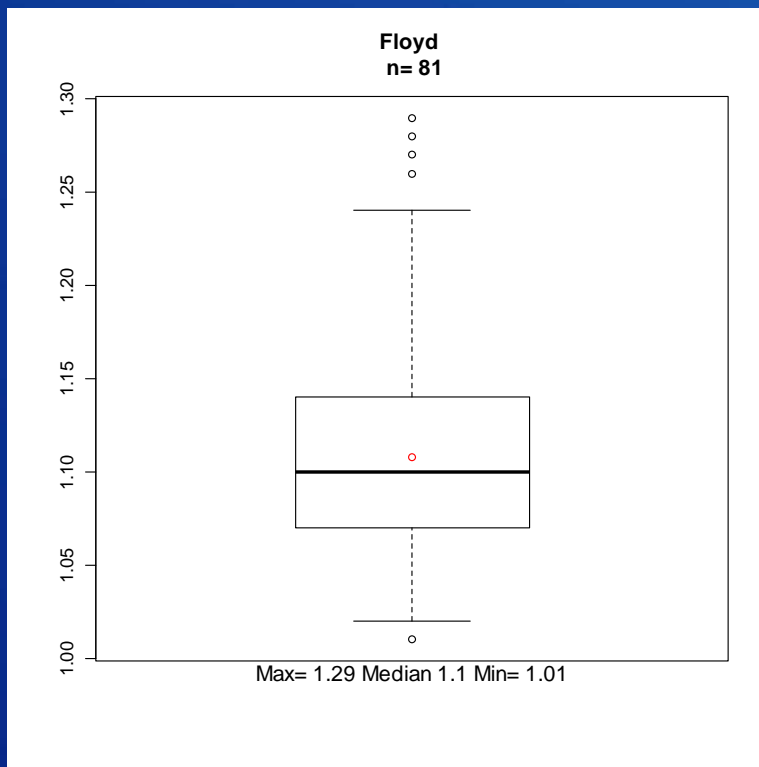
# Floyd – HMR 51 PMP Comparison



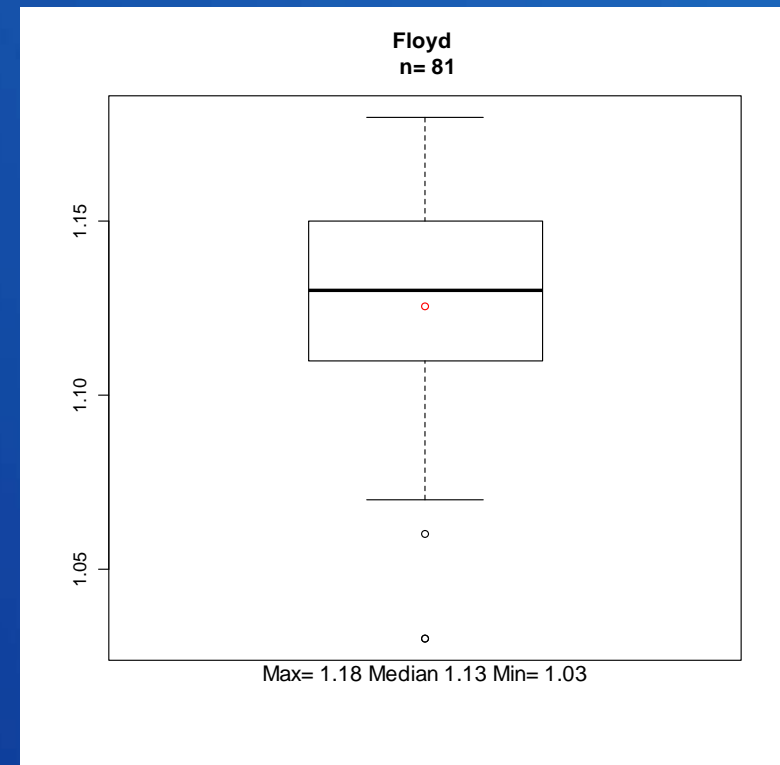
Comparison of DADx curves from MPR (solid) and HMR51 (dashed) for Floyd 1999. Exceedance of HMR51 PMP values are evident where solid lines cross dashed lines of the same color.

# 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<br>(km <sup>2</sup> ) | Area<br>(mi <sup>2</sup> ) | HMR51   | MPR<br>(max) | MPR<br>(median) | % diff<br>(max) | % diff<br>(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

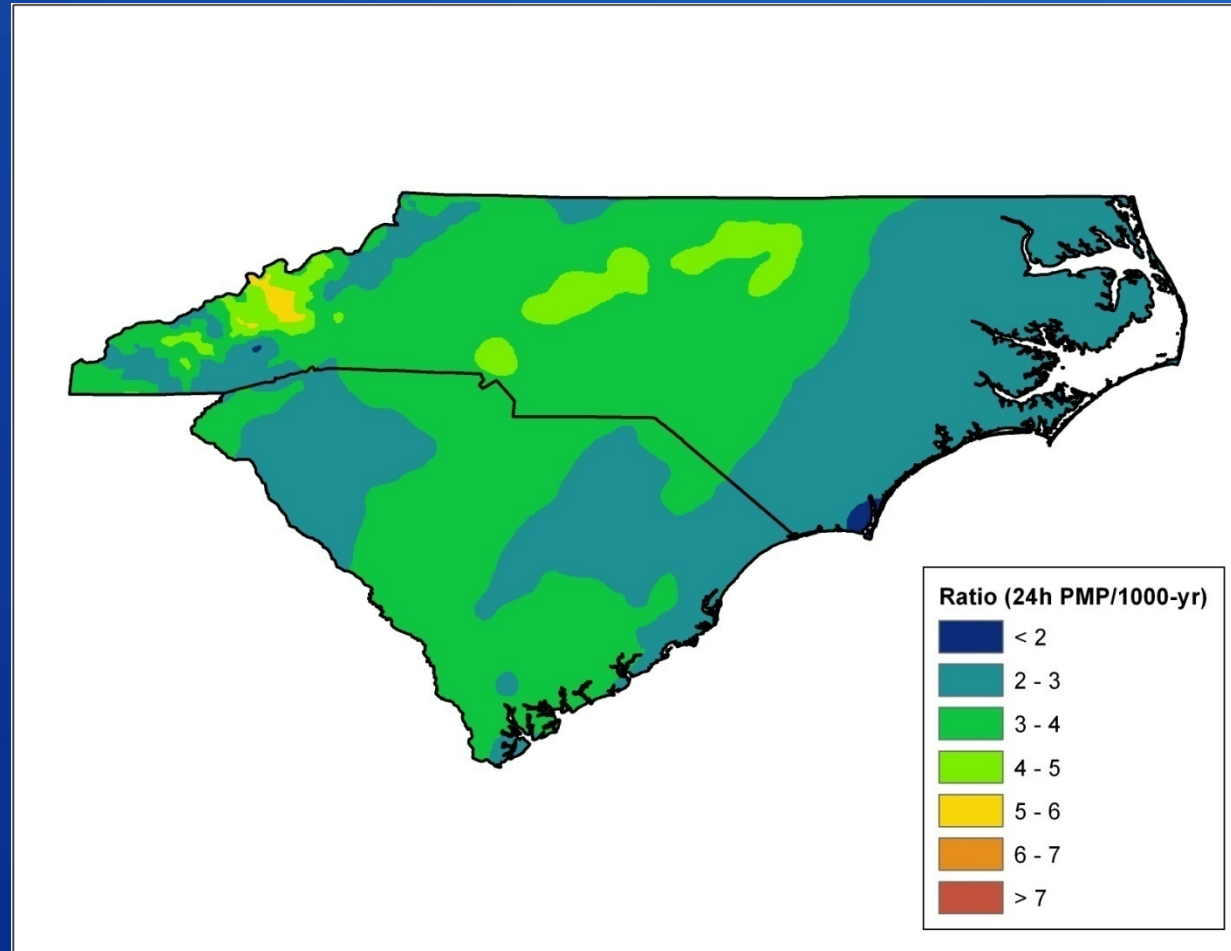
- Maximum Moisture trends – ***Climate Change Impacts?***
- Frequency Estimates of PMP
  - NOAA COOP, NOAA 14 and Regional Frequency
  - Precipitation Frequency Ratios
  - PMP Frequency Estimates
  - Point Frequency Estimates
- See H44E-08 Thurs for related work

# 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<sup>2</sup> PMP from HMR 51 and NOAA 14 24-hour, 1000-yr precipitation

# 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 Paleoflood 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

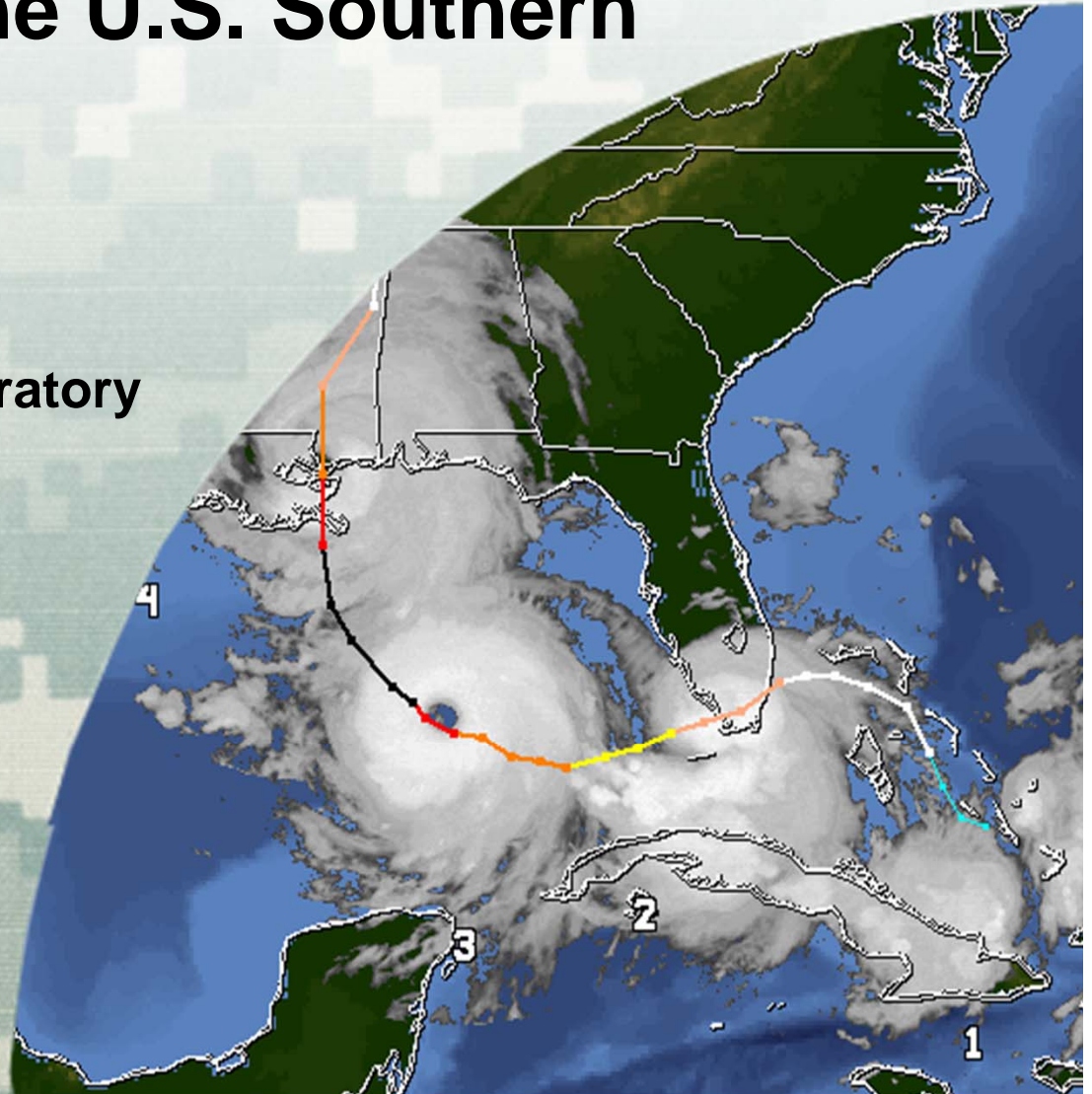
Engineer Research and  
Development Center

Coastal and Hydraulics Laboratory

Don Resio and Ty Wamsley



US Army Corps of Engineers  
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# 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

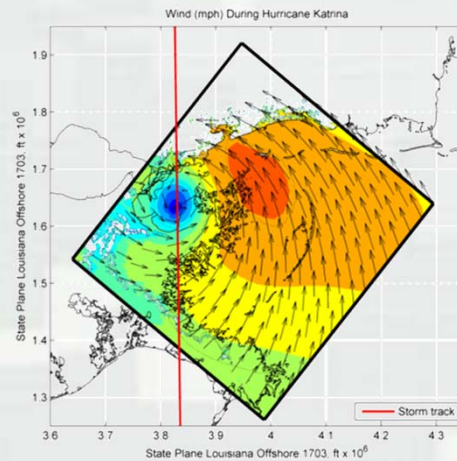
1. Apply coupled numerical model system that properly define the physical system and includes all relevant processes.
2. Allow for MPI storm central pressure and estimate size as a conditional probability
3. Consider uncertainty.



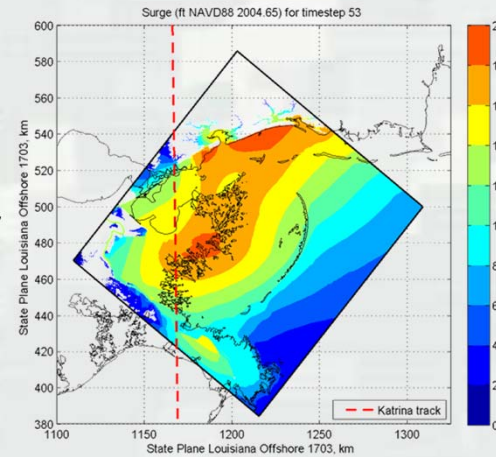


# Modeling System

***CSTORM-MS***

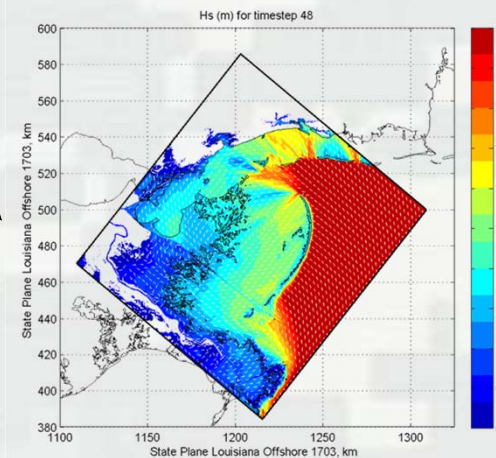


PBL Model  
Wind fields &  
Wind stresses



Surge  
model:  
ADCIRC

Coupling



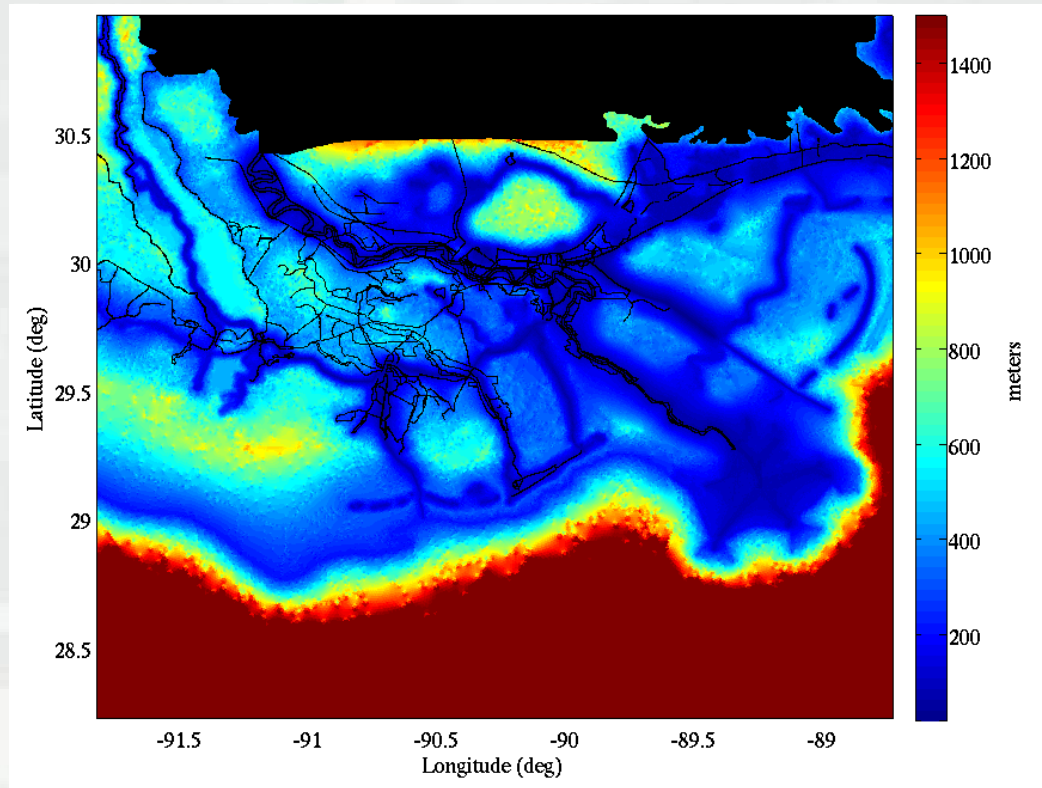
Offshore  
waves:  
WAM  
Nearshore  
waves:  
STWAVE-  
FP



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# 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 Probabilistic 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.



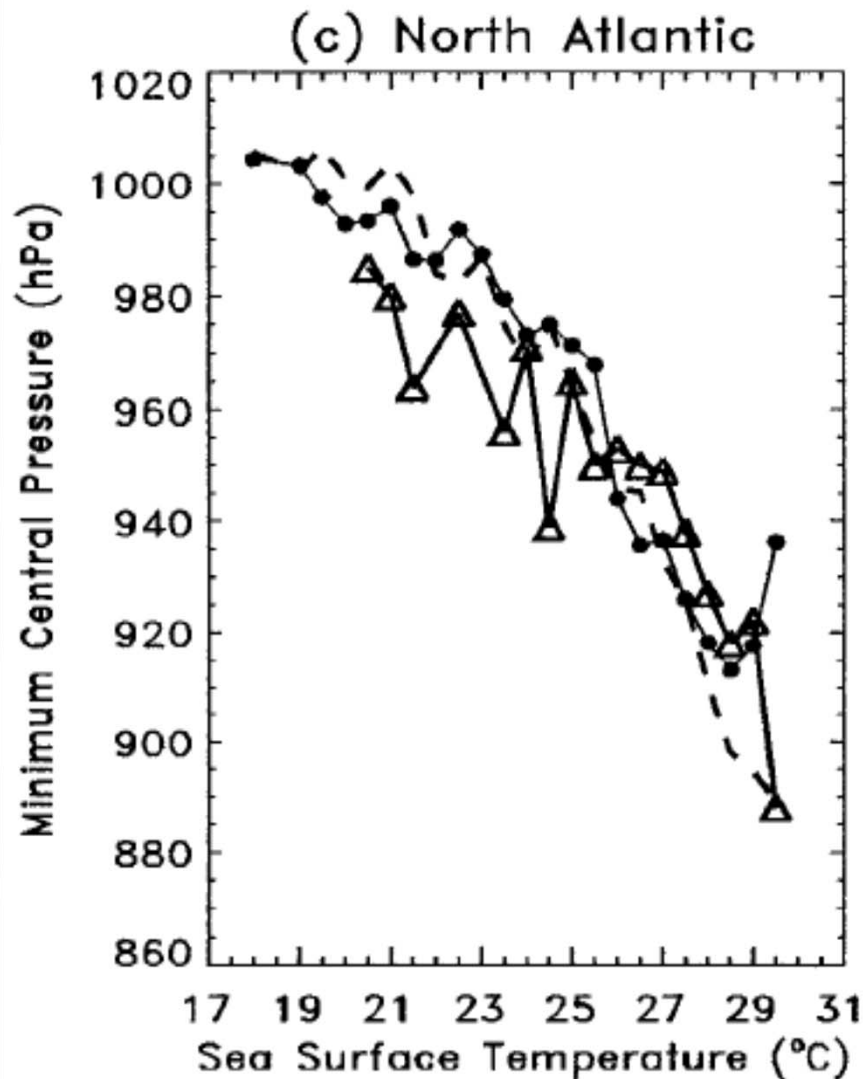
# Hurricane Parameters with Asymptotic Limits

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

- 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?



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