Advisory Committee on Water Information
Subcommittee on Hydrology

Extreme Storm Events Work Group

FINAL
July 24, 2008

Charge of Work Group

I. Sponsorship:

The Extreme Storm Events Work Group (Work Group) is a working group of the Subcommittee on Hydrology (SOH) of the Advisory Committee on Water Information (ACWI).

II. Purpose, applicability, and scope:

A. Purpose. The overall purpose of the Extreme Storm Events Work Group is to coordinate studies and databases for reviewing and improving methodologies and data collection techniques used to develop design precipitation estimates of large storm events up to and including the Probable Maximum Precipitation (PMP). The Work Group will develop a detailed scope of work/plan of study, and determine the necessary funding requirements to update the ***Catalog of Extreme Storms*** and ***Hydrometeorological Reports*** (HMR) for estimating PMP. The statement of work presented below thoroughly describes the problem and issues that the Work Group should address.

B. Applicability. Extreme storm hydrometeorology studies impact extreme flood estimates and assessments for dams, nuclear power plants, levees, and other high-hazard structures within the United States. Without these studies, engineering planning and design costs will increase due to the need for site-specific studies because generalized approaches are outdated.

C. Scope. The Work Group will promote cooperation among agencies on development of design storm studies and facilitate information transfer amongst the agencies and to the public. The initial effort will be a review of extreme storm event data since 1972, and to update HMR's for the U.S. east of the 105th Meridian. The Work Group will formulate a detailed plan to cover the remainder of the U.S. with emphasis on resolving uncertainties for PMP estimates in mountainous terrain.

III. Membership:

A. The Work Group shall have open membership from Federal/State agencies, universities, the private sector, and others with expertise in hydrometeorology.

B. During meetings, the Chair will announce and the group will act on new membership applications received at least two weeks prior to the meeting.

C. The Chair and Vice Chair will be selected from among the members. The Chair and the Vice Chair will serve two year terms ending December 31. The Vice

Chair will then become Chair, and the members will elect a new Vice Chair to replace the Chair. Also, the Vice Chair will serve in the absence of the Chair. A special election will be held if either the Chair or Vice Chair terminates their association with the work group before their terms expire.

D. Members are expected to attend, in person or by teleconference, all meetings of the Work Group. If a member does not attend at least 50 percent of the meetings in any calendar year, the Chair may remove the member from the rolls. A member can be reinstated by informing the Chair of their desire to renew their participation in the Work Group.

IV. Meetings and Procedures:

A. The Work Group will meet at least two times a year and more frequently as designated by the Chair. The Chair will determine the dates, times, and locations of the meetings in consultation with the members. The Chair will be responsible for announcing meetings 2 months in advance and distributing agendas and information about meetings to all members at least 2 weeks in advance of the meetings.

B. Members of the Work Group will receive no pay, allowances, or benefits from the SOH or the ACWI. All travel expenses will be borne by the individual member organizations.

C. The Work Group will conduct business in an open fashion by discussing and attempting to resolve all issues through consensus and by recognizing the legitimate interests and diverse views of the Work Group members. If complete agreement cannot be reached on a specific issue, then the following procedures will apply:

1. A consensus will exist unless one or more members request a vote.

2. Once a vote is requested, the Chair will poll the voting members. An affirmative vote of a majority of the members present will constitute approval of a motion. Two-thirds of the members will constitute the quorum necessary for a formal vote. Each member except for the Chair may cast one vote. In the event of a tie, the Chair will cast the deciding vote. The chair will record how the votes were cast.

3. The Chair will sign and forward to the Chair of the SOH decisions of the Work Group that are proposed advice, guidance or recommendations intended for implementation. Members may prepare minority reports and provide them to the Chair within 3 weeks of a decision. Such minority reports will be forwarded along with majority reports.

D. Meetings of the Work Group will be open. Each meeting will include time for individuals who are not members to make statements or to have written statements distributed during the meeting.

E. The Chair will prepare and distribute minutes with action items of Work Group meetings to members and to the Chair of SOH.

V. Termination:

The Chair of the SOH has the authority to terminate the Work Group in consultation with the SOH. At least 60 days notice must be provided in advance of termination.

VI. Authority:

The Work Group reports to the SOH of ACWI that operates under the Federal Advisory Committee Act. The Work Group will be subject to the direction of the SOH and will report activities to the SOH during their quarterly meetings.

Statement of Work

Issue

Storm-based precipitation is one of the major inputs to rainfall-runoff models, and is the dominant forcing variable that causes extreme floods. Data and methods for estimating extreme storms, up to and including the Probable Maximum Precipitation (PMP), are currently lacking. Currently, there is no mechanism in place within Federal Agencies to routinely collect, analyze, and archive extreme storm data that is useful for estimating extreme floods. In addition, there are no procedures in place to update storm data sets, methodology, and reports that are used to develop generalized PMP estimates. For example, the most recent PMP report was published in 1999 (Corrigan et al., 1999) and used data up to February 1986. Thus, extreme storms that caused major floods such as January 1997 in California, February 1996 in Oregon, January 1995 in Pennsylvania and rainfalls from Hurricanes Andrew (1992), Katrina (2005), Floyd (1999), and the 2008 Mid-West U.S. floods are not well-documented and not part of any storm catalog (e.g., USACE 1945-1973) or data set useful for flood estimation. Improved extreme storm estimates, including exceedance probability estimates of storm properties, can be used for dam safety assessments, nuclear power plant designs and assessments, risk analysis, and understanding extreme flood processes.

Federal Role and Responsibility

The basis for extreme storm rainfall estimates and PMP in the United States is depth-area duration (DAD) studies of notable extreme storms (e.g., USACE, 1945-; USWB, 1946). For at least the past 50 years, the U.S. Army Corps of Engineers, Bureau of Reclamation, and National Weather Service (and others) have jointly collaborated in collecting and analyzing storm rainfall data and publishing DAD data. These agencies have also collaborated in developing and improving PMP techniques. Stallings et al. (1986) describe how the cooperative studies evolved. Hansen (1987) provides a review and summary of the PMP methods that are in current use.

Federal agencies have pioneered the development of PMP and its usage for designing and assessing large dams and other structures such as nuclear power plants in the United States. In particular, the Bureau of Reclamation, Corps of Engineers and Tennessee Valley Authority own and operate many of the largest and highest hazard dams in the United States. For example,

these include the Columbia River system, Upper and Lower Colorado River systems, the Tennessee Valley system, and many dams on the Missouri River and Ohio Rivers. A Federal role is required in defining and developing extreme storm techniques, up to and including PMP, for assessing these large Federal water projects using PMP and other extreme storms. In addition, the Federal Energy Regulatory Commission has a unique role as the regulatory body of non-Federal dams that produce hydropower in the United States. FERC has adopted PMP and the Probable Maximum Flood (PMF) as the base standard for assessing high-hazard dams that it regulates (FERC, 2001), similar to the Bureau of Reclamation (Cudworth, 1989) and Corps of Engineers (USACE, 1991). The current Federal guidelines for dam safety (FEMA, 1998) define PMP and its use.

Extreme Storm DAD Data

The DAD data and PMP methods are used to provide "generalized" PMP estimates over large regions of the United States (Figure 1). The PMP estimates have been published in Hydrometeorological Reports (HMRs) (Table 1).

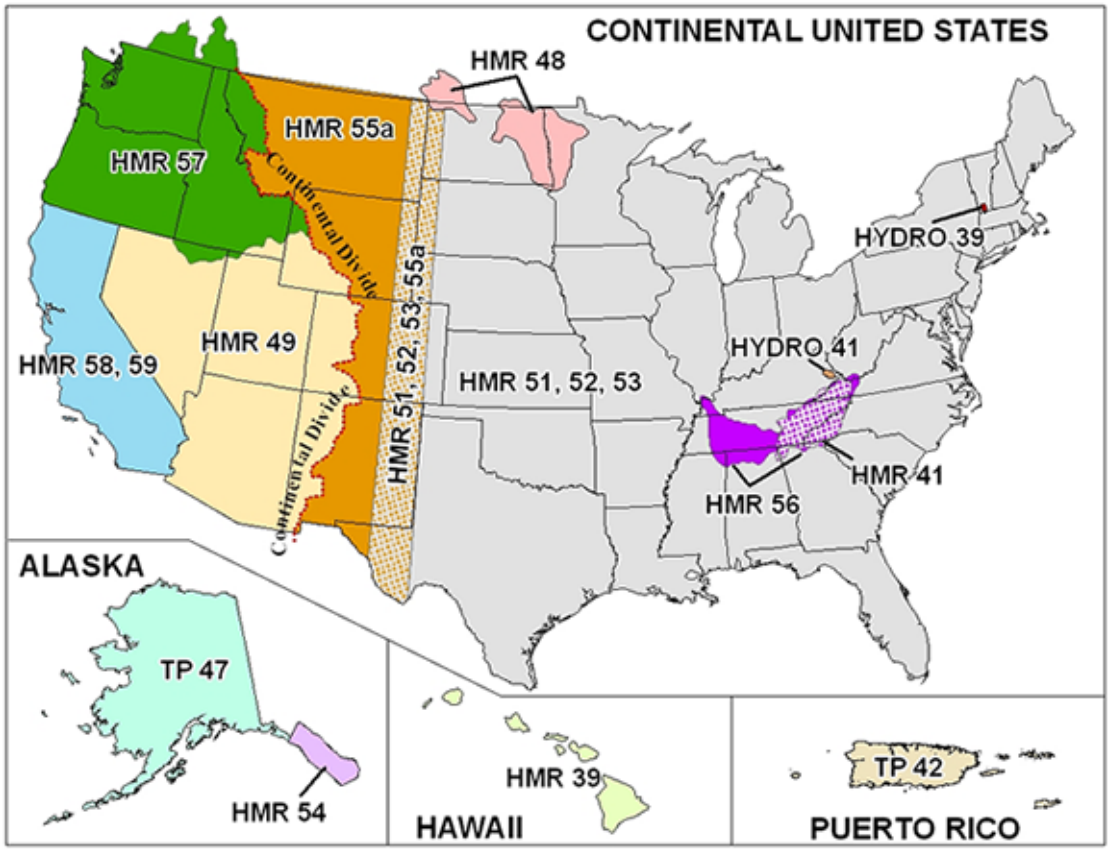

Figure 1. Regional coverages of generalized PMP reports in the United States (from NOAA/NWS Website: http://www.weather.gov/oh/hdsc/studies/pmp.html).

Table 1: Status summary of Hydrometeorological Reports (focus here is on larger generalized reports; for full listing of all HMR see: http://www.weather.gov/oh/hdsc/studies/pmp.html)

HMR No.	Publication Date	Latest Storm Used	Comments
49	1977	Sept. 3-7, 1970	see HMR 50 (Hansen and Schwarz, 1981) for storm info; 1983 Prescott, AZ storm exceeds PMP (Leverson, 1986)
51	June 1978	June 19-23, 1972	Replaced HMR 33 (1956)
55A	June 1988	Aug. 1-4, 1978	Replaced HMR 55 (1985) and TP 38 (1960)
57	October 1994	Dec. 24-26, 1980 (general) Aug. 16, 1990 (local)	Replaced HMR 43 (Nov. 1966)
59	February 1999	Feb. 14-19, 1986	Replaced HMR 36 (Oct. 1961)

Other than the storms used in the HMRs, little to no storm data have been collected and analyzed for regional or generalized PMP estimates. Some limited extreme storm data have been collected and summarized for some states (e.g. McKee and Doesken, 1997; Lanning-Rush et al., 1998) and by some consultants for site-specific PMP work. However, these data sets have not been analyzed for use in a larger region or for application to multiple structures. The data in Table 1 indicate that there is a definite need for storm data collection. There is also a lack of major storm data within an existing HMR (Figure 2, HMR 55A). There are several limitations noted in the HMRs on providing space-time estimates of PMP, especially within orographic areas. Unlike the procedures in HMR 52 (Hansen et al., 1982), there are no methods for spatially and temporally distributing PMP over a watershed for locations other than the eastern United States.

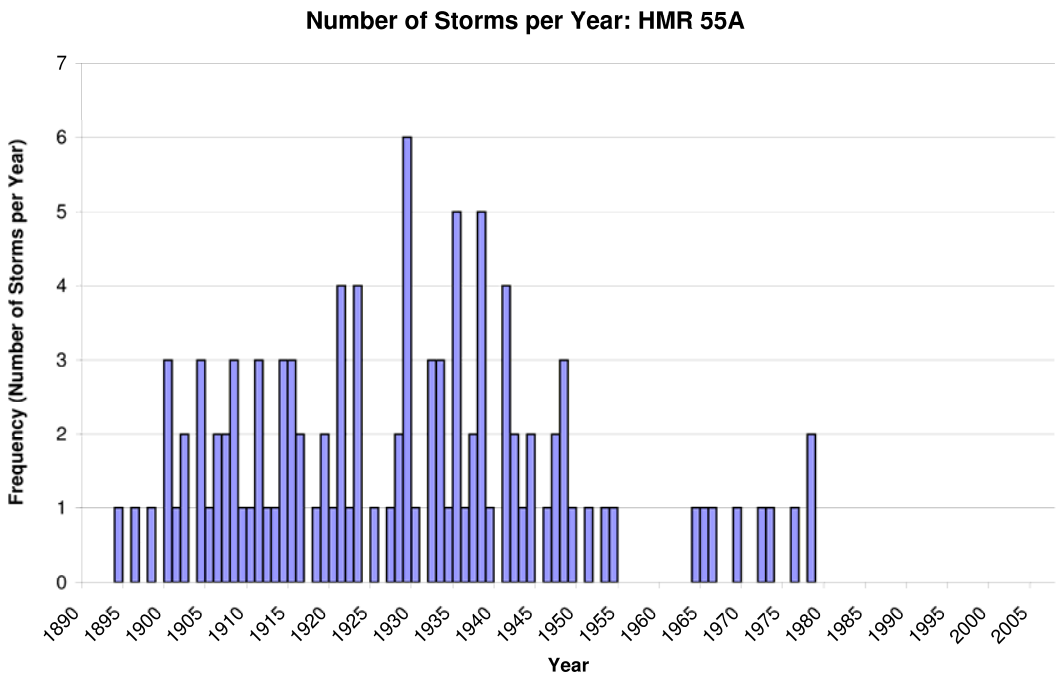

Figure 2. DAD data considered in developing PMP (HMR 55A), expressed as number of storms per year. Please note the lack of data in the 1960s and post 1978.

Problem Statement and Need

The Hydrometeorological Reports that form the basis for generalized probable maximum precipitation estimates rely on data that does not include the large storms that have occurred in the last 20 to 40 years. This creates a need to supplement these reports with site-specific analyses to incorporate the largest storms that have occurred in a particular region. Site-specific storm studies to date are done typically on an ad-hoc, individual dam or structure basis. The full benefits of these studies are not materialized, because there is no central archive for the documentation, storage, and sharing of extreme storms and related analyses. The extreme storm catalog should be expanded to include recent storms, and the HMRs should be updated to include the latest data.

An updated storm catalog is required to estimate the rainfall magnitude and spatial and temporal storm characteristics for various watersheds throughout the United States. Many agencies are using this information to develop extreme storm rainfall estimates for risk assessment and to determine the maximum flood potential at a particular location. Most of the storm information included in the extreme storm catalog was derived from published sources and supplemented with bucket survey information. Bucket surveys were used to get better definition of the rainfall magnitudes near the storm centers. Budget constraints have eliminated collection of bucket survey data in the past 20-30 years. Recent advances in use of radar reflectivity data should be examined as a source of information to supplement published rainfall data to expand the extreme storm catalog.

Many recent precipitation studies have used computer models to examine extreme storms. The HMRs use storm transposition and maximization techniques for determining generalized PMP estimates. These techniques should be compared against available computer modeling approaches that have been more recently developed. The advantages and disadvantages of each approach should be considered to determine the most appropriate approach for use in estimating extreme floods and to estimate the uncertainty in the estimates (NRC, 1994).

Impacts and Applications

The proposed studies impact extreme flood estimates and assessments for dams, nuclear power plants, levees, and other high-hazard structures within the United States. The investigations also complement ongoing rainfall frequency studies and mapping efforts by the National Weather Service. Without these studies, engineering planning and design costs will increase due to the need for site-specific studies because generalized approaches are outdated.

Work Group Tasks

1. Solicit Work Group membership from Federal and state agencies, universities (e.g. Bill Cotton, Colorado State University; Jim Smith, Princeton), professional organizations (e.g., AMS, ASCE) and others with expertise in hydrometeorology, including consultants (e.g. Mel Schaefer, MGS Engineering; Ed Tomlinson, AWA), and Federal and other labs (e.g. NOAA-NSSL, NOAA-ESRL, NCAR, etc.). Elect a chair and vice-chair.
2. Perform a literature review. Investigate improvements to methodologies (NRC, 1988; NRC, 1994; NRC, 2005; Cotton et al., 2003) and data collection techniques.
3. Develop a detailed scope of work/plan of study, and determine the necessary funding requirements to accomplish the work. Develop a long term plan to update the extreme storm catalog and HMRs for estimating PMP. Consider use of new technologies for storm analysis and data collection and dissemination. List possible approaches for acquiring funding to implement the plan.
4. Develop a list of individual Federal agency needs.
5. Inform the SOH and ACWI of the present state of Federal funding support, and the need to develop future budget support for long-term cooperative efforts to: maintain extreme storm databases; periodic review and updating of HMR's and the Catalog of Extreme Storms; development of site-specific studies of PMP and extreme storm event contributions to flooding, and support dam safety and nuclear facility installation evaluations.
6. Consider sponsoring an extreme storm workshop or specialty conference (e.g. at AMS, AGU, ASCE, etc.).

Identification of Federal Agency Needs and Support:

Bureau of Reclamation

Reclamation's Dam Safety Program mission is "To ensure that Reclamation dams do not present unacceptable risks to people, property, and the environment". As the owner of over 350 high- or significant-hazard storage dams in the western U.S., Reclamation is committed to providing the public and the environment with adequate protection from the risks that are inherent in collecting and storing large volumes of water. Traditional design and analysis methods have focused on selecting a level of protection based on spillway evaluation flood loadings, which were usually based on the Probable Maximum Flood (PMF). Many factors influence the ultimate magnitude of the PMF hydrograph, but the intensity and duration of the rainfall are the most important. Considerable analysis and discussion of the derivation and application of PMP estimates has taken place in the past. In 1981, Reclamation, the National Weather Service, and the U.S. Army Corps of Engineers adopted a mutually acceptable, uniform definition of the widely used term PMP. The PMP, as defined by these three agencies at that time, is "theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location at a certain time of the year." PMP must always be termed as an estimate because there is no direct means of computing and evaluating the accuracy of the results. Since the mid-1980s, Reclamation has considered that the series of HMRs prepared and updated by the National Weather Service provide the best estimates of PMP potential within the limits of each report. The Bureau of Reclamation uses PMP estimates obtained from the NWS HMRs in order to compute PMFs for dam safety. Reclamation uses the PMF as the upper limit of flood potential at a site for storm durations defined by the PMP. Because of this, Reclamation has a strong interest in updating extreme storm data sets and methods used in HMRs, and to assist in updating the HMRs.

Since 1995, Reclamation has used a risk assessment process to determine an appropriate level of public protection by evaluating a full range of loading conditions and possible dam failure consequences. This is in contrast to the traditional approach of using upper bound events such as the PMF, without regard to their likelihood of occurrence and without assessment of their incremental consequences. The ideal flood inputs required for risk analysis are frequency distributions of peak flows, volumes, and peak reservoir stages which, for dams with potentially high loss of life, might extend to very low exceedance probabilities.

In order to make these extreme flood risk estimates, Reclamation has a need for extreme storm rainfall frequency estimates, including point rainfall frequency, basin-average rainfall depth frequencies and extreme storm models, up to and including PMP. Much of the applied work in this area to date is in its infancy as applied to extreme flood and dam safety problems. Reclamation supports developing an interagency group on extreme storms to help fulfill PMP and extreme storm probability needs. Some specific areas that are of interest to Reclamation are: updating HMR 49; developing a coupled radar and extreme storm catalog in the western United States; developing spatial and temporal storm patterns for PMP in the western U.S. (like HMR 52 for Eastern U.S.); linking regional L-moments statistical techniques with PMP; and developing and testing space-time extreme storm probability models and concepts such as stochastic storm transposition.

U.S. Army Corps of Engineers

The US Army Corps of Engineers (USACE) is committed to insuring that its dams can safely pass the largest meteorological events possible. USACE regulations require the use of the most recent hydrometeorological studies available for general studies and requires Site Specific studies be developed for unusual conditions or that are thought to need additional refinement beyond the general studies to define specific drainage basins.

It is well recognized that large dam construction in the U.S. is not a high priority mission area at this time. However, USACE is intensely involved in assessing their existing dams for safety and reliability. To properly convey the hydrologic risk associated with each dam, USACE must first be able to determine if each dam can safely pass the Probable Maximum Flood (PMF). Many USACE dams were constructed prior to establishment of Probable Maximum Storm (PMS) data as presented in Hydrometeorological Reports (HMR). Others were constructed in areas were historic data was too limited to expect reasonable HMR results. Therefore, these studies must be revisited and updated as applicable new data becomes available.

The Corps will continue the requirement to use the most accurate and up-to-date HMR studies to properly evaluate their existing portfolio of over 600 dams or to properly design any new dams. USACE has historically been dependant on the NWS to provide accurate and unbiased estimate of PMS through HMR studies as well as Site-Specific Studies since the 1950's. USACE will support SOH to the extent possible in establishing a work group to insure that interim and long term measures are taken to complete required extreme event needs in the future. USACE will attempt to secure personnel and/or funding to support the work group as necessary to at least provide updates or coverage of the Continental U.S. and it Territories.

Federal Emergency Management Agency

FEMA supports the establishment of the Extreme Storm Events Work Group as part of the Subcommittee on Hydrology (SOH) of the Advisory Committee on Water Information (ACWI). The primary mission of the Federal Emergency Management Agency is to reduce the loss of life and property and protect the Nation from all hazards, including natural disasters, acts of terrorism, and other man-made disasters, by leading and supporting the Nation in a risk-based, comprehensive emergency management system of preparedness, protection, response, recovery, and mitigation. For more than 25 years, the Federal Government has been working to protect Americans from dam failure through the National Dam Safety Program (NDSP). The NDSP, which is led by FEMA, is a partnership of the states, federal agencies, and other stakeholders to encourage individual and community responsibility for dam safety.

As a member of the proposed Extreme Storm Events Work Group, FEMA will participate in reviewing proposed methodologies and data collection techniques used to develop design precipitation estimates of large storm events up to and including the Probable Maximum Precipitation (PMP). Support for research on hydrometeorology related to dam safety is also available from FEMA in a limited capacity, through the NDSP.

Federal Energy Regulatory Commission

The Federal Energy Regulatory Commission (FERC) is responsible for the safety and adequacy of 2523 non-Federal, jurisdictional dams. The Commission, through its dam safety program requires regulated dams to have adequate spillway capacity to pass the project's Inflow Design Flood (IDF). The IDF is the flood flow above which the incremental increase in flow and water surface elevation due to a failure of a dam or other water impounding structure is no longer considered to present an additional, unacceptable threat to downstream life or property. The PMF is the upper limit of the IDF analysis. Thus the Commission has an interest in any coordinated effort to review extreme storm data and update HMR's for use in extreme storm development. Currently the engineering profession is developing PMF values for extreme storm events based on outdated storm information. The Commission supports the efforts of the Extreme Storm Events Work Group to promote the cooperation and coordination among agencies to improve methodologies and data collection techniques to develop estimates of large storm events up to and including the Probable Maximum Precipitation (PMP).

U.S. Nuclear Regulatory Commission

To comply with U.S. Nuclear Regulatory Commission (NRC) requirements, applicants for new nuclear plants must demonstrate the ability of their proposed facilities to withstand the Probable Maximum Flood (PMF). This demonstration is scrutinized by the NRC internally and through a public review process. To assist in this effort, the NRC Staff is updating technical guidance on "Design Basis Floods for Nuclear Power Plant Sites" as documented in Regulatory Guide 1.59 (RG 1.59). This guidance provides information for evaluating conditions resulting from the worst site-related flood probable at a nuclear power plant [e.g., PMF, seismically-induced flood, hurricane, seiche, surge, heavy local precipitation] with attendant wind-generated wave activity. These events and their resulting conditions constitute the design basis flood that safety-related structures, systems, and components identified in NRC regulatory guidance must be designed to withstand.

A key input to the determination of the PMF for a particular reactor site is the Probable Maximum Precipitation (PMP) for the hydrologic unit within which the nuclear power plant is to be located. Many extreme storm events have occurred since the issuance of Revision 2 to RG 1.59 in 1977, and they need to be evaluated in updating regulatory guidance. The NRC Staff needs to review and update its technical bases, specifically NOAA's HydroMeteorological Reports (HMR) for estimating PMP for specified areas, durations and seasonal variations. The NRC Staff intends to support Federal Interagency efforts to update these reports. These updates will provide the technical basis for the NRC to develop guidance for license applicants on acceptable methods and data sources for estimating and using PMP to calculate Probable Maximum Floods.

The NRC has proceeded to begin funding Interagency Agreements with other Federal agencies to acquire the latest knowledge and data on PMP and extreme storm events. Currently these research studies focus on updating HMR 52 since most of the proposed new plants are in the southeastern U.S. This effort should be incorporated into the proposed standing Work Group on Extreme Storm Events of the Subcommittee on Hydrology.

U.S. Geological Survey

The Mission of the U.S. Geological Survey (USGS) is to provide reliable, impartial, timely information that is needed to understand the Nation's water resources. The USGS maintains a leadership role in the development and application of techniques for analysis of flood frequency, hydrologic and water-quality trends, regionalization, and geomorphologic response. The accurate regional and temporal characterization of extreme precipitation is essential to this work. Precipitation is the starting point for many hydrologic models and analytical tools for the analysis of precipitation intensities and distributions are closely allied with those used in analysis of flood and flow-duration frequencies. Innovations in one sphere can lead to new developments in the other. Hence, the USGS supports the establishment of the Extreme Storm Events Work Group, commits to participating in its advisory and coordination activities, and will aide the development and testing of methods and protocols developed under its purview.

National Hydrologic Warning Council

The National Hydrologic Warning Council (NHWC) has an explicit interest in the activities of the Task Force on Extreme Storm Events. The importance of the use of Probable Maximum Precipitation (PMP) and corresponding Probable Maximum Flood (PMF) estimates in the design of major reservoirs has long been established. NHWC members and affiliates do operate reservoirs. Consequently, we are most interested in the impacts of any proposed changes to design and safety standards for dams. We are also concerned with reducing the potential for injuries, deaths, and property damage caused by floods. One way to accomplish this goal is by effective use of community-based flood warning systems. Our annual conferences afford an opportunity to be aware of all of the latest developments associated with early flood detection and warning systems. The NHWC maintains a close association with private sector venders, consultants, and government agencies involved with the business of flood warning systems. However, the NHWC is newly formed and currently unable to support Task Force activities financially.

Natural Resources Conservation Service

The United States Department of Agriculture's Natural Resources Conservation Service (NRCS) is active in the construction and rehabilitation of small dams which are or were constructed under various programs administered by the NRCS.

The dam design criteria utilized by NRCS (Technical Release No. 60), specifies use of Probable Maximum Precipitation (PMP) estimates obtained from the National Weather Service's Hydrometeorological Reports (HMRs), or ratios of the PMP storm events, to hydrologically size dams and other hydraulic control structures in order to convey large storm events safely for the protection of property and people living downstream of such dams. The HMRs currently in use were developed in the 1950's and few updates have occurred since that time. Since then, additional large storms have occurred which should be factored into the PMP analysis and technological advancements have occurred which should be incorporated into PMP analysis procedures.

NRCS supports the establishment of an Extreme Storm Events Work Group as part of the Subcommittee on Hydrology (SOH), a subcommittee of the Advisory Committee on Water Information (ACWI). NRCS commits to work group participation; serving as advisors to the work group; and assisting with the assessment and review of data collection techniques and potential methodologies for analyzing PMP.

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Additional information sources are:

Links to NWS Sites on Precipitation Analyses:

Precipitation Frequency Data Server (PFDS) (http://hdsc.nws.noaa.gov/hdsc/pfds/)

Probable Maximum Precipitation (PMP) Documents (http://www.nws.noaa.gov/ohd/hdsc/studies/pmp.html)