NRR-PMDAPEm Resource

From: Kuntz, Robert
Sent: Monday, September 08, 2014 3:10 PM
To: RILEY, Jim (jhr@nei.org)
Cc: Whaley, Sheena; Cook, Christopher
Subject: NRC Comments on NEI white paper regarding warning time for LIP event
Attachments: Warning Time for Extreme Precipitation Events (NWS Protocol) Rev2 9-8-14 with NRC comments.pdf

Jim,

Attached are the NRC staff's comments on NEI's LIP warning time white paper. If you have any questions let me know.

Robert Kuntz
Sr. Project Manager
NRR/JLD/JHMB
(301) 415-3733

Hearing Identifier: NRR_PMDA
Email Number: 1552

Mail Envelope Properties (Robert.Kuntz@nrc.gov20140908150900)

Subject: NRC Comments on NEI white paper regarding warning time for LIP event
Sent Date: 9/8/2014 3:09:35 PM
Received Date: 9/8/2014 3:09:00 PM
From: Kuntz, Robert

Created By: Robert.Kuntz@nrc.gov

Recipients:
"Whaley, Sheena" <Sheena.Whaley@nrc.gov>
Tracking Status: None
"Cook, Christopher" <Christopher.Cook@nrc.gov>
Tracking Status: None
"RILEY, Jim (jhr@nei.org)" <jhr@nei.org>
Tracking Status: None

Post Office:

Files	**Size**	**Date & Time**
MESSAGE	214	9/8/2014 3:09:00 PM
Warning Time for Extreme Precipitation Events (NWS Protocol) Rev2 9-8-14 with NRC comments.pdf	937222	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

Warning Time for Maximum Precipitation Events

Rev 1a, 8-14-14

1.0 Introduction

Local Intense Precipitation (LIP) is a maximum precipitation event postulated using synthetic storms which can project rainfall in excess of 19 inches for 1-hour over 1-mi^2. If a nuclear site's protection is not permanent and passive, a rainfall event of this magnitude may require actions to be taken prior to the storm to protect or mitigate flooding impacts on required Systems, Structures and Components (SSC's). As such, warning time is a key component in the planned response to the LIP rain event.

Despite improvements in forecasting accuracy of precipitation, the present state of the meteorological science's tools and techniques are not able to accurately predict LIP events explicitly in time and space (Ralph et al. 2010, Olson et al 1995). This is due in part to limitations in weather model capabilities and also due to the limited frequency of extreme precipitation events. Yet, despite these limitations, forecasting tools are available to detect the conditions conducive for extreme events to provide lead time to implement mitigation actions ahead of the occurrence of an LIP. Recognizing the limitations in forecasting accuracy for extreme events, methods to establish warning time for maximum precipitation events are based on:

1. Recognition that maximum precipitation events that produce LIP level rainfall require both substantial atmospheric moisture and a sustained atmospheric lifting mechanism which can be recognized and anticipated.
2. Setting warning thresholds conservatively based on less extreme (and more predictable) storms to assure that active protection or mitigation can be executed prior to consequential flooding.
3. Including additional conservatism to compensate for forecasting uncertainty by setting monitoring and trigger thresholds that are a fraction of the LIP precipitation level that would result in consequential flooding.

Using existing forecasting tools and addressing known forecast limitations with conservative measures to compensate for uncertainty can provide a reliable warning time to implement active defenses for LIP maximum precipitation events.

Comment [NRC1]: Suggested revision to text:

Local Intense Precipitation (LIP) is a hypothetical locally heavy rainfall event that is used to design flood protection features and/or procedures. LIP is typically assumed to be equivalent to the local probable maximum precipitation (PMP) derived from National Weather Service (NWS) Hydrometeorology Reports (HMRs) or from a site-specific PMP study. LIP estimates derived from the HMRs can, in some locations, project rainfall in excess of 19 inches for 1-hour over 1-mi^2.

Comment [NRC2]: Suggested wording change: The NRC defines the abbreviation SSC to mean structure, system, and component (note word order).

Comment [NRC3]: Accuracy does not appear to be defined in this paper. Since the topic is quantitative precipitation forecasting (QPF), it should be unequivocally defined and discussed.

Comment [NRC4]: Suggest including Sukovich et al. 2014 here too.

Comment [NRC5]: This point was raised by NRC staff during the public meeting discussion of the first draft of this paper. The NRC staff was expecting to see more discussion of this idea and see how it might be factored into warning time determination. As written this revised version the paper introduces the idea with the highlighted statement, but does not develop the idea. It does not show up anywhere else in the paper.

Comment [NRC6]: The definition or quantification of reliable" is unclear. Consider defining.

Comment [NRC7]: Minor terminology comment: JLD-ISG-2012-05 defines the following:

- *Active (flood protection) feature*: An incorporated, exterior, or temporary flood protection feature that requires the change of a component's state in order for it to perform as intended. Examples include sump pumps, portable pumps, isolation and check valves, flood detection devices (e.g., level switches), and flood doors (e.g., watertight doors).
- *Passive (flood protection) feature*: An incorporated, exterior, or temporary flood protection feature that does *not* require the change of state of a component in order for it to perform as intended. Examples include dikes, berms, sumps, drains, basins, yard drainage systems, walls, removable wall and roof panels, floors, structures, penetration seals, temporary watertight barriers, barriers exterior to the immediate plant area that is under licensee control, and cork seals.

Therefore, plant response to LIP events may include more than just "active defense."

2.0 Basis for Local Intense Precipitation (LIP) Maximum Precipitation Events

LIP events that are determined using NUREG/CR-7046 are based on the 1-hr, 2.56-km2 (1-mi2) Probable Maximum Precipitation (PMP) at the location of the site. Some sites may assume longer duration events based on their location, however such an analysis still includes a maximum 1 hour rainfall within the assumed duration. NUREG/CR-7046 recommends the use of the most recent hydrometeorological (HMR) report unless an approved site-specific HMR or PMP study is available. PMP is defined as, "theoretically the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of the year" (Hansen et al., 1982). For most nuclear sites east of the 105th meridian, the current HMR's are: HMR-51 (all season PMP values), HMR-52 (application guidance), and HMR-53 (seasonal guidance).

3.0 Sources of Maximum Precipitation Events

The highest recorded worldwide one hour rainfall event is 15.79" in Shangdi, Inner Mongolia, China in 1975. The highest recorded 1 hour rainfall event in the U.S. is 12" in Holt, Missouri in 1947. These record storms are significant but still less than the 19" maximum precipitation 1 hour storm predicted by HMR-52. Storms that have the potential to deliver rainfall that approaches or exceeds world record rainfall would be detectable in advance with current forecasting methods/models based on the anomalously large amount of moisture and level of atmospheric instability (lift) required to generate precipitation of this magnitude. Because of the short duration of sustained lift, lack of moisture, and transient nature, individual air mass (isolated) thunderstorms do not have the capacity to produce LIP magnitude rainfall.

Comment [NRC8]: Suggested rewording:

"NUREG/CR-7046 recommends that LIP events can be based on the 1-hr, 2.56-km2 (1-mi2) Probable Maximum Precipitation (PMP) at the location of the site. Some sites may need to consider longer duration events if they result in higher water level elevations than the 1-hr event. However such an analysis, if performed, should still include a maximum 1 hour rainfall within the assumed duration."

Comment [NRC9]: Consider rewording to clarify that this is meant to indicate the watershed for the site. The staff is not aware of site specific HMRs, but believes the author is referring to regional HMRs.

Comment [NRC10]: As discussed in the public meeting, this statement needs clarification. The Holt MS storm produced 12" over a 42 minute duration. The NWS reports that the U.S. 1-h rainfall record is 13.8" (estimated) during the August 1943 Burnsville, WV storm. Also please provide a source for these events.

Comment [NRC11]: **Technical issue:** This sentence appears to be trying to "put the HMRs in context." However, when doing this, it is important to note that, in any given severe rainfall event, it is unlikely that the most severe rainfall will occur at the specific location of a gauge in a sparse network (i.e., it is unlikely that the largest rainfall will actually be recorded). This is particularly true of historic events. Therefore, considering only recorded events to be a reflection of the possible (and actually occurring) large rainfall events can be misleading.
It is also noted that Harrison (2006) has shown that there are several instances in which PMP has been exceeded by or are very close in magnitude to observed events.
Ref: J. Harrison, "Extreme Events: Graphs, Photos, Videos," in *Dam Safety 2006: Proceedings of the 2006 Annual Conference of the Association of State Dam Safety Officials*, Lexington, KY, September 10-14, 2006.

Comment [NRC12]: **Technical note:** Even if large rainfall events of the magnitude of the PMP can be detected, it is important to note that smaller rainfall events may still be consequential to the site and are not easy to predict.

Comment [NRC13]: Suggested rewording: Replace with "are is not likely"

Comment [NRC14]: (1)Consider addressing whether or not an isolated thunderstorm could still be consequential (as discussed in Section 52) even if they do not produce a LIP magnitude rainfall.
(2)Consider introducing a discussion on, the notion of LIP vs. consequential events earlier in this paper.
(3)NRC staff does not categorically rule it out unless one has a study or paper that can be cited.

Storms that have the potential to produce LIP magnitude events would be detectable in advance utilizing current forecasting methods/models. The large weather systems capable of producing LIP rainfall include:

- Tropical Systems
- Synoptic Storms
- Mesoscale Convective Complexes (Organized Thunderstorms)

The three basic storms types (including combinations of these storms) that could lead to LIP magnitude events are briefly described below along with a discussion of the contribution of orographic effects.

3.1 Tropical Systems

This storm type includes warm core systems with origins over the tropical waters of the Atlantic Ocean or Gulf of Mexico (including the Caribbean Sea). It should be noted that in extremely rare occasions modified tropical cyclones have made landfall over California and far southern Arizona. This storm type can produce PMP and LIP level rainfalls in these locations in a modified form where the storm has begun to transition into an extra tropical storm. High levels of tropical atmospheric moisture can produce extreme rainfall, especially when enhanced by convection/thunderstorms and slow movement.

Forecasting the track, intensity, storm surge, and potential rainfall accumulation associated with a tropical system has improved in recent years (Needham and Keim, 2014). This has allowed lead times of forecast tracks to extend out 5-7 days. In all cases, as the time of potential landfall approaches, the forecast track and rainfall amounts become more refined. Three days out, the accuracy of these forecast has become more certain with increasing accuracy each day until event occurrence.

3.2 Synoptic Storms

This storm type includes large scale frontal systems created by the interface between contrasting air masses. Synoptic storms can occur at any location across North America. These occur most often in the winter along the Gulf Coast and southern/mid-Atlantic region and along the West Coast. This pattern shifts northward through the spring and summer, before shifting south again in the fall. This is directly related to the climatologically preferred region of the jet stream (polar and sub-tropical). Synoptic storms are not typically capable of producing LIP level rainfall. However, the frontal systems associated with synoptic storms can include imbedded convection in the form of thunderstorms. These thunderstorms when related to strong synoptic scale events like deep mid-latitude low pressure systems or intense cold fronts can produce heavy rainfall due to atmospheric instability and dynamic lifting. In rare cases rainfall amounts associated with this form of large scale frontal systems with embedded thunderstorms could produce a LIP event if the system moves slower than normal, especially if there is some additional form of topographic or synoptic enhancement to the updraft. This storm type can also produce PMP level rainfalls for locations where a 24-hour or longer event and 500-square mile or larger basin affects a given site.

Forecasting the location, movement, and potential rainfall accumulation associated with synoptic storm systems has improved in recent years with the advancement of Numerical Weather Prediction. This has allowed lead times of forecast to extend out 5-7 days. In all cases, as the time of the potential storm affecting a given location comes closer, the forecasted movement and rainfall amounts become more refined. Within 3 days, the accuracy of these forecasts has become more certain, increasing each day until event occurrence.

Comment [NRC15]: **Technical issue:** See earlier comments regarding distinguishing between LIP and potentially more limiting consequential events. It is not clear that consequential events are limited to these types of systems. Therefore, limiting the discussion is in the paper to these types of events may be misleading.

Comment [NRC16]: Consider identifying examples of specific tropical cyclones that have made landfall in this area.

Comment [NRC17]: The citation provided does not appear to discuss the information cited in this entire paragraph. The cited paper is a study of correlations between storm surge height and winds before and at landfall. Forecasting accuracy/reliability for storm track and rainfall are not mentioned or cited in the paper and thus the conclusion in the paper regardng lead times of forecasted tracks should be referenced.

Comment [NRC18]: **Technical issue:** Note earlier comments regarding the importance of distinguishing between LIP level and potentially more limiting consequential events.

Comment [NRC19]: **Terminology question:** What is the threshold for "rare"?

Comment [NRC20]: Reference(s) needed for this section. Although the cited lead-times may be accurate for the storm in general, it is the timing and location of the most intense portions of the storm that is important for LIP. That important distinction should be made here.

Remnants of tropical storms can interact with synoptic storms, especially slow-moving storm systems, and produce large amounts of rainfall. PMP level rainfalls are possible in these situations. The weather forecasting community including the NWS has long recognized this set-up as a "classic" heavy rainfall and flooding situation and therefore anticipates these events well in advance with current forecasting models.

3.3 Mesoscale Convective Complexes

A Mesoscale Convective Complex (MCC) is an organized group of thunderstorms over a spatial scale larger than individual thunderstorms, but smaller than synoptic-scale storm systems. These systems can occur at any location across North America, but is much more likely in regions away from the stabilizing effects of the cool waters of the Pacific Ocean. These storms are most common in the spring through early fall, though they are possible in the winter months as well. MCC development is directly related to availability of atmospheric moisture which is usually supplied by a low-level jet stream feature and excessive lift through a significant portion of the atmospheric column (instability). The atmospheric lift is enhanced through thermodynamic or dynamic processes or a combination of both. Typically, these systems move quickly, helping to limit extreme rainfall amounts. However, this storm type can produce rainfall that can approach LIP levels. Excessive amounts of rainfall associated with MCCs will most typically occur when the system is moving very slowly producing large amounts of rainfall within heavy downpours.

Forecasting the location, movement, and potential rainfall accumulation associated with a MCC has also improved with the advancement of Numerical Weather Prediction. This has allowed lead times of forecast to extend out 3-5 days. In all cases, as the time of potential storm affecting a given location comes closer, the forecasted storm movement and rainfall amounts become more refined. Within 3 days, the accuracy of these forecasts has become more certain, increasing in accuracy each day until event occurrence. The parameters and physics involved in producing the model forecasts in the Numerical Weather Prediction are designed to best represent average or historical conditions.

3.4 Orographic Effects

Orographic effects can mechanically produce the constant atmospheric lift to generate extreme precipitation in the absence of a synoptic scale event or mesoscale convective forcing. This occurs when terrain (e.g. located in or near mountainous regions) serves as an immovable source of lifting which is the key in enabling an extreme precipitation scenario. Examples where strong orographic lift contributed to three extreme MCC precipitation events include Smethport, PA - 1942, Central West Virginia – 1943, and Simpson KY – 1939. Orographic effects have the potential to reduce warning time.

4.0 NOAA/National Weather Service Severe Weather Forecasting and Notification Tools – The National Weather Service (NWS) has central national monitoring and local branches that monitor developing weather conditions to detect and provide warning for severe weather prior to its arrival. There are a number of different forecasting tools and services for severe rain events provided by the NSW. The skill levels (accuracy of the prediction) and the information provided vary depending on the tool. The recommended tool for a warning time trigger is a quantitative precipitation forecast which provides a specific amount of rain for a given time period. Additional tools are also discussed below which can be used to provide supporting information on the basis for the rainfall amount being forecasted.

4.1 Excessive Rainfall Forecast - The NWS **Weather Prediction Center (WPC)** mission is to forecast the potential for significant weather events dealing with heavy rainfall or snowfall, to discuss precipitation forecasts and model differences relating to general weather and precipitation

Comment [NRC21]: What criteria is used to determine when lift is "excessive"?

Comment [NRC22]: This seems to suggest that the predictions are better for the "average" type of events but not as successful for more rare or extreme type events. If this is the case, then the text should clearly reflect this distinction.

Comment [NRC23]: Same comment as before. Generally true statements about storms, but not necessarily for the timing and location of the most intense rainfall.

Comment [NRC24]: It is unclear what the author means by defining "skill level" in this manner. A suggested alternative:

The accuracy of predictions and the kind of information provided will vary from one tool to another.

Comment [NRC25]: Consider adding any available outlook products for conditions conducive to heavy rainfall

forecasts. The WPC issues several focusing tools such as: Quantitative Precipitation Forecasts (QPFs), Probabilistic Quantitative Precipitation Forecasts (PQPFs), and Excessive Rainfall Outlooks.

The WPC short range meteorologist prepares 6 through 60 hour forecasts for the continental U.S. These products are issued twice daily using numerical model output from the National Weather Service's (NWS) Global Forecast System (GFS) and North American Mesoscale model (NAM). Coordination with the surface analysis, model diagnostics, quantitative precipitation, winter weather, and tropical forecast desks is also performed during the forecast process. The short range forecast products include surface pressure patterns (isobars), circulation centers and fronts for 6-60 hours, and a depiction of the types and extent of precipitation that are forecast at the valid time of the chart. The primary goal is to depict accurately the evolution of major weather systems that will affect the continental U.S. during the next 60 hours. In addition, discussions are written on each shift and issued with the forecast packages that highlight the meteorological reasoning behind the forecasts and significant weather across the continental United States. Precipitation levels are not included on the 60-hour forecast chart

4.1.1 Quantitative Precipitation Forecasts (QPF) – QPF's depict the amount of liquid precipitation expected to fall in a defined period of time. In the case of snow or ice, QPF represents the amount of liquid that will be measured when the precipitation is melted. Precipitation amounts can vary significantly over short distances, especially when thunderstorms occur,. For this reason QPFs issued by the WPC are defined as the expected "areal average" (on a 20 x 20 km grid) in inches. Methods for producing QPFs are similar to other meteorological forecasts. First, meteorologists analyze the current state of the atmosphere. Then they use model forecasts of pressure systems, fronts, jet stream intensity, etc., to form a conceptual model of how the weather will evolve. The WPC has unique access to the full suite of operational and ensemble model guidance from modeling centers in the U.S., Canada, and Europe (the foreign models are global models, so they also make predictions over the U.S.). The WPC stores output from several consecutive runs of all of these models, allowing for trend analysis of model QPFs.

> **Comment [NRC26]:** **Clarification request:** It would be helpful to provide examples of the defined time periods considered and discretization. This request is made because some licensees have set "triggers" for flood protection actions that look like "x inches in y hours" but the staff is not aware of NWS tools that produce such a forecast.

WPC forecasters often engage in discussion with the local National Weather Service Forecast Offices (122 locations), River Forecast Centers (12 locations) in the Continental United States), and other national centers such as the Storm Prediction Center and National Hurricane Center. The WPC provides the rainfall forecast (known as a rainfall statement) that the National Hurricane Center inserts into each tropical cyclone advisory it issues. The WPC is also co-located with NOAA's National Environmental Satellite, Data, and Information Services (NESDIS) Synoptic Analysis Branch (SAB). The SAB provides information on satellite trends which helps refine short range QPFs. Together, the SAB and Day 1 QPF desk at the WPC are known as the National Precipitation Prediction Unit (NPPU). This collaborative process makes WPC forecasts generally more accurate than any individual model.

> **Comment [NRC27]:** **Technical note:** While it is helpful to know that the collaborative process improves accuracy, the text still does not address the actual accuracy (e.g., accuracy may be improved through the collaborative process, but the overall accuracy may still be relatively low).

The QPF contours (isohyets) are drawn to encompass areal average amounts of 0.01, 0.25 inch, 0.50 inch, 1 inch, 1.50 inches, and 2.00 inches (see Attachment 1). Any values greater than 2.00 inches are drawn in one-inch increments. In addition, the location of QPF maxima are indicated on the chart by an "X", with the associated maximum value printed underneath. It is important to note the valid time period when viewing each product. Specifically, for the Day 1, 2, and 3 forecasts, QPFs are manually created for 6-hour periods and an accumulated 24-hour total QPF is also issued. For the Days 4/5 and Day 6/7 QPF, forecasters manually create a 48-hour

accumulation of areal average rainfall. Computer programs then take advantage of model forecasts of the timing of precipitation to break the WPC forecast down into 6-hourly QPFs.

4.1.2 Probabilistic Quantitative Precipitation Forecasts (PQPF) - The WPC produces 6-hour QPF's for forecast projection days one through three at 6-hour intervals (72-hour duration). Deterministic forecast models, including the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS), the NCEP North American Mesoscale (NAM) model and the global model from the European Centre for Medium-Range Weather Forecasts (ECMWF), along with the NCEP Short-Range Ensemble Forecast (SREF) system produce forecasts covering this time period. These model runs constitute an ensemble from which uncertainty information is obtained to construct a probability distribution about the WPC QPF. This distribution is utilized to generate probabilistic forecasts of precipitation. The 6-hour QPFs are summed to obtain 24-h QPFs, which are the basis for 24-h probabilistic QPFs (PQPF's) generated using the same multi-model ensemble and the same method as for the 6-h probabilistic QPFs. The probabilistic QPF forecasts provide information in two different forms (see Attachment 1):

Comment [NRC28]: Editorial/technical note: The actual map image in Attachment 1 only shows information in the second form (precipitation amount by percentile). However, it does show the tool with tabs for the different types.

<u>Probability of Precipitation of at Least a Specific Amount</u> show filled contour levels of probability that the 6- or 24-hour accumulation of precipitation will equal or exceed the given threshold.

<u>Precipitation Amount by Percentile</u> show filled contour levels of precipitation amount associated with a given probability percentile in the distribution with a range of values from the 5th to 95th percentile.

4.1.3 Excessive Rainfall Outlooks - The Excessive Rainfall Outlooks provide a forecast of the risk of flash flooding across the continental United States. A closed contour with an arrowhead delineates the probability forecasts, with risk areas defined to the right of the direction of the arrowhead. The probability categories are based on calibration studies conducted at WPC. The calibration for the excessive rainfall graphics are based on the frequency of events for which observed rainfall exceeded flash flood guidance values for a given risk category. When forecasters outline risk areas they are expecting greater organization of excessive rainfall than would be observed under average conditions. As confidence of excessive rainfall increases the category respectively evolves from Slight to Moderate to High. Day-1 Excessive Rainfall Outlooks (graphic and associated discussion) are issued four times per day: 03, 06, 15, and 18 UTC. Day 2 and Day 3 excessive rainfall forecasts are issued only twice per day
Flash Flood Guidance values incorporate soil type, land coverage, and a host of other factors in an attempt to describe the rain rate necessary to yield significant surface runoff and flash flooding over a given area. The River Forecast Centers issue guidance values for 1-, 3-, and 6-hour periods. Flash Flooding is considered to be caused by rainfall occurring in 6 or fewer hours, whereas longer duration rainfall represents areal flooding or inundation. The WPC excessive rainfall products focus specifically on flash flooding.

4.2 Mesoscale Precipitation Discussions

The WPC provides short term guidance to the National Weather Service (NWS) Weather Forecast Offices during heavy rain events when there is a threat of flash flooding. These are also provided to the media, emergency managers and interested partners. Guidance is given in the form of Mesoscale Precipitation Discussions (MPDs), that are issued 1-6 hours ahead of time. Each MPD consists of a graphic indicating the area of concern and any pertinent meteorological features as well as a brief text discussion focused on the mesoscale features supporting the anticipated heavy rainfall.

4.3 Tropical Public Advisories
The WPC will issue public advisories after the National Hurricane Center (NHC) discontinues its advisories on subtropical and tropical cyclones that have moved inland, but still pose a threat of heavy rain and flash floods in the conterminous United States or adjacent areas within Mexico which affect the drainage basins of NWS River Forecast Centers. The last NHC advisory will normally be issued when winds in an inland tropical cyclone drop below tropical storm strength, and the tropical depression is not forecast to regain tropical storm intensity or re-emerge over water. WPC advisories will terminate when the threat of flash flooding has ended.

4.4 Local Precipitation Climatological Studies
Local NWS offices often produce local climatology studies which focus on specific forecasting problems in the NWS office's specific county warning responsibility area. Some of these studies focus on precipitation forecasting and contain results based on years of accumulated knowledge of local climatology. These studies may be available from the internet, or upon from request from the local NWS office. Local NWS forecasters often cite results from these local studies as part of their daily forecast discussions. Forecast discussions from local NWS offices are available on the internet. Results of local studies, and the additional comments provided by local NWS forecasters in the forecast discussions, can be quite useful when assessing potential and actual heavy rainfall situations for specific locations.

4.5 Severe Weather Forecast Process - the NWS **Storm Prediction Center (SPC)** employs meteorological forecasting tools and models to generate severe weather forecasting notifications. The Storm Prediction Center receives input from the WPC on excessive rainfall that could lead to flash flooding for severe weather forecast and warnings. SPC Forecast and Discussions are intended for use by qualified personnel such as state, local or commercial meteorologists. Forecasts provided include:
Day 4-8 Severe Weather Outlook - graphic and text issued daily
Day 3 Convective Outlook - issued daily
Day 2 Convective Outlook - issued twice daily
Day 1 Convective Outlook – narrative and graphics with timing and severity, issued 5 times daily

- Flash flooding watches – issued with projection for time, location, and rainfall amount

5.0 Excessive Rain Event Trigger & Warning Time

Rainfall projected for the LIP based on the maximum physically possible synthetic storm cannot be reliably forecast using current models and forecasting methods which were developed and validated based on historical rainfall. However, warning time for maximum precipitation events can be established based on less extreme events that occur infrequently but fall on the high end of normal rain events. These high precipitation forecasts include the large storms systems that contain enough moisture for LIP level rainfalls without relying on the capability to accurately forecast maximum precipitation rainfall levels. This approach establishes monitoring and triggers based on less extreme events that will bound the maximum precipitation LIP event. Locations without terrain that can produce orographic lift can support the longer warning time due to the significant size of the storms required to produce precipitation approaching the maximum LIP event.

Excessive rain event triggers and warning time mechanisms can be developed based on the time needed to implement any flood protection or mitigation that are not passively based. Notification levels can be established using a single trigger or multiple triggers. Multiple triggers can be established if the response to an extreme rain event is done in graduated steps (e.g. stage equipment at 48 hours, assemble equipment at 12 hours, and complete implementation at 6 hours).

Comment [NRC29]: As discussed in the two most recent public meetings, objective criteria for forecast reliability need to be included in the decision process. As shown in Sukovich et al. (2014), the QPF skill levels (POD, CSI, etc.) for rainfall events that are only a fraction of PMP are qualitatively not very high.

Comment [NRC30]: **Editorial note:** It might be helpful if this is acknowledged earlier in the document. The previous sections have described various tools and statements about how far in advance they can predict (which may be interpreted as being able to predict LIP events). It is not until Section 5.0 that the paper acknowledges that these tools have difficulty predicting large events.

Comment [NRC31]: **Technical note:** This is another place where it's worth distinguishing max events vs. potentially more limiting consequential events.

5.1 QPF Forecast for Monitoring and Triggers:
Medium Range Forecast (monitoring)
Days 4-7 –QPF forecast are issued twice a day with valid periods of 48 hours
Day 3 – QOF and PQPF forecast are issued twice a day with valid periods of 24 hours

Short Range Forecast (trigger)
Day 2 – QPF and PQPF forecast are issued twice a day (WPC forecast model updates every 6 hours) with a valid period of 24 hours. Additional information that can be used to supplement the PQPF include Excessive Rainfall Outlook (ERO) forecasts and event driven updates. Excessive Rainfall Outlook forecast are issued twice a day with a valid period of 24 hours.
Day 1 - PQPF forecast are issued twice a day (WPC forecast model updates every 6 hours) with a valid period of 24 hours. ERO forecasts are issued twice a day with a valid period of 24 hours. ERO forecast are issued four times a day with a valid period of 21 to 30 hours. Unscheduled, event driven updates may be issued as determined by NWS/WPC

Other Monitoring Data Sources include: (NWS) Storm Prediction Center, National Hurricane Center, local National Weather Service Forecast Offices (122 locations nationally), internal licensee meteorologist, and private weather forecasting consulting organizations.

5.2 LIP Warning Time & Trigger: Warning time needed to provide a reliable response time to prepare for a LIP event can be established using NWS forecast. LIP warning thresholds should be set conservatively based on less extreme (and more predictable) events to assure that active protection or mitigation can be executed prior to site specific consequential flooding (point at which required SSC's are impacted by flooding levels) occurring. Consequential flooding may occur prior to the peak LIP flooding level (see Figure 1). In addition to identifying consequential flooding levels, the warning time needed should consider the time required to execute mitigation actions (e.g. closing doors, installing stop logs, staging equipment, etc) and other conditions (e.g. wind, lightning, personnel availability) that could impact the time to execute the mitigating actions.

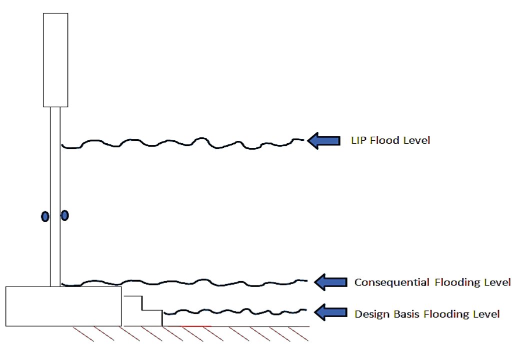


Figure 1 Consequential Flooding Illustration

LIP warning time should be based on the storms (Tropical, Synoptic, and Mesoscale Convective Complexes) that can produce the LIP level rainfall for a given nuclear facility location. Mesoscale Convective Complexes (thunderstorms) for sites with local terrain that can provide orographic lift, may have the shorter warning times. A meteorologist can determine what storm types apply to a given location including whether terrain has the potential to produce

Comment [NRC32]: Typo: Should read "QPF"

Comment [NRC33]: Technical note: This is another place where it's worth distinguishing max events vs. potentially more limiting consequential events.

Comment [NRC34]: Terminology note: Note earlier comment regarding active vs. passive protection. Similar comments apply to other references later in the document, but the comment is not repeated.

Comment [NRC35]: Suggestion: Per earlier comments, the discussion of consequential vs. max events should be introduced early in the document and then the concept used throughout the document. Similar comments apply throughout this section.

Comment [NRC36]: Terminology note: Note distinction between protection (e.g., keeping water out of structures) and mitigation in JLD-ISG-2012-05.

Comment [NRC37]: Technical note: As described above, warning time needs to consider events that can produce consequential rainfall (not just max levels).

orographic lift. An acceptable method that provides a conservative warning time is to establish a monitoring threshold followed by a ~~n~~ mitigation action trigger. The recommended precipitation forecasting tools are QPF's for monitoring during medium range forecast, and PQPF's for the mitigation action trigger for short range forecast for Day 1 and Day 2. This approach can be developed as follows:

> A monitoring threshold can be set by establishing a level of extreme rainfall for the basin where the nuclear facility is located. For most locations east of the 105th meridian a value of 3.7 to 5.7 inches in 24 hours would be considered an extreme rainfall based on a threshold of 0.001 frequency (the top 0.1% of days with rainfall) (Ralph et al 2010). This threshold can be set using the medium range forecast 3 to 7 days prior to the event. If this threshold still is met based on short range forecast on Day 2, the nuclear site would be notified (unless an earlier notification is desired) which would initiate site monitoring once per shift as directed by site procedure.
>
> A mitigation action trigger for can be set at ½ of the maximum 1 hour LIP rainfall amount that requires mitigation action by the site. For example if a site's maximum 1 hour LIP is determined to be 18" but the site specific consequential flooding occurs with an 8" per hour rain event, the action trigger would be set based on the more limiting event at 4''. This trigger value from a 1 hour rainfall event would be applied to a 24 hour rainfall projection based on the Day 1 or 2 PQPF. Using ½ of the 1 hour LIP (or the more limiting event) would provide a conservative trigger value when applied to a 24 hr rainfall 95th Percentile PQPF. The 1 hour LIP used in developing the trigger should be based on the site specific LIP for the nuclear site using the appropriate HMR (e.g. HMR-52, or an updated site specific HMR).
>
> Based on the desired warning time, the 95th Percentile PQPF can be selected from the 24 hour short range forecast on Day 1 or Day 2. The 95th Percentile PQPF is recommended over the QPF for a Day 1 or Day 2 trigger to compensate for uncertainty by including probability distribution. When this trigger is reached, action would be taken to put active protection or mitigation measures into place.

The accuracy of extreme rainfall forecast decreases as the projected levels exceed climatologically normal values and longer lead times. The use of "1/2" of the 1 hour LIP provides a level of conservatism intended to compensate for uncertainties in the precipitation forecast. 24-hour precipitation values of 1/2 of the 1-hour LIP (e.g. 6"-9" from HMR-52) correspond to precipitation return rates on the order of 1/1000 (0.001 or 0.1%), or less, for most sites east of the 105th meridian. Sukovich et al. (Figure 6) shows a moderate level of skill of forecasts of the top 0.1% of precipitation forecasts, suggesting that using 1/2 of the 1-hour LIP is a reasonable approach based on forecast skill.

A meteorologist should evaluate the nuclear site location to validate the acceptability of the monitoring threshold, trigger, and warning time based on the meteorological impacts of the local terrain and a review of weather history for the region associated with the nuclear site.

The above method represents one approach that can applied. The conservative bias of this approach increases the likelihood of false alarms. However, the consequence of a false alarm are minimal assuming the trigger actions are limited to reversible actions such as securing doors/gates or staging equipment.

Comment [NRC38]: As discussed in a previous comment about skill metrics. Sukovich et al. (2014) shows that, depending on the location and time of year, the probability of detection (POD) for the one-day QPF can be as low as 20% for the top 1% of rainfall events. That is a very low skill level, especially for a monitoring threshold trigger.

Comment [NRC Staff39]: **Editorial**: Appears that "for" should be deleted or some additional text is needed.

Comment [NRC40]: Consider deleting "maximum 1 hour." This appears to be somewhat redundant to the definition of "LIP rainfall."

Comment [NRC41]: **Clarification requested:** Confirm that this is suggesting, in the case of the above example, that the trigger for action would be 4 inches of rain over 24 hours. Confirm what action is being referenced here (e.g., staging or implementation).

Comment [NRC42]: **Technical note:** This should also reference the potentially more limiting consequential event.

Comment [NRC43]: One can argue about what is a "moderate level" of skill since the level of skill required will vary with the application. The referenced figure shows POD of about 30% for 1-day QPF (average for CONUS, other figures show lower POD for some regions and seasons). Is this sufficient for the application at hand? Is it consistent with risk tolerances for a nuclear facility?

Comment [NRC44]: The skill levels reported by Sukovioch et al. (2014) suggests that this may not be true.

Other methods can also be used based on government and private forecasting models. Sites located within 50 miles of coastal areas should include monitoring of hurricane and tropical storm advisories from the National Hurricane Center in addition to the Weather Prediction Center precipitation forecasts. Plant sites west of the continental divide need to consider atmospheric river events where heavy bursts of rain can occur within an overall synoptic storm. An atmospheric river is a narrow corridor or filament of concentrated moisture in the atmosphere that develops along the boundaries between large areas of divergent surface air flow. These can occur from October through March, and are a significant source of moisture and flooding.

Comment [NRC45]: Consider removing the word "overall" as this is implied by a synoptic system.

Comment [NRC46]: Consider moving this discussion to the section that describes storm types.

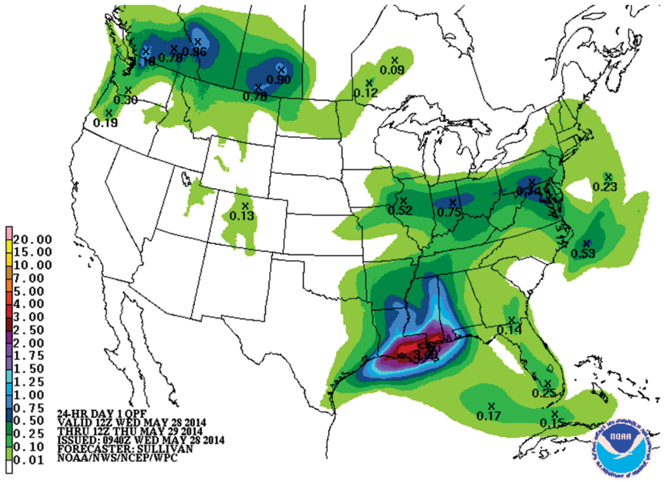
Attachments:

Attachment 1 - Probabilistic Quantitative Precipitation Forecast, Excessive Rainfall Outlooks
Attachment 2 - NWS Web Sites (Source Material), References

Attachment 1

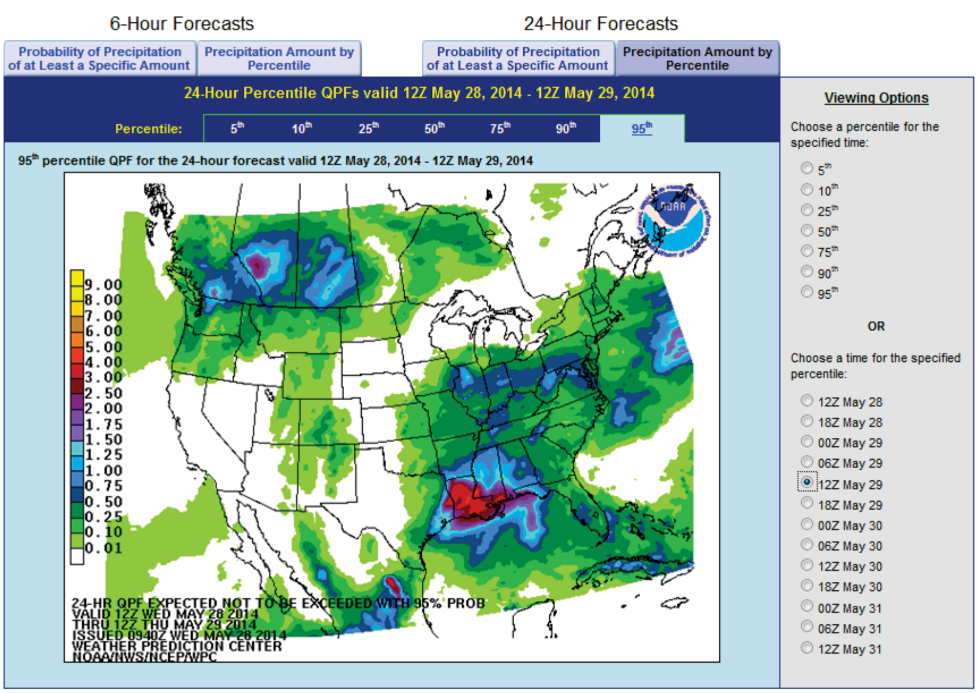
Quantitative Precipitation Forecasts (QPFs) – EXAMPLE

(http://www.hpc.ncep.noaa.gov/qpf/qpf2.shtml)



Probabilistic Quantitative Precipitation Forecasts (PQPFs) – EXAMPLE

(http://www.hpc.ncep.noaa.gov/pPQPF/conus_hpc_percentile.php?fpd=24)



Attachment 2

NWS Web Sites (Source Material)

NWS Weather Prediction Center (WPC)
http://www.hpc.ncep.noaa.gov/html/fam2.shtml - Website describing the WPC Products
http://www.hpc.ncep.noaa.gov/index.shtml - Website with QPC's and Excessive Rain Forecast
http://www.hpc.ncep.noaa.gov/pqpf/conus_hpc_percentile.php?fpd=24 – Website for Probabilistic QPF's

NWS National Hurricane Center (NHC)
http://www.nhc.noaa.gov/ - Home page for NHC

NWS Storm Prediction Center (SPC)
http://www.spc.noaa.gov/misc/aboutus.html
http://www.spc.noaa.gov/misc/about.html#Day 1 Convective Outlook

NWS Weather Alerts
http://alerts.weather.gov/

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)1 (includes recurrence intervals up to 1000 years and includes a 1 hour storm – listed by state)
http://hdsc.nws.noaa.gov/hdsc/pfds/index.html

NWS and Non-NWS listings of Weather Service Providers
http://www.nws.noaa.gov/im/metdir.htm

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4. Needham, H. and B. Keim (2014). “Correlating Storm Surge Heights with Tropical Cyclone Winds at and before Landfall.” *Earth Interact.*, **18**, 1–26.

5. Ralph, F., E. Sukovich, D. Reynolds, M. Dettinger, S. Weagle, W. Clark, and P. J. Neiman (2010). “Assessment of Extreme Quantitative Precipitation Forecasts and Development of Regional Extreme Event Thresholds Using Data from HMT-2006 and COOP Observers.” *J. Hydrometeor.*, **11**, 1286-1304.

6. Olson, D.A., N. Junker, and B. Korty (1995). “Evaluation of 33 Years of Quantitative Precipitation Forecasting at the NMC.” *Wea. Forecasting*, **10**, 498-511.

7. Sukovich, E., F. Ralph, F. Barthold, D. Reynolds, and D. Novak, (2014). “Extreme Quantitative Precipitation Forecast Performance at the Weather Prediction Center from 2001 to 2011.” *Wea. Forecasting.* doi:10.1175/WAF-D-13-00061.1, in press

Contributing Authors

1. William Henson, PhD, AMEC
2. William D. Kappel, President/Senior Meteorologist, Applied Weather Associates
3. Brian Kolts, Meteorologist - First Energy
4. Stanton Lanham, Meteorologist - Duke Energy
5. Peter C. Manousos, Meteorologist - First Energy
6. Erwin T. Prater, PhD, MBA, CCM, CFA, Certified Consulting Meteorologist