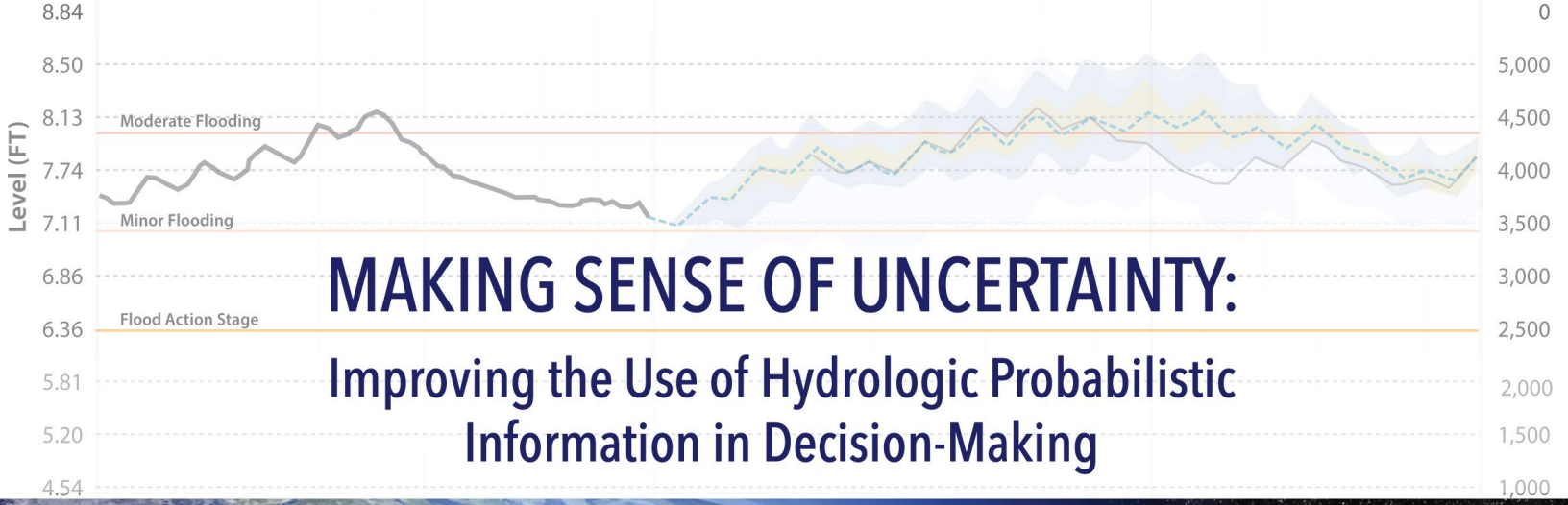

MAKING SENSE OF UNCERTAINTY:

Improving the Use of Hydrologic Probabilistic Information in Decision-Making

Prepared by Nurture Nature Center and East Carolina University, 2020
with funding from NOAA'S JTTI Program

THE NURTURE NATURE CENTER

Award #: NA18OAR4590365 OAR JTTI
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ECU

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Executive Summary

Advancing prior research about how various audiences use and understand probabilistic hydrologic forecast information, in the fall of 2018 Nurture Nature Center with its research partner, East Carolina University, undertook a two-year mixed-methods social science research study of three forecast products to propose improvements to the display and communication of uncertainty and probabilistic information in hydrologic forecasts. Specifically, the research team sought to understand how: a) Advanced Hydrologic Prediction Service (AHPS) and regional hydrographs (e.g., hydrographs developed by National Weather Service (NWS) River Forecast Centers (RFCs) or Weather Forecast Offices (WFOs); b) outputs from the Hydrologic Ensemble Forecast Service (HEFS), including seasonal water supply forecast related products; and c) briefings for impact-based decision support services (IDSS), can work together to convey the complexity of certainty and uncertainty in short, medium-term and seasonal hydrologic forecasts and to recommend modifications to the HEFS based on user feedback.

The study involved 16 focus groups and surveys conducted throughout 2019 with professional and residential audiences in four locations in the United States, partnering with local weather forecast offices and regional river forecast centers: Owego, NY, with Binghamton, NY WFO and Middle Atlantic River Forecast Center; Durango, CO and Gunnison, CO, with Grand Junction, CO WFO and Colorado Basin River Forecast Center; and Eureka, CA with Eureka, CA WFO and California-Nevada River Forecast Center. Professional audiences included emergency managers, water resource managers, and others who use forecast products in the course of professional duties. Residential participants reflected a range of backgrounds and forecast experience, as well as experience with flooding and drought events. Focus groups centered around a scenario-based discussion of an impending severe hydrologic event in each region, and elicited feedback from users in an iterative series of focus groups and online survey about the ways in which they used and understood hydrologic forecasts, particularly focusing on probabilistic forecast data.

Studying these three products – the hydrograph, briefings, and HEFS – in different regions of the country provides a more comprehensive view of the issues associated with probability and public understanding than has been considered to date. Previous research by the team has shown that the hydrograph is a much-preferred product for hydrologic information, and participants have requested that probabilistic information be shown in the context of a deterministic product. But these products have also proven to be difficult for many to understand together. In addition, the results of the team's previous research as well as feedback from forecasters, have shown that briefings, which allow forecasters to use a combination of text and graphical products to explain impacts from events, help advance understanding. As such, this study was undertaken to understand the relative influence of various factors across these products that help to improve understandability and utility, and to propose prototypes that build upon these elements to create new, improved methods for display.

Research questions address:

- how to time briefings for probabilistic vs. deterministic information;
- how to express varying levels of confidence across different forecast types (low/medium/high flows) and geographic regions;
- how changes in forecast probabilities over time affect user confidence;
- how display needs of these products vary for different users (i.e., water managers vs. public);
- how users tolerate divergence in probabilistic and deterministic forecasts; and
- how deterministic and probabilistic river level forecasts can be presented simultaneously without causing confusion for the user.

Findings from the study are detailed herein and include analysis of quantitative focus group data from participants as well as qualitative analysis of focus group discussions.

Findings address the research questions above, including detailed discussion of: the ways that users respond to probabilistic forecasts when they diverge from deterministic forecasts; the varied needs of professional vs. residential audiences; and geographic-specific needs for data and information delivery.

The report contains a recommendation for a proposed national HEFS output, developed in response to feedback from the iterative variations tested throughout the project. This national product includes features most frequently favored across the regions and is informed by visual risk communication principles. In recognition that a "one-size-fits-all" product is not likely to achieve all of the needs of local offices for communicating probabilistic information to audiences, additional examples of HEFS outputs are provided for each test region, reflecting the specific needs and established practices of each location.

Additionally, the report includes a series of recommendations for decision support related to probabilistic information, including issues related to product presentation, product interactivity, the utility of emergency briefings for conveying complex forecast information along with impact information, and the need for building trust with users.

Introduction

In previous National Oceanic and Atmospheric Administration (NOAA) funded studies, Nurture Nature Center and East Carolina University tested various National Weather Service (NWS) probabilistic flood forecast products among other NWS tools. The first included the significant river flood outlook, watches and warnings, the Advanced Hydrologic Prediction Service (AHPS) hydrograph, and the Meteorological Model Ensemble Forecast System (MMEFS) used in the Eastern Region to provide probabilistic hydrologic guidance (Hogan Carr et al., 2016a). Among the recommendations from that study were changes to the products so that they would be more easily understood by users and more likely to motivate action. The other study to address probabilistic products focused on the Hydrologic Ensemble Forecast System (HEFS) and found that the presentation of probabilistic information via HEFS alongside deterministic information (i.e., hydrograph) in a scenario-based focus group created significant understanding barriers (Hogan Carr et al., 2018). Audiences struggled to understand the deterministic and probabilistic information together and, in one situation, experienced decreased trust in both the hydrograph and the HEFS products as a result. Additionally, the study found that modifications to the display and presentation of the information helped improve user understanding of the forecast. A third study undertaken by the team funded by NOAA Sea Grant and the New Jersey Sea Grant Consortium as part of the Coastal Storm Awareness Program (CSAP) made a series of recommendations related to the potential use of the emergency briefing as a primary communication tool for flooding events. The research study identified that the briefing – with its ability to prioritize risk, clarify meteorological details and language, emphasize impacts, "push" information to broad groups of users, and be distributed by local emergency managers and others – was a promising communication tool for delivering complex hydrologic forecasts to a variety of users (Hogan Carr et. 2016b). The results of these studies led to additional questions about how best to present probabilistic information through testing in geographic regions with distinct water resource issues, which are the focus of this project.

The technical capacity for probabilistic forecasting has advanced considerably, and there have been calls for wide dissemination of these forecasts. Indeed, the US National Research Council (2006, p.12) asserted that, "By providing mainly single valued categorical information, the hydrometeorological prediction community denies its users much of the value of the information it produces—information that could impart economic benefits and lead to greater safety and convenience for the nation." Similarly, Michaels (2015, p. 44) has indicated that "The use of probabilistic flood forecasts is in tune with the wider trend in public policy to employ risk-based decision making." Despite these and other acknowledgements of the importance of probabilistic forecasts, it has been recognized that there is still much work to be done to make this information usable to various public and professional audiences (Wood et al. 2012; Spiegelhalter et al. 2011; Ramos et al. 2010). On one hand, some question whether people can successfully make use of uncertainty information given biases and expectations that may influence interpretations of this information (Joslyn and Savelli 2010) while others assert that providing uncertainty information to the public in an accessible format may help people decide how much confidence to place in a given forecast (Morss et al. 2008). Indeed, research has suggested that communicating information about data uncertainty has the potential to increase trust in results and to support decision-making that uses that data (Kinkeldey et al. 2014), whether it is the public or professional users.

Communicating forecasts effectively requires understanding how intended audiences interpret and use forecast information presented in different ways (Murphy et al. 2010). As suggested by Palmer (2002, p. 753), ". . . most of the time, the ordinary person does not have the motivation to digest the extra information that is implicit in a probability weather forecast." This aligns with the findings of Joslyn and Savelli (2010) that many people anticipate some uncertainty in the deterministic forecasts. At the same time, when deterministic and probabilistic forecasts are both available and there are discrepancies between them in the data shown, as mentioned earlier, trust in both declines (Hogan Carr et al., 2018). In contrast, practitioners may make poorer decisions if they do not have the benefit of taking forecast uncertainties and risks into account (Hirschberg et al. 2011). For instance, one study reported that professionals in national hydrologic services in Europe found that threshold forecasts that used both deterministic and probabilistic forecasts were more useful to better evaluate the risk of a potential flood (Ramos et al. 2007). Combined, these studies illustrate the complications that arise from the fact that there are differences in the understanding of probabilistic forecasts depending on the type of user, but there are also differences within groups (Hogan Carr et al. 2018, Kox et al. 2015). Further, the thresholds at which such information will motivate action differ among users (Morss et al. 2010).

It is clear from the research that both deterministic and probabilistic information are important to a wide range of users, even though the relative utility of each will vary depending on the users' needs and decisions as well as their understanding of the data presented in a given product. Further, it is not just the availability of ensemble forecasts that is important, but how that information is presented. Indeed, one study reported that among the lessons learned in their research is the need for engagement and collaboration on the design of probabilistic forecasts (Nobert et al., 2010). Thus, in addition to understanding how to present deterministic and probabilistic forecasts simultaneously without diminishing the value of either or both, it is also necessary to consider how uncertainty should be presented to be most effective for various audiences.

This project, then, advances prior research about how various audiences use and understand probabilistic hydrologic forecast information, testing three forecast products and proposing improvements to the display and communication of uncertainty and probabilistic information in hydrologic forecasts. Specifically, the research team sought to understand how: a) Advanced Hydrologic Prediction Service (AHPS) and regional hydrographs (e.g., hydrographs developed by NWS River Forecast Centers [RFCs] or Weather Forecast Offices [WFOs]); b) outputs from the Hydrologic

Specifically, the research team sought to understand how: a) Advanced Hydrologic Prediction Service (AHPS) and regional hydrographs (e.g., hydrographs developed by NWS River Forecast Centers [RFCs] or Weather Forecast Offices [WFOs]); b) outputs from the Hydrologic Ensemble Forecast Service (HEFS), including seasonal water supply forecast related products; and c) briefings for impact-based decision support services (IDSS), can work together to convey the complexity of certainty and uncertainty in short, medium-term and seasonal hydrologic forecasts and to recommend modifications to the HEFS based on user feedback.

Ensemble Forecast Service (HEFS), including seasonal water supply forecast related products; and c) briefings for impact-based decision support services (IDSS), can work together to convey the complexity of certainty and uncertainty in short, medium-term and seasonal hydrologic forecasts and to recommend modifications to the HEFS based on user feedback.

Studying these three products – the hydrograph, briefings, and HEFS – in different regions of the country provides a more comprehensive view of the issues associated with probability and public understanding than has been considered to date. As mentioned above, previous research by the team has shown that the hydrograph is a much-preferred product for hydrologic information, and participants have requested that probabilistic information be shown in the context of a deterministic product. But these products have also proven to be difficult for many to understand together. In addition, the results of that research as well as feedback from forecasters, have shown that briefings, which allow forecasters to use a combination of text and graphical products to explain impacts from events, help advance understanding. As such, this study was undertaken to understand the relative influence of various factors across these products that help to improve understandability and utility, and to propose prototypes that build upon these elements to create new, improved methods for display.

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Methodology

AHPS, HEFS and briefings were tested through three methods, in four different geographic locations, and with two different audiences. In-person focus groups and surveys, and an online survey, were conducted with residents and professionals (emergency managers, water resources professionals) in Eureka, CA, Owego, NY, Gunnison, CO, and Durango, CO (Figure 1). Two rounds of in-person focus groups were held (Round 1 in Spring of 2019 and Round 2 in Fall of 2019), and in each round, two focus groups were held at each of the four locations – one for professionals and one for residents.

Figure 1. Focus group locations: Eureka, CA, Owego, NY, Gunnison, CO, and Durango, CO.

Working with NOAA RFCs and NWS WFOs in each location, the project team developed four hypothetical scenarios (one for each region) with forecast products that were used as the basis for two hour focus groups. These products included a range of NWS forecast products as well as products from other government agencies, including the United States Geological Survey (USGS) and the National Resource Conservation Service (NRCS). Scenarios included emphasis on the products at the center of this study, namely, ensemble forecasts (HEFS), hydrographs (AHPS) and briefings, as well as supporting weather information, including precipitation and temperature forecasts, watches and warnings and snowmelt information. An example of some of the products used for Round 2 in Eureka is shown in Figure 2. Scenarios started from 2 months to 7 days ahead of the target weather date, to incorporate the different regional contexts. These scenarios were constructed in the ESRI Story Map platform so they would be easily shared (links to each location's Round 2 scenario are provided in Appendix A).

The project team worked with NOAA partners to determine easily accessible public meeting places, ranging from a public library in Durango to meeting space at a fairground in Gunnison. Flyers for each focus group were developed and shared through partner's contacts, as well as through social media, local news outlets and local organizations focused on waterways. Participants were required to register for each session via an online web form. All non-governmental participants were offered $50 as compensation for their time.

When participants arrived for their respective focus group, they were each given an iPad and asked to complete a pre-session survey. They kept the iPads to follow along with the scenario. The scenario was simultaneously projected on a large screen and on each iPad. This allowed participants to zoom in on product details if needed. Dr. Montz facilitated the session, walking the participants through each day in the scenario, asking questions about understanding, motivation to take action, and resource needs (specific questions are shared in Appendix B). Discussion was recorded and transcribed for analysis with NVivo. A post-session survey was completed by all participants (survey instruments are included in Appendix C). The same process was used for both Round 1 and Round 2, with the exception of using revised HEFS products in the Round 2 scenarios. Round 2 focus groups were conducted with new participants.

The graphical and design revisions to the probabilistic flood forecast products were based on analysis of pre- and post-session surveys as well as focus group notes and transcripts. Survey responses were analyzed using Excel and transcripts were analyzed using NVivo to identify trends and themes about individual products in the focus group discussions. Of particular relevance were specific post-session survey questions asking about every element in the product and whether each was

useful or not. Participants could explain which elements were most or least useful. Following each round, revisions were made that included changes to the color scheme, design, legends, and title, and the addition of needed information, such as a forecaster's note. Region-specific revisions included adding an interactive text box for USGS historical values for Colorado products, and adding a river level exceedance vertical bar as a side box for California and New York.

Following analysis of the second round of focus groups, the HEFS graphics were revised again and an online survey was developed and administered in March 2020 to all previous participants from both Rounds 1 and 2. This survey showed the newly revised HEFS products, as well as a prototype of a national version of the HEFS (the survey is included in Appendix D). Residential participants received a $50 Amazon gift card for completion of the survey.

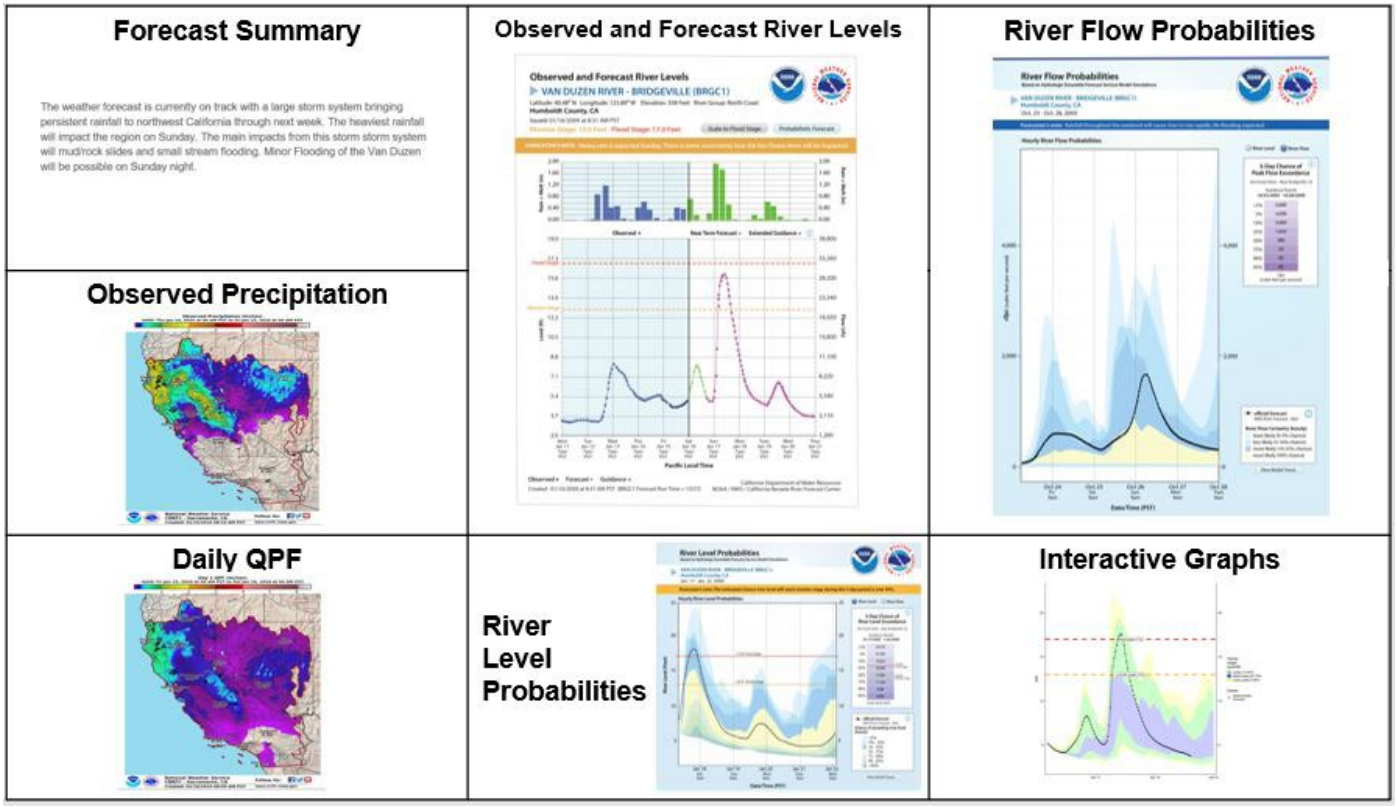


Figure 2. Some of the products shown throughout the flooding scenario as part of the focus groups in Eureka, CA during Round 2. Participants were asked to rate the usefulness of each of these products in the post-session survey.

Results

Characteristics of participants

The total number of participants by location and focus group for both Round 1 and Round 2 are shown in Table 1 and Appendix E, along with demographics. For the follow-up online survey, 107 participants (33 professionals and 74 residents) participated, a 75% overall response rate (88% for residents and 56% for professionals). Specific numbers by location include: Eureka, CA 13 professionals and 28 residents; Gunnison, CO 6 professionals and 6 residents; Durango, CO 5 professionals and 18 residents; and Owego, NY 9 professionals and 22 residents.

Focus group participants had varied experience with flooding in all locations and sessions, as shown in Table 2 and Appendix E, along with differing perceptions of flood risk and how much advance notice they preferred to have prior to a significant event. These varying characteristics highlight the diverse factors experienced by different regions.

Table 1. Number of participants by location for Round 1 and Round 2.

	Professionals		Residents	
	R1	R2	R1	R2
Eureka, California	11	11	15	12
Gunnison, Colorado	10	3	6	5
Durango, Colorado	7	3	11	11
Owego, NY	10	4	12	14

Table 2. Flood related characteristics of participants as reported in the pre-session surveys by focus group and location for Round 1 and Round 2.

	Eureka Pro		Eureka Res		Gunnison Pro		Gunnison Res		Durango Pro		Durango Res		Owego Pro		Owego Res	
Live in Floodplain	**R1**	**R2**	**R1**	**R2**	**R1**	**R2**	**R1**	**R2**	**R1**	**R2**	**R1**	**R2**	**R1**	**R2**	**R1**	**R2**
Yes	0%	18%	53%	25%	30%	0%	0%	80%	29%	67%	18%	9%	10%	75%	25%	57%
No	100%	82%	47%	33%	70%	100%	83%	0%	71%	33%	45%	55%	90%	25%	58%	36%
Unsure	0%	0%	0%	42%	0%	0%	17%	20%	0%	0%	36%	36%	0%	0%	17%	7%
Flood Experience																
Yes	82%	45%	60%	83%	60%	0%	67%	100%	57%	67%	55%	36%	100%	100%	100%	100%
No	18%	55%	40%	17%	40%	100%	33%	0%	43%	33%	45%	64%	0%	0%	0%	0%

Survey results related to products

While the pre-session survey provided an understanding of participants' experience with extreme events, the post-session survey sought to quantify the utility and perception of the forecast products shown during the focus group. Of particular interest was change in usefulness of the HEFS product from Round 1 to Round 2, which would partially reflect the effectiveness of design changes to the product. For instance, in Eureka, CA, the usefulness of the various products changed from Round 1 to Round 2, as shown in Figure 3(A) with an increase in those reporting the probability of stage, flow, and the hydrograph as extremely or very useful and a corresponding decrease in participants reporting these were not at all or only slightly useful. While having different participants in Round 1 from Round 2 may partially explain these differences, there is some evidence that the changes to the HEFS products increased their utility: for Eureka, Durango and Gunnison, the percentage of professionals/residents reporting the probability of stage and flow to be extremely or very useful increased in Round 2 to varying degrees, as shown in Figure 3 with green and orange blocks that are above the 0% representing an increase in participants reporting extremely or very useful perceptions of the products. These findings provide encouragement that the design changes between Round 1 and Round 2 were effective in increasing understanding and utility.

Figure 3. Difference from Round 1 to Round 2 in ratings of usefulness of products shown in the scenario for professionals (left) and residents (right) for Eureka, CA (A), Owego, NY (B), Durango, CO (C), and Gunnison, CO (D).

In the final online survey, participants were asked about the usefulness of the three main products the study focused on – the hydrograph/deterministic product, the HEFS (probability of river level), and the briefing package. As shown in Figure 4, most professionals and residents rated all products as very to somewhat useful.

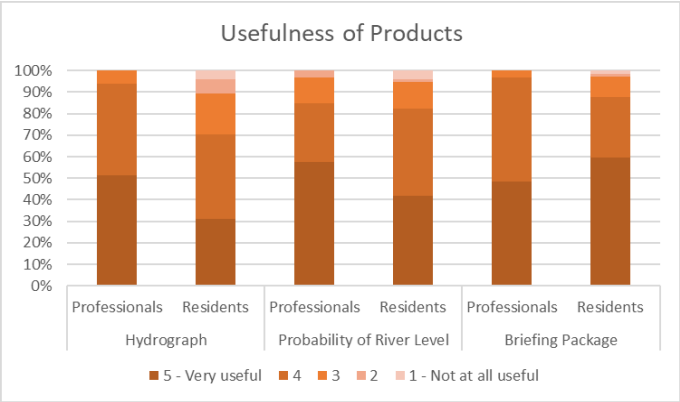
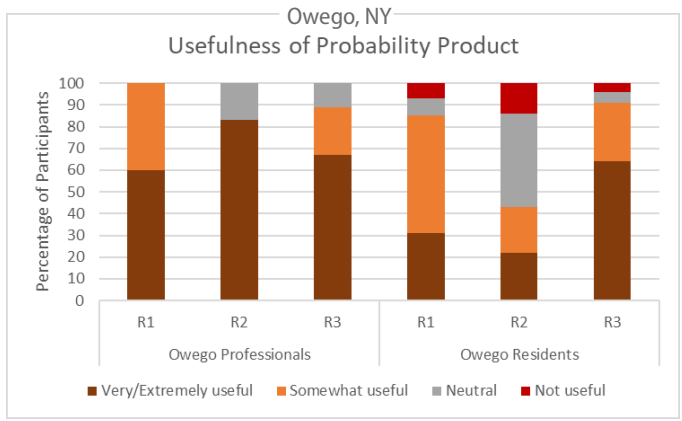
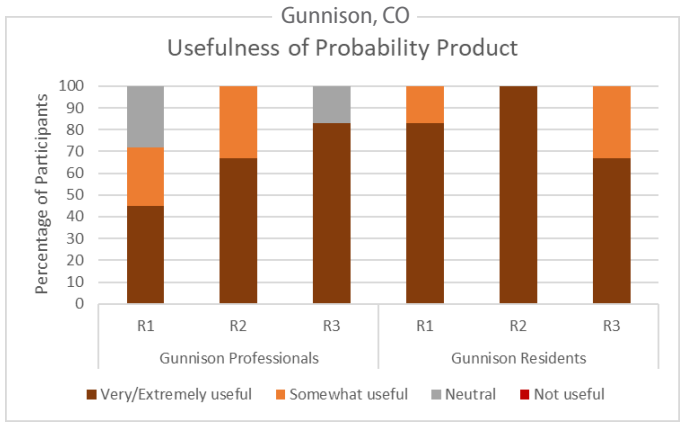
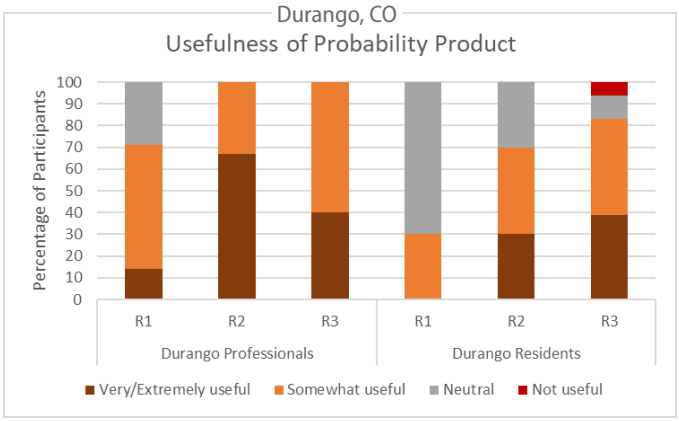


Figure 4. Rating of usefulness of the hydrograph, HEFS, and briefing package on a scale of 1 (not at all useful) to 5 (very useful) for professionals and residents in the online survey.

Focusing on the usefulness of the probability product by location, Figure 5 shows the progression of usefulness for the regional HEFS products over all three rounds of testing for each location. For many, but not all, locations and user groups, the ratings of very/extremely useful increased from R1 to R2 to R3. Recall that the graphics were revised between each round with the goal of enhancing understandability and usability.







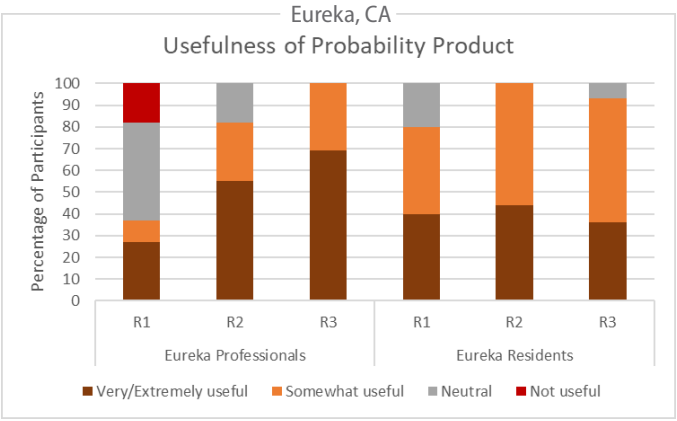


Figure 5. Percentage of participants reporting usefulness of the probability of river level products in Round 1, Round 2, and Round 3 by focus group location, reflecting changes to the product between rounds.

In Round 3, the online survey, the participants were also asked about the usefulness of a national HEFS (probabilistic river level forecast) product, different from the regional product they had seen in the focus groups and surveys. The national product used all the highly rated elements of the regional product designs to inform its development. A strong majority (over 80%) for each region and user group rated the national HEFS product as very or somewhat useful, with all but Eureka and Colorado residents having over 60% stating it was very useful (Figure 6A). Most were also very or somewhat likely to use the product (Figure 6B). Eureka showed the strongest likelihood to use it, while Colorado showed the least, though participants in Colorado tended to report using USGS discharge products as we note later in this report.

Figure 6. Percentage of online survey (Round 3) respondents rating the usefulness of the national probabilistic river level product (A) and likelihood to use it (B).

Another element on which the online Round 3 survey sought clarification was whether shaded probabilities were preferred to lines in the national HEFS product. In the Middle Atlantic River Forecast Center (MARFC) region, an existing ensemble product called the MMEFS, uses a shaded 25-75% category with lines for the 5 and 95% probability lines (see option 1 in Figure 7). The survey tested this option of showing percentages compared to shaded categories for all levels (see option 2 in Figure 7). All locations and user groups preferred option 2 (the shaded probabilities, no lines), despite confusion over which was 5% and which was 95% when they are part of the same shaded category.

Exploring whether percentages or general 'likely' categories were easy to understand, ratings varied by location and user group when asked to rank on a scale of 1 (confusing) to 5 (easy to understand) (Figure 8). A higher percentage of Owego professionals found the likely categories to be easier to understand than percentages, while fewer Gunnison professionals found the likely categories to be easy to understand compared to percentages. While a higher percentage of Owego residents found the percentages to be easy to understand compared to the likely categories, most groups found the likely categories to be easier to understand.

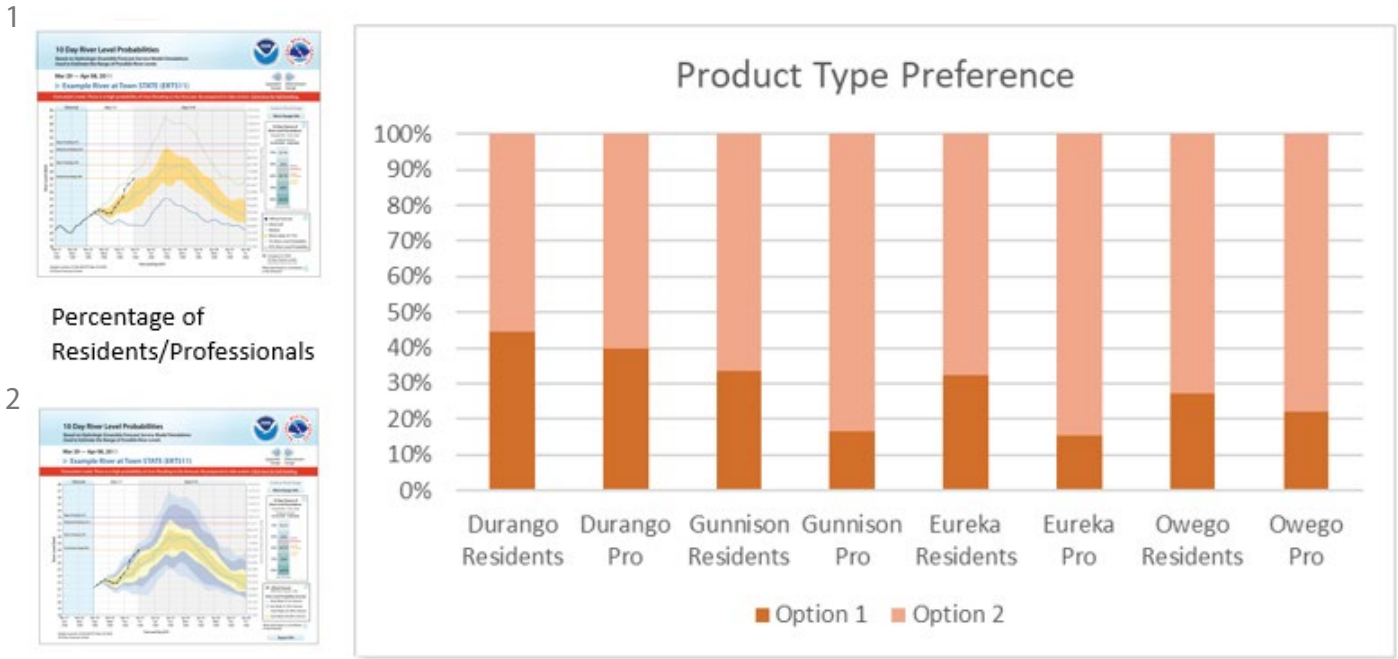


Figure 7. Percentage of online survey (Round 3) respondents who preferred option 1 (shaded/line probabilities) or option 2 (shaded probabilities) for the national HEFS (probabilistic river level) product.

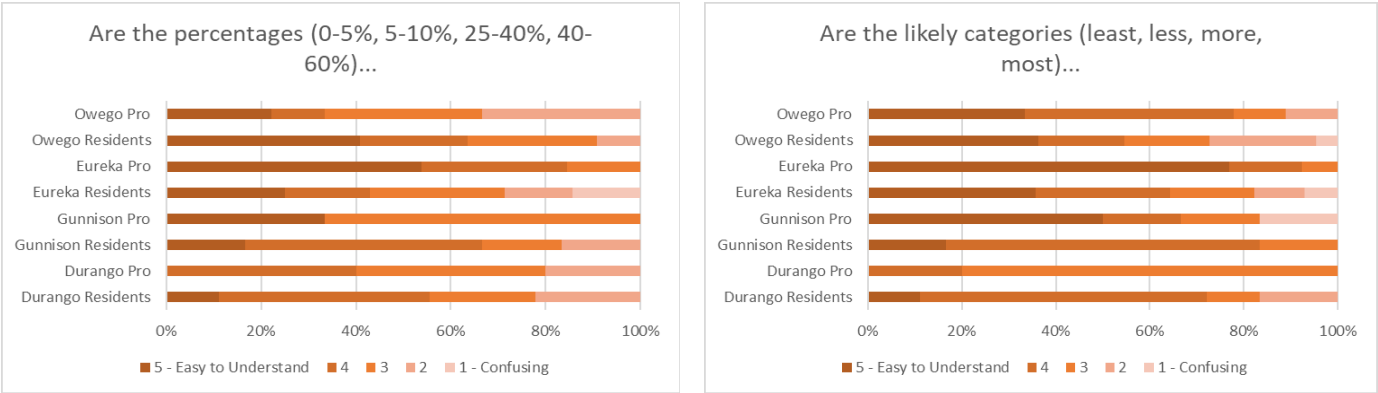


Figure 8. Percentage of online survey (Round 3) respondents who rated percentages and likely categories on a scale of 1 (confusing) to 5 (easy to understand).

A focal research question of this study was the tolerance for divergence between the probabilistic and deterministic river level forecasts. The impact of these differences was explored in focus group discussions as well as asked in the post-session surveys and online Round 3 survey. Specifically, participants were asked how they would react to a divergence, including ignoring the forecast, seeking out more information, having less confidence in both or either forecast, or asking an expert (they could also write in a response). Comparing the impact of the divergence from Round 1 to Round 2, there was about a 20% decrease in the number of professionals who reported less confidence in the probabilistic product but an increase (about 8%) of those having less confidence in both. There was a decrease in the percentage of residents that would ignore the forecast, have less confidence in the probabilistic and would seek out more information. The revised design of the probabilistic product in Round 2 may have increased understanding and confidence in the product (Figure 9A). Comparing the impact of the divergence from Round 2 to Round 3 (Figure 9B), there was an 11% decrease in professionals and 5% decrease in residents having less confidence in both products while there was a 5% increase in professionals having less confidence in the probabilistic. More professionals than residents would seek out expert assistance and more information. However, it is important to note that many of the percentage changes are not very high (less than 5%), and it could be reasoned the revisions did not overwhelmingly influence confidence where there is a divergence between the deterministic and the probabilistic forecasts. More details on the professionals' and residents' perceptions and confidence in the deterministic and probabilistic forecasts when there is a difference are elucidated in the focus group analysis that follows.

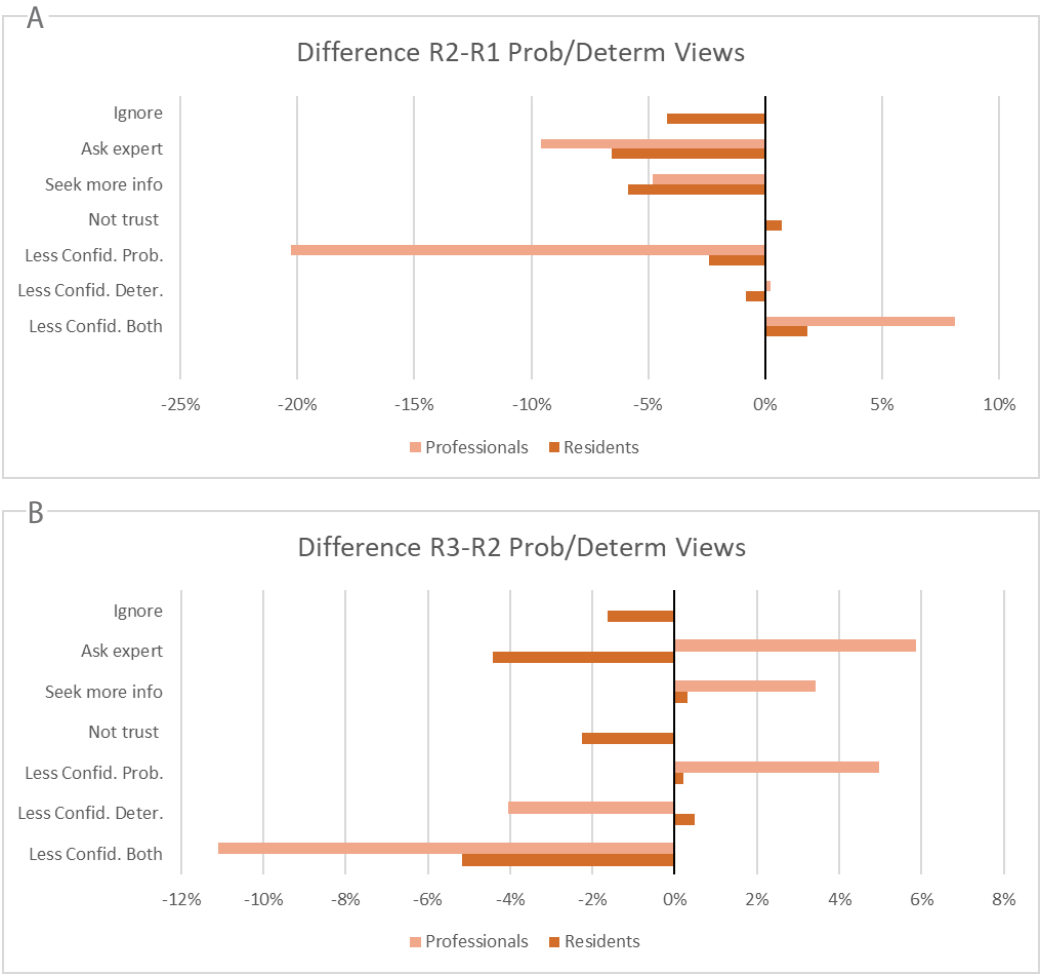


Figure 9. Differences in percentage of professionals and residents in response to how a divergence in the probabilistic and deterministic products would impact their perceptions of confidence, from Round 1 to Round 2 (A) and Round 2 to Round 3 (B).

The survey results from Round 1, Round 2, and Round 3 (online) provide evidence for improved understandability and usability for the HEFS products after design revisions were implemented. There is an expressed interest in the information conveyed in a probabilistic river level product overall, but distinct and important differences appear regionally regarding useful content and elements to include in graphics.To understand the nuances of these differences and develop a more comprehensive picture of survey results, a detailed analysis of each round of focus group follows.

Focus Group Analysis: Round One

As described in the Methods section, focus groups were held with professional users (including water resource managers and emergency management professionals) and with residential users in each of the four locations: Eureka, CA; Owego, NY; and Gunnison and Durango, CO. For purposes of analysis, we will discuss findings from the focus group conversation by location, noting specifically the findings from each audience.

California - Eureka

Water Resource and Emergency Management Professionals

Participants in this session were presented with two separate scenarios, an initial longer scenario which focused on a 5-day lead up to a flooding situation, and a second, briefer 5-day scenario that focused on low flow conditions. After both scenarios were finished, participants were given a brief overview of a prototype interactive probabilistic forecast tool that would allow users to define various parameters for forecast information.

In addition to context-setting products including a quantitative precipitation forecast (QPF), the high-flow scenario featured: hydrographs issued through the California Nevada River Forecast Center (CNRFC); 5-day Maximum Peak Stage and Peak Flow Probability graphics; and companion tables under conceptual development in the CNRFC. The scenario also included narrative forecast information of the kind delivered by the WFO in email updates and briefings to partners.

Participants reflected on the need to understand how certain a forecast was when making decisions based upon it. In discussing uncertainty, one participant expressed frustration about times when forecasted river levels did not materialize, causing needless planning or leading to under-planning: *"I mean, last night, I was expecting high water 8500, 8300 cfs, last night -- it barely cracked 3200. ... I had prepared for water and I was actually anticipating it ... and it's just like a non-event for us."* Acknowledging this situation, another professional said that he scans for additional forecast information to determine confidence in the forecast: *"I would have said, what's the snowpack, what's the antecedent conditions? ... I would be asking, what's the duration ... are we talking atmospheric river or are we talking a broad front that's going to go through, and then that helps me understand the forecast."*

Participants provided specific comments about the hydro- graph, acknowledging that adding lines indicating the monitor stage and flood stages would be helpful to visualize the risk posed by the forecast (Figure 10). Participants largely struggled to understand the 5-Day Maximum Peak Stage Probability product and asked for a written explanation of a couple sentences to explain the product. The static color bars were confusing to participants who expected them to fluctuate over time. Participants accustomed to reading a hydrograph read the deterministic line as a forecast against a time background, but this product shows the 5-day deterministic forecast layered on top of a separate graph that shows the probability of reaching maximum peak stages at any time during that same 5-days. Shown together this way, the product misled participants into thinking the deterministic aligned with the probabilities on an hour-by-hour or day-by-day basis.

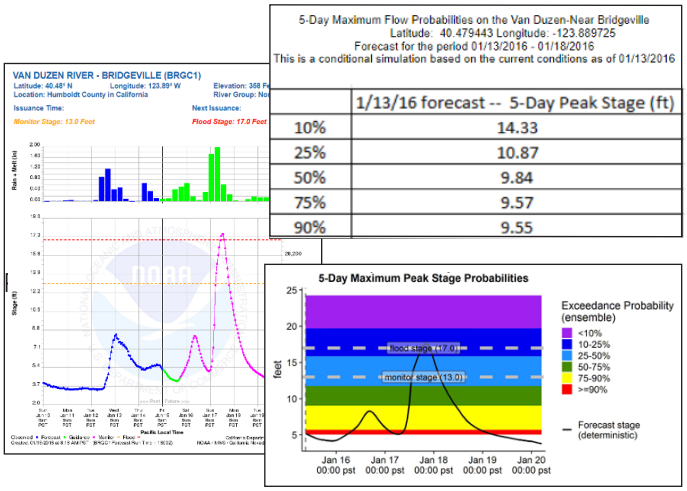


Figure 10. Eureka, CA - Round 1 Hydrograph (left); 5-Day Maximum Flow Probabilities (right top) and 5-Day Maximum Peak Stage (right bottom).

the product revealed continued confusion about what the various elements were displaying, with one suggesting that the forecast certainty was represented as constant across the 5-day period, and said that "*doesn't seem credible*" and that "*It has increasing uncertainty as time goes by.*" Another asked why the probabilistic and deterministic forecasts didn't seem to match and indicated decreased trust upon finding the discrepancy: *"I don't understand why the probabilistic isn't at the 50 percent, if it's deterministic, it should be the 50 percent probability. Otherwise, what are you giving me?"* Despite some confusion and a lack of clarity about whether the probabilistic information was being properly understood, when presented the product several times during the scenario, users began to express that receiving probabilistic information would be important to decision-making. *"I'd be telling him, this might not happen, but you're going to have to prepare as though it will because the cost for not preparing is too high."*

Some participants favored the 5-day Maximum Flow probability graphic (Figure 10) for readability, though one user complained that similar to the stage product discussed previously, the table represented the probabilities as equally certain across a 5-day period, even though a 1-day forecast period would have much higher certainty than subsequent days. Despite this concern, some found this table easier to digest than the graphic presentation.

Some expressed that there is value in direct NWS expressions of confidence such as those relayed in forecast discussions, citing the helpfulness of explanations such as *"we have poor run-to-run agreement on the model' or "this is very widespread – we have high confidence in this."*

Participants asked for details that would assist in understanding model performance over time, reflected through statements such as: *"If I was doing this, I would look in past years about what I predicted and then what happened. And I do that over and over again until I just made my own (distribution)."*

During the low-flow scenario, participants expressed appreciation for a seasonal email prepared by the WFO that addressed flow conditions for the fall season, which functions much like an emergency briefing insofar as gathering text and graphics on multiple parameters into one transmission, which includes *"... more confidence information. The whole thing in one email – yup, it's what's so awesome. You see the graphs, you see the text, you see the tables and it's all pulled together and it's a really great product."*

Feedback indicated that the interactive probabilistic product, which showed forecast ranges with probabilities, was well received. Some were confused why the 5-95 percent spread was so wide and questioned its value but participants expressed an interest in receiving uncertainty, with one saying: *"I'd rather them just be honest about it. Just say, 'look, we are not all that confident. It's a really wide error bar'. I'd rather know that than just have one line and say, 'here's our prediction'."*

Participants remained confused when the deterministic line fell outside the "most likely" category on the probabilistic forecasts, and asked for more information about what was driving the forecasts: *"Do they include antecedent precipitation for example? Was that in the ensemble or not? Was it in the deterministic or not? It would be helpful to have that, yes."* Participants suggested that products include short descriptions of the information to make the data as clear as possible to users up front: *"Maybe summarize what we are looking at here. We're not just looking at a graph. Okay. What's happening tomorrow? Like, you know, you want to have a brief understanding of what you are looking at before you look at it."* Another noted: *"For the general public it would be helpful just to really spell it out and not expect us to be as smart as meteorologists."*

Residential Users

Participants in this session were presented with a 5-day high-flow scenario, followed by a brief discussion of various ways of displaying the 5-day Maximum Peak Stage Probabilities product, including variations showing traces and different forecast periods (5-day and 1-day variants). Products shown were the same as the professional scenario, including QPF, hydrograph, 5-day maximum peak stage and flow probability products and tables, and briefing information, followed by a brief display of the interactive prototype.

As with the professional group, participants in this session discussed limited confidence in the hydrograph until the very short-term forecast, saying *"The weather around here changes in the blink of an eye. They predict storms that are going to be huge and then we get a half inch instead of three inches."* Hydrograph information was more trusted in the 24-hour range. Residents expressed a need for clear description of terms like "guidance" and ways to understand clearly how various forecast levels link to impacts.

For the 5-day Maximum Peak Stage forecast product, users struggled to understand the product at all, needing more clarification on the elements of the product, including needing to know the location (gage) and to understand that the numbers were referencing river level. Some participants expressed appreciation at receiving probabilistic information, even as their understanding of the particular representation was generally low, saying the product would focus them on the river's potential *"because we never know what it's going to do."* Others said that a 5-day forecast was not helpful because the *"weather is so extreme"* and because *"most people who live next to the river (would be) looking at the water, not at the computer."* The use of color on the product was sometimes problematic, as for the user who pointed out that the red color would seem to imply an area of flooding, though in fact the red was used to imply a level of confidence. Echoed by another, *"we were looking at red and we think risk."*

Some participants preferred the 5-day Maximum Peak Flow Probability forecast product, describing it as clear and easier to read. Response was nearly evenly split when asked their preference between this graphic and the 5-day Maximum Peak Stage presentation of probabilistic information. When presented with the interactive version of the HEFS outputs, response was much more favorable. People found this version of probabilistic information *"more readable,"* and requested that it include the action/monitor and flood stage lines that were shown on the hydrograph. People appreciated the options for interactivity.

New York - Owego

Water Resource and Emergency Management Professionals

Participants in this session were shown a series of products as part of a 5-day river-flood scenario. Products included hydrographs, HEFS graphics showing deterministic and probabilistic forecasts on one graph (Figure 11), briefing packages from both the WFO and the MARFC, quantitative precipitation forecasts, snow products, 5-day river flood outlook, flood watches and warnings and other products. This analysis will focus on response to the hydrograph, HEFS and briefing materials.

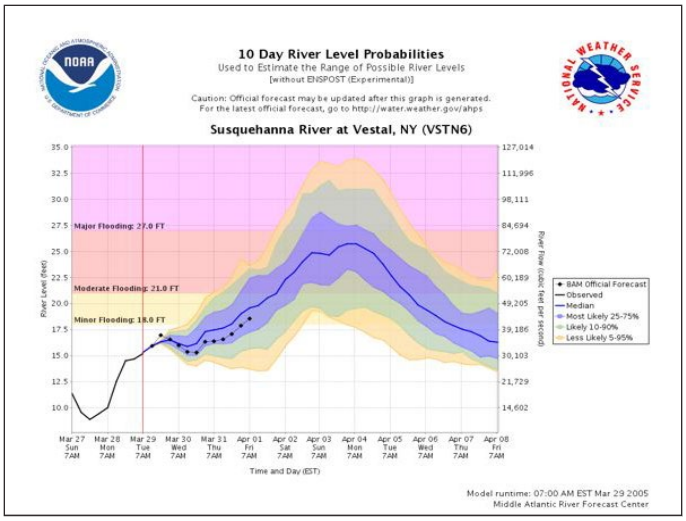


Figure 11. Owego, NY - Round 1 HEFS product.

Professionals in this group were familiar with the hydrograph and used it regularly. Some participants found interpreting the HEFS product (Figure 11) difficult and commented that the legend information was too small and hard to identify. Some suggested that this information would be helpful, but not for public consumption, because it would require too much explanation. Others suggested that sharing with the public might trigger additional preparedness when people see the potential for worse outcomes: *"It might not be a bad idea because with some people, they need a panic situation before they move."* Another suggested that public users may be less careful, and see a shaded area as a high level without understanding the probability of reaching that level is very low: *"I think that they might take a glance and go, oh my god, look it's at 37 feet, and not really look at the legend."*

Participants appreciated the longer time horizon offered by the HEFS. One participant asked to see the trends on the probabilistic forecast to see how probabilities are changing day to day and how they compare to actual river levels reached. Others agreed that they would like to "ground truth" the product during a significant storm to see how probabilities compared to actual levels before relying on the information. In response to rising probabilities of a flood, participants indicated they would seek other information to confirm the likelihood of the event, such as *"checking the weather again ... really just seeing, you know, where the storm's at,"* and whether the ground is frozen, for instance.

Participants requested the ability to list historical flood crests on the HEFS display for quick reference to estimate impacts. They indicated they would use the product, with one participant calling it *"another tool in the toolbox,"* and that they would use it in conjunction with the hydrograph as the event approached.

Participants were familiar with emergency briefings and reported using and sharing them with public audiences, including via Facebook to the village's central page. *"We all know about it somehow,"* one participant said, identifying that the briefing information is circulated in the professional community. One participant suggested that the presence of a briefing itself was a threshold event that indicated it was time to pay attention to the weather: *"They don't do a briefing just for the heck of it."* Participants valued impact descriptions, as well as historical comparisons, and requested evacuation route information. They also cited the importance of the relationship with the forecasters at NWS who are distributing the information, noting that information via phone call can be very powerful in addition to written briefings. Recalling one meteorologist who expressed verbal dread at the coming event in a phone briefing, the participant said, "*I remember that was spot on. Yep. Yeah, it really got our attention.*"

Residential Users

Participants in this session were shown the same products as the professionals. They had some familiarity with the hydrograph, and a few were aware of various gages in the region. Participants suggested more education to the public about the availability of hydrographs would be important to increase their use.

Participants gave detailed suggestions for improving the display, including clearer labeling on the river level and what exactly that meant, and suggested including the word "gage" so people could understand how the levels were being measured and forecast. One participant noted that the small legend beneath the hydrograph showed "forecast" with a blue icon, followed by "series" with a pink icon to represent the observed area, but that this order is in fact backward compared to the way that the elements are shown on the product (with forecast occurring after series) and further, asked what "series" meant. Participants noted that seeing past major flood events on the hydrograph would be helpful for understanding potential impacts from current forecasts, as would seeing past forecasts along with the observed data to understand how well the forecasts have been performing: *"That would increase my confidence,"* said one participant in agreement with this idea.

Participants were mixed in initial response to the HEFS and were unfamiliar with probabilistic forecasts. Overall, feedback indicated that the product needed to be simpler, legend items larger and clearer, and that the color scheme needed adjustment to be less distracting, with some suggesting simple lines may work better than filling in the ranges with solid colors, and another suggesting patterns instead of colors. Immediate response generally reflected a sense of being overwhelmed on the part of the participants. With repeated exposure to the product, participants began to suggest that showing past events and past performance of the ensemble forecasts would help build trust and understanding: *" Say, ok, this is what happened in 2011, 2005, and ... I think if you can show me what ... the past was like, I can say, you know, they were spot on or they were really off."* Another confirmed: "ground-truthing." Participants also began to analyze their risk in light of the ensemble data, discuss plans for preparing for a potential flood, and to talk about the other information

Overall, feedback indicated that the product needed to be simpler, legend items larger and clearer, and that the color scheme needed adjustment to be less distracting, with some suggesting simple lines may work better than filling in the ranges with solid colors, and another suggesting patterns instead of colors. Immediate response generally reflected a sense of being overwhelmed on the part of the participants.

they would begin to look for, such as evidence of any ice jams. When presented with divergence between the deterministic and probabilistic forecasts, participants wanted more information to explain the discrepancy. Some indicated trust in the deterministic because it was perceived to be influenced by forecasters with experience: *"I think the reason why you see that diverge (is) because the National Weather Service knows more about our areas than the models do. And so they are taking their experience and saying, OK ... it's going to be worse than what the model is going to predict."* Others indicated a preference for following the higher forecast when in conflict, to be over rather than under prepared. Some suggested that the HEFS be presented as an interactive platform that would allow increasing levels of sophistication of data to accommodate less and more experienced users.

The emergency briefing was generally well received, with participants appreciating its brevity and easy-to-read, straightforward format. Participants suggested that the briefings should be a trigger for local action and asked that they be issued more frequently, every 6 hours, during acute events. Participants provided specific feedback on components of the briefing, suggesting that some terms in the product showing Risk for Flash Flooding were not immediately intuitive – for instance, the difference between marginal and slight – and noting that using green as a color for excessive rain could confuse people as green can be perceived as a "comforting" color. The flood warning polygon was not favored but information about saturation was considered important, as were risk and impact information.

Colorado – Gunnison

Water Resource and Emergency Management Professionals

Participants in this session were presented a month-long scenario with high snowpack and possible flooding along the East River near Almont. In addition to mocked-up hydrographs and probabilistic HEFS products (Figure 12B), the scenario included hydrologic outlooks, snowpack products from the NRCS as well as the Colorado Basin River Forecast Center (CBRFC), river flow compared to normal, modeled soil moisture products, text-based weather forecast summaries including temperature, flood watches and warnings, and impact statements. Following the scenario, participants also were shown a Mean Daily Peak Flow Forecast product in existing and proposed formats, a water supply forecast, Chance of Exceeding River Stage (Figure 12A), Weekly Chance of Exceeding River Stage products, and a variant format of the hydrograph as issued from the CBRFC currently, showing forecast probabilities. Together, these products told the story of an impending possible flood through the region.

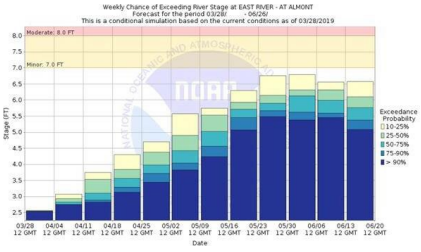


Figure 12A. Gunnison, CO - Round 1 Weekly Chance of Exceeding River Stage.

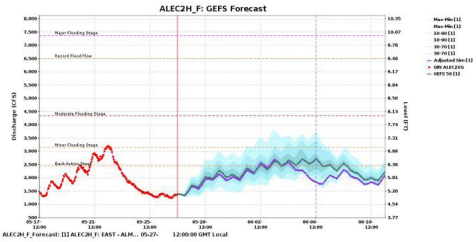


Figure 12B. Gunnison, CO - Round 1 HEFS product.

Professionals in this group had some familiarity with the hydrograph. They asked for clear definitions of the defined stages (action, minor, moderate, major) allowing them to understand how the stages were established and what impacts could be expected at each level. Some had previous positive experience with hydrographs that created a trust in the forecast, while others indicated a lack of trust that the levels had been established by historical events and suggested they

Participants expressed value in receiving probabilistic forecasts as far as a month out, suggesting that their municipal decision-makers want this information, and that it could be helpful for sharing with the public via a website or social media.

would use them, but would compare them to other data for improved confidence when making decisions. For instance, one participant said that a few days in advance of a forecasted flood, *"I'm going out myself to known areas, just seeing how much it is rising, cause I've seen it be very accurate and I've seen it be kind of like, Eh, not so much."* Participants expressed value in longer-term deterministic forecasts, longer than five days as shown, though some participants indicated that they would still be using probabilistic forecasts at nine days out, citing limited skill in deterministic forecasts at that range. Participants also expressed a need for product elements to be clearly defined in the legend and asked for an easy way to bookmark and export the graphic for sharing.

Participants expressed value in receiving probabilistic forecasts as far as a month out, suggesting that their municipal decision-makers want this information, and that it could be helpful for sharing with the public via a website or social media. One participant reiterated that most professionals have a trusted suite of forecast tools and that presenting too much new information can create a state of being overwhelmed that is not helpful, or that will get *"lost in the fog."* He requested a *"one-stop shop"* for natural hazards that could *"summarize in narrative what the data is out there."*

Participants said the probabilistic information would be helpful for monitoring and planning water-based activities, such as rafting and festival events that occur seasonally. Also, participants discussed that information that appears anomalous, such as a forecast that diverges from the probabilistic median, should be called out on the product and addressed. Participants sought clarity on the data included in the forecasts, such as how historical data was included.

Briefings were valued especially for information about anticipated impacts, with participants noting that flooding in some low-lying areas might be largely agricultural with limited impacts, but some areas might be housing animals or homes, and the ability to understand anticipated impacts was critical.

Residential Users

Participants in this session were shown the same products as in the professional session. When presented with the hydrograph, participants needed explanation about how to read the graphic, including, for instance, how to distinguish the observed and forecast sections of the product. At a month out, trust in the hydrograph was limited and participants wanted historical data to compare the forecast.

Residential participants struggled to understand the probabilistic product (Figure 12B), asking for clarity on the title and legend elements, which they said were small and hard to read and understand. Listing the gage code in the title, for instance "ALEC2H ... F: GEFS Forecast", was not helpful to participants who could not identify that as the location for the forecast; simpler explanations were requested. Technical terms, such as "adjusted SIM" were not clear or understood. With repeated chances to view the HEFS over the course of the scenario, participants began to express that it would have value for them, particularly for showing the duration of potential high flows over time.

Participants said that presenting the HEFS in conjunction with weather forecasts including temperature information, as well as reservoir management details, would be helpful. Some participants expressed concern about how they could access the information or learn about it, living in a rural area not generally covered by metropolitan broadcast meteorologists, with some noting that information such as a flood watch or warning can be hard to receive. Participants discussed wanting to be able to receive email updates with a summary of important weather information, such as a briefing, to help bring their attention to major events. Additionally, participants favored having deterministic and probabilistic forecasts shown together, as demonstrated on the product shown at the end of the scenario with both elements. Some also favored showing historical data (such as the 30-year average), and probabilistic and deterministic forecasts all in one product.

Colorado - Durango

Water Resource and Emergency Management Professionals

Participants in this session were presented with a two-and-a-half month low-flow scenario, that included similar products to the Gunnison session, including, in addition to the HEFS and hydrograph, snowpack products from NWS and NRCS, modeled snow conditions, departure from normal temperature, soil moisture, river flow compared to normal, USDA drought monitor and drought products, weather forecast summaries and temperature and precipitation outlooks, hurricane cone, quantitative precipitation forecasts, flood warning and watches and impact statements. As in the Gunnison session, participants also were shown a series of products post-scenario including a Mean Daily Peak Flow Forecast product in existing (Figure 13) and proposed formats, a water supply forecast, Chance of Exceeding River Stage, Weekly Chance of Exceeding River Stage products, and a variant format of the hydrograph as issued from the CBRFC currently, showing forecast probabilities.

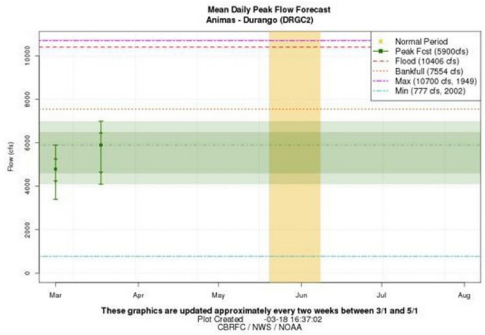


Figure 13. Durango, CO - Round 1 Mean Daily Peak Flow Forecast

Participants expressed familiarity with the hydrograph, with some indicating that real-time information is more important than forecasts. Most participants found a lot of utility in the probabilistic forecasts, with one calling it *"much, much better"* than the hydrograph because it provides a fuller range of information. A few indicated that they trust the hydrograph's capacity to handle snowmelt more than rainfall events, which they viewed as less predictable.

Some participants thought seeing model traces in the ensemble would be helpful, and participants requested an explanation of the factors driving the probabilistic forecast, asking if it includes predicted snowfall, for instance. One explained that without understanding how the probabilities were derived, he would not feel confident, wondering if it was perhaps *"Just some guy saying, 'well I have a lot of local knowledge so I'm going to put the peak at 12,000 cfs because I have local knowledge.'"* Participants also asked for the legend elements to be larger and easier to read. Some participants expressed that probabilities are helpful because they have limited confidence in the precipitation forecasts: *"The models ... never do a very good job at predicting rainfall peaks. But I guess that's the point of putting the probabilities ...."* Another echoed that the forecast peaks from anticipated rainfall would provide an "order of magnitude" about what was likely, but that he didn't have faith in the actual peak level as shown because of the difficulty of forecasting precipitation in the region. There was general agreement that they would use the probabilistic forecasts to share with clients who must make decisions and to notify municipal departments.

> *When asked about how they would respond to deterministic and probabilistic forecasts that diverge, participants said that they would call the RFC or WFO.*

When asked about how they would respond to deterministic and probabilistic forecasts that diverge, participants said that they would call the RFC or WFO. As in Gunnison, professionals in this session asked for historical river levels, modeled ensemble forecasts and deterministic forecast information in one product.

Overall, participants in this session expressed trust and faith in the local forecasts from the NWS generally, and said there is a need for a way to more easily navigate through the tremendous amounts of data available on the NWS websites, such as quick-reference pages that could be customized to help them view the products they use frequently.

Residential Users

Residential participants were shown the same products as the professionals, described above. Overall, they had limited experience with the NWS hydrograph, though some were familiar with gage data provided through the USGS.

Participants had almost no experience with probabilistic forecasts and indicated that they required more information about the basis of the forecast to determine whether it was useful or not. Several suggested that the probabilistic information could likely be helpful to professionals while a few indicated it might be of limited use for their residential purposes. In trying to understand the product, participants wanted to understand if the forecasts were based on historical data or *"fancy models,"* with one asking: *"Is it based on some kind of real world data?"* Echoing this sentiment one participant said, *"It is difficult to put any faith in that if you don't know where the information is coming from."*

Participants expressed that experience with the forecast would help in building trust. Additionally, participants provided specific ways to improve the display of information to improve its utility, suggesting that the title and the legend were not clear; for instance, participants did not know what GEFS stands for and could not extract meaning from the acronym to help determine what they were viewing. Participants requested very clear labeling about where the gage was located and when the forecast was issued. Further, in the drought scenario, participants wanted to understand how the river levels compared to normal and requested clear presentation of historical data to compare the ensemble forecast to past levels. When the scenario shifted to show a potential for river rise, participants requested information on impacts, and asked if the forecast could connect to flood elevations determined by the Federal Emergency Management Agency (FEMA) to help homeowners know when river levels might affect their properties. Participants also requested clear definitions for flood levels, as was the case in other focus groups.

Participants were enthusiastic about the idea of having interactive data that they could customize, which would have filters or layers they could turn on and off.

Overall, participants in this session expressed trust and faith in the local forecasts from the NWS generally, and said there is a need for a way to more easily navigate through the tremendous amounts of data available on the NWS websites, such as quick-reference pages that could be customized to help them view the products they use frequently.

Focus Group Analysis: Round Two

California - Eureka

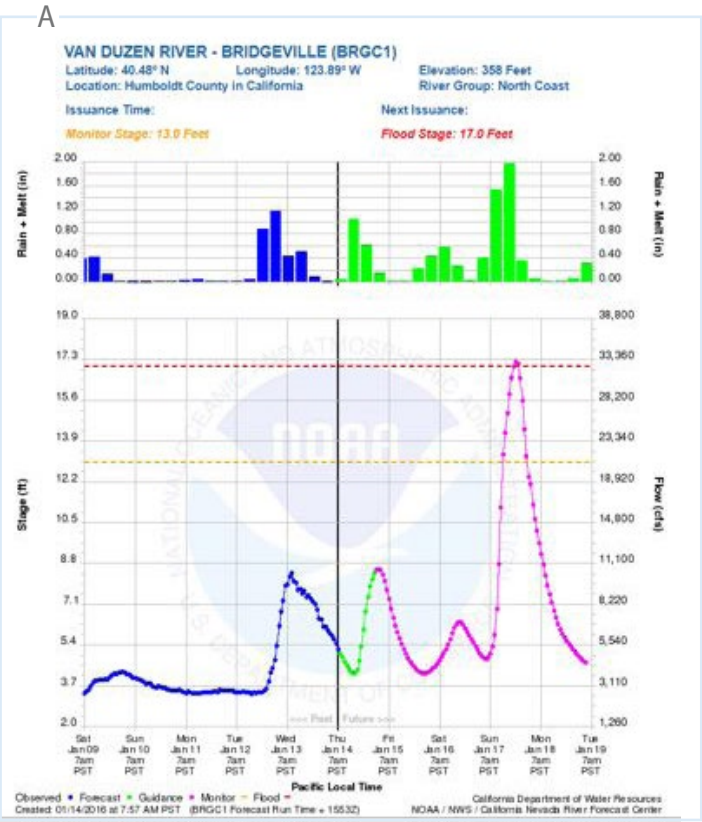
Water Resource and Emergency Management Professionals

Professionals in Round 2 were shown the same scenarios (including high flow and low flow) as Round 1 participants. In this round, the hydrograph (Figure 14) and HEFS (Figure 16) outputs displayed were revised versions that incorporated Round 1 feedback. Results based on the HEFS and hydrograph here, then, respond to the revised mockups.

Participants responded generally favorably and with strong interest in the hydrograph and suggested that they relied on hydrograph information in their work already. Participants expressed some confusion that the purple dots indicating the extended guidance portion of the forecast did not correspond to any purple on the area above the graphic showing snow-melt and rain.

Response to the revised HEFS was very favorable, with initial feedback suggesting it was more helpful than deterministic forecasts alone: *"This gives you a lot more information as a manager, to, you know, when you need to mobilize and when to ... protect your field equipment and initiate different field protocols... ."* Others suggested they would need time to use the product before assessing its usefulness. Participants asked for a description of the elements that drove the forecast - wondering if the product accounted for dam operations, for instance, or soil saturation. Participants also suggested that the forecaster's note section was helpful and could be used to note changes from previous forecasts or confidence in the forecast. Participants also appreciated the vertical bar graph format on the right side as an addition to the graphical ensemble forecast display.

Participants suggested they would share the product with other professionals, but thought that for many individuals, the information would be difficult to use without explanation: *"You have to be into looking at hydrographs and thinking about probability and I think even managers, it would have to be a really simple explanation."* One user asked for a spatial map of probabilistic forecasts, so that a professional who



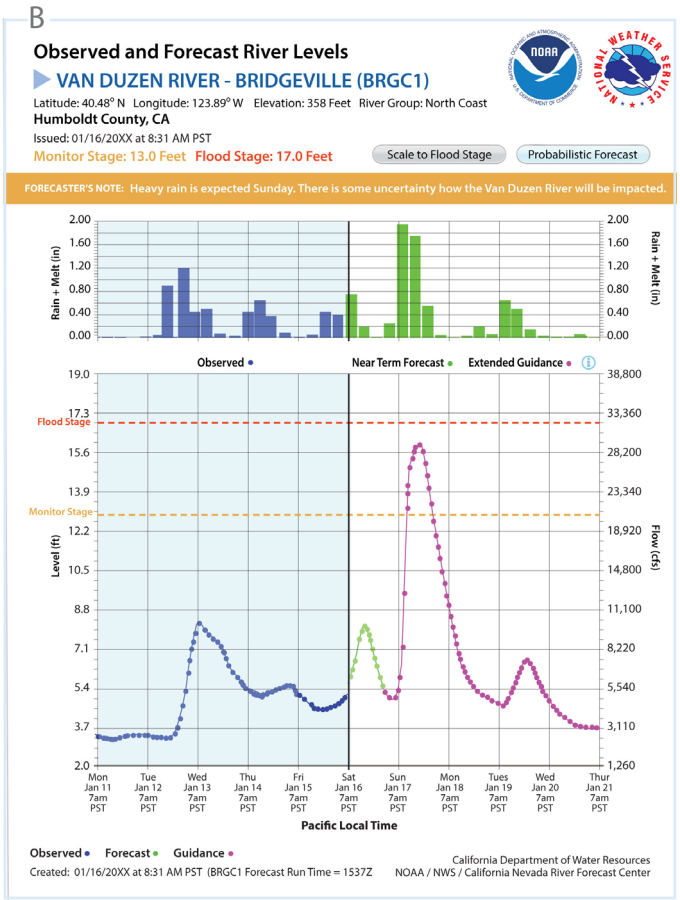


Figure 14. Regional hydrograph shown during the Eureka, CA focus group scenario in Round 1 (A) and Round 2 (B).

monitors a broad region could look at a map to see where areas were showing possible high or low flows. Participants also discussed the value in being able to view two gage locations at the same time.

As with previous groups, participants suggested it would be important to explain how the deterministic and ensemble forecasts are each calculated, with one person suggesting a button that would provide details on the general forecast drivers for each element. This issue became even more important when the deterministic and ensemble forecasts diverged.

A second variant of the HEFS forecast (Figure 15), which showed fewer categories for probabilistic ranges and labeled those categories with text definitions (Least, Less, More and Most Likely) was considered "user-friendly for public," though some expressed concern that the phrase "most likely" may cause confusion when conflated with the deterministic forecast, which is what forecasters actually consider to be the anticipated outcome. That participant worried a "most likely" label may cause users to distrust or avoid the deterministic forecast: "*I think the words are more understandable for people, the public. But they can lead to a false sense of security.*"

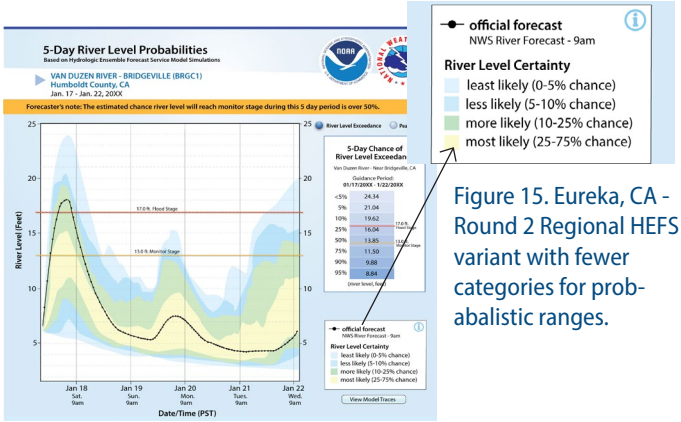


Figure 15. Eureka, CA - Round 2 Regional HEFS variant with fewer categories for probabalistic ranges.

Most participants responded favorably to the interactive display of probabilistic information, with the caveat by one that *"it's gonna overwhelm most people."* One participant said it would be helpful to present forecast information alongside data showing how the forecast has been performing in the previous days *"to see how the forecast is trending for that spot because if the forecast kind of missed it over the last few days...."* Participants said interactive displays would require buttons explaining various layers, such as traces, and should include toggles so that users can define the layers they wish to see and not be overwhelmed by information they do not need.

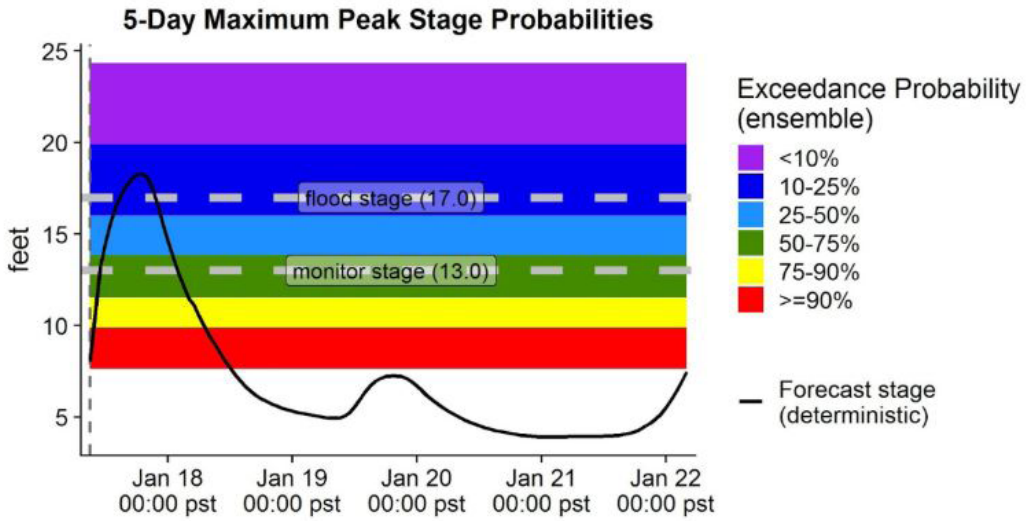
Residential Users

Residents in Round 2 were shown the same products as professionals. When shown the hydrograph, familiarity was mixed, with some having seen hydrographs previously and some seeing it for the first time during the session. Participants raised a question asked also by the professional group, namely, why the purple forecast section under "extended guidance" did not correspond to any purple color above on the rain and snowmelt. Further, the participants asked for a chart explaining the three time periods of observed, near-term forecast and extended guidance, not finding the terms immediately understandable, and they asked for more general clarity on the legend – increasing size, explaining rain and melt, and improving overall readability. As with the professionals in Eureka in Round 2, participants liked the Forecaster's Note element on the hydrograph as a way to draw attention to important information.

Participants expressed interest in using and understanding the HEFS but were not immediately familiar with the data. They required explanation of the deterministic line and its relationship to the ensemble forecast portions and favored having information buttons as shown to describe what each of the elements meant. Participants wanted to understand if historical data and current conditions were used in the models to drive the ensemble forecasts. The vertical bar graph representation of HEFS data was relatively well received but required some explanation. When shown the discrepancy between the deterministic and probabilistic forecasts, participants indicated that a big divergence would cause less trust in the forecast and require explanation: *"had that not been explained to me, I'm not sure I would have sussed that out on my own,"* one participant said of the overlay of deterministic and ensemble forecasts. Another participant suggested the table could help reinforce a users' understanding of information relayed through the graphical display. Participants requested tutorials, including videos, to describe how the various products should be understood and used, suggesting these *"would make (people) feel more confident in what they were reading and looking at."*

Participants welcomed interactivity as interesting and suggested that an interactive site would have good educational value for teaching children, but they were not all certain how much they would use an interactive component if available.

A



B

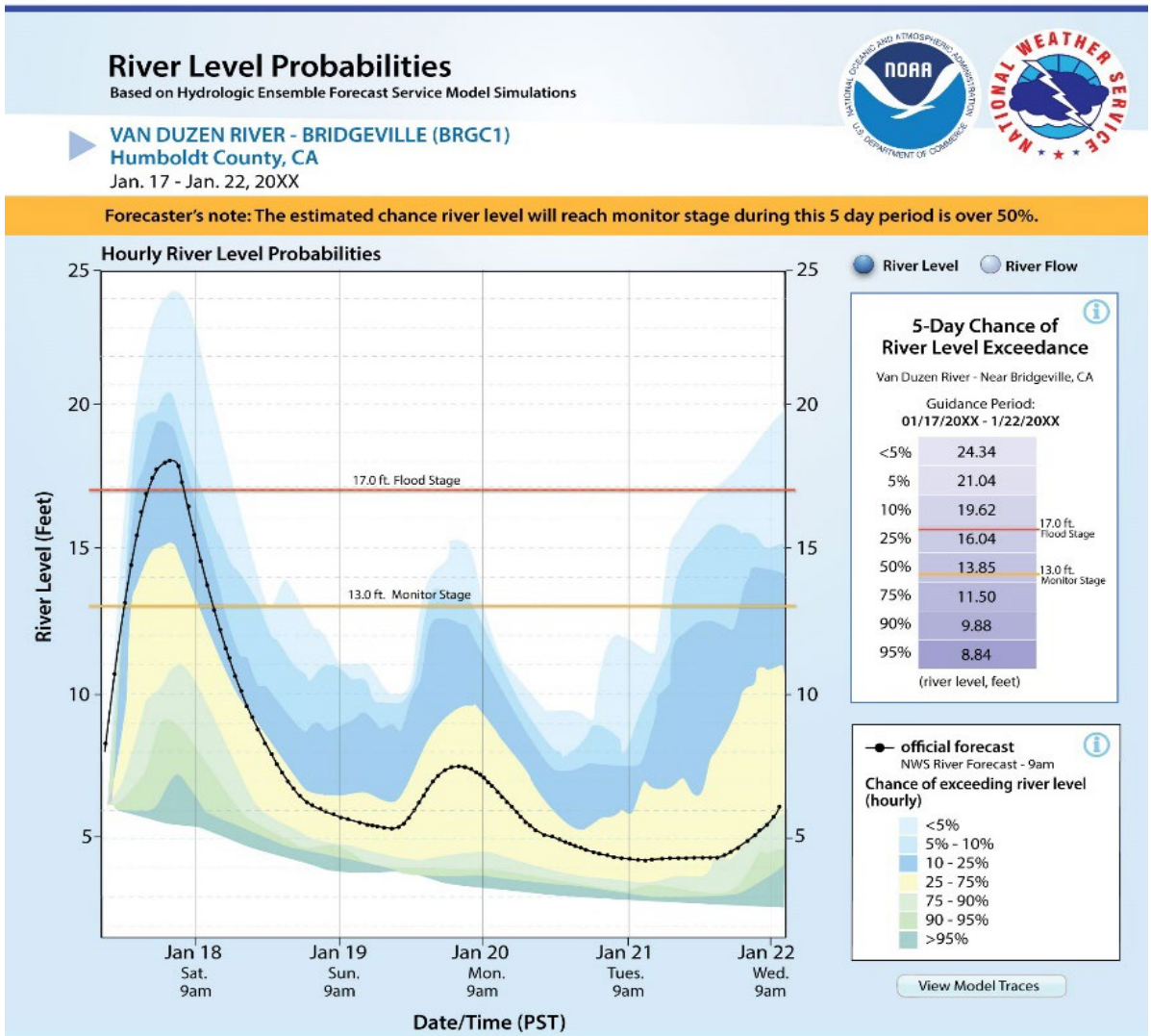
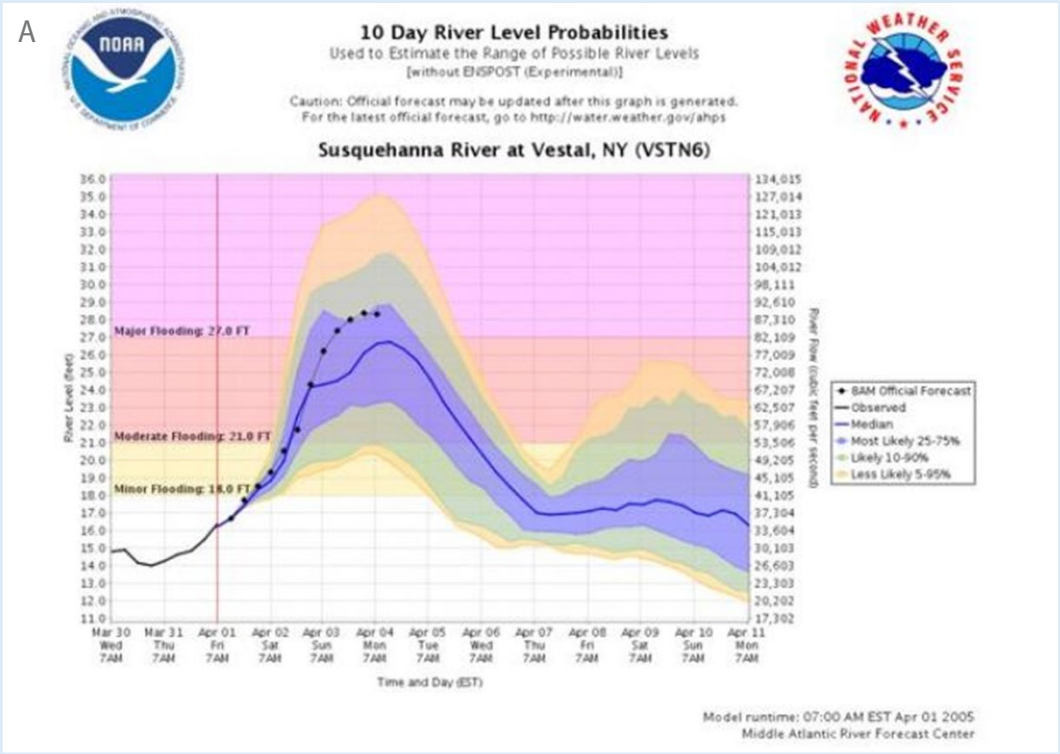


Figure 16. Regional HEFS product shown during the Eureka, CA focus group scenario in Round 1 (A) and Round 2 (B).



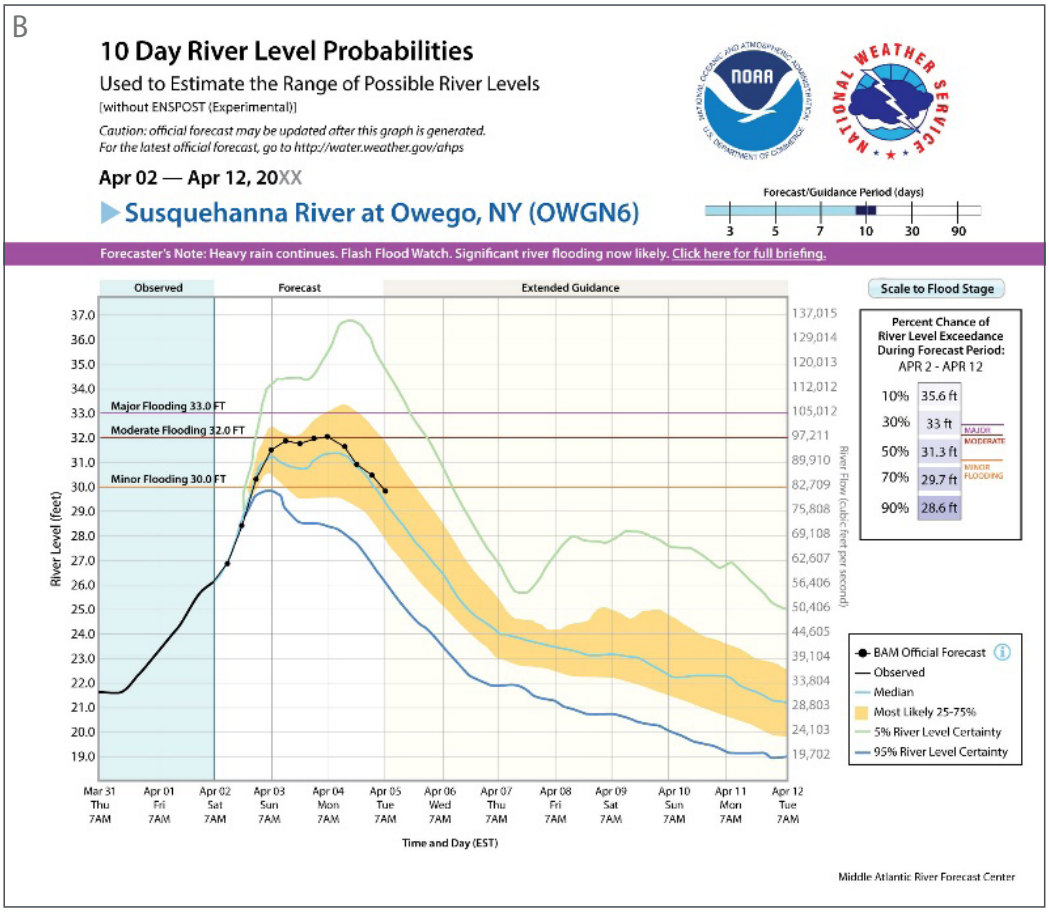


Figure 17. Regional HEFS product shown during the Owego, NY focus group scenario in Round 1 (A) and Round 2 (B).

New York - Owego

Water Resource and Emergency Management Professionals

Professionals in this session were shown the same scenario as in Round 1. In this round, the HEFS outputs were revised versions (Figure 17) that incorporated Round 1 feedback. Results based on the HEFS presented here respond to the revised mockups.

Professionals in this group had familiarity with both the hydrograph and probabilistic forecasts generally, though not necessarily the HEFS product (the Eastern Region's MMEFS has been issuing probabilistic outputs used by some professionals in the region for several years). Participants suggested they would use the probabilistic information in planning for emergency response as well as decisions related to managing water resources, such as *"whether I need to put in a stop lock closure"* or whether to notify county officials. Some participants, in trying to interpret the graphic, made errors, such as in misunderstanding how the probabilities related to the median line, and some suggested that they would be relying upon trained weather observers and other data for decision-making during events. Participants indicated that other information, such as forecast rainfall to the north, would help them when using the probabilistic forecasts. As with past sessions, professionals in this group requested information on what is included in the forecast, questioning whether factors such as terrain and elevation are considered in forecasts, and noting that briefings sometimes contain this helpful information: "*I want to know what they're taking into account to make this graph.*" Participants said the 10-day timeframe was helpful and as far out as they would consider to be potentially reliable, with some indicating that anything more than 7 days was unlikely to be reliable.

Participants made discrete design suggestions for the HEFS to make it more readable, such as enhancing the shading on the HEFS product to distinguish the forecast from extended guidance periods. The addition of a vertical bar graphic showing chance of exceedance, was well received by the audience. The forecaster's note was favored by the professionals, and it was suggested that space could be used to direct people to emergency briefings. Professionals in this group indicated that they needed the probability percentages to be listed alongside any text descriptions such as "most" or "least" likely, which are insufficient descriptions for their purposes.

As with past sessions, professionals in this group requested information on what is included in the forecast, questioning whether factors such as terrain and elevation are considered in forecasts, and noting that briefings sometimes contain this helpful information: "I want to know what they're taking into account to make this graph."

Noting when divergence occurred between deterministic and probabilistic forecasts, some participants suggested they would be following the deterministic forecast, which showed a higher forecast river level than the probabilistic ensemble indicated. Others said they would be looking for further information when forecasts don't converge, or when facing anomalous information, such as when the gage at Vestal shows significantly worse outcomes than Owego: *"What other information do I need to consider to make this more accurate?"* asked one professional. Participants said they would call the local NWS WFO to understand the difference between outcomes at the two gages, or participate in helpful briefing calls, which allow people to engage in a group conversation and ask questions together.

Participants said they would be preparing internally for flooding as far as four days out but would wait to notify the public of potential risk until certainty increased. They also said they would share the HEFS graphic with others, such as their county executive, for decision-making during acute events.

Participants appreciated the briefings shown in the scenario because they provide text explanations and other weather information in addition to river levels. Impact information issued through the flood warning was identified as extremely valuable, with one suggesting *"It's probably the most valuable thing that's been put up."* Others echoed that impact statements were important for validating messaging to the public. At least one suggested they would stop using the probabilistic within 48 hours of an event, because they need to get a story released to the community with more precise information on impending weather.

Residential Users

Participants in this session viewed the same scenario as the professionals. Residents had less familiarity with the hydrograph though some had experience using the product. Like those in other sessions, the residents asked to see historical events plotted on the graph to compare forecasts to damaging floods whose impacts were familiar to people. They also requested the chance to see nearby gages side by side, or displayed jointly, so they could consider the movement of water from the gage at Vestal to Owego, for instance, which participants indicated was important information for planning downstream. Participants requested that terms be clearly defined, including "action stage," which caused confusion that this was the level at which residents should act to prepare for flooding, even when flooding was not yet forecast.

When presented with the HEFS, participants generally welcomed the idea of longer-term probabilistic forecasts, even as some questioned the helpfulness of the very wide range of probabilities shown (95%-5% range): *"If I can prepare several days before, if it doesn't happen that's grand, you know, but if it does, I think it helps even emotionally and psychologically."* Participants indicated they would use the product for situational awareness and would check it daily to see how the situation was advancing.

In digesting the change from deterministic to probabilistic forecast information, some reported that the probabilistic information in the graphic made the event feel more intimidating, and that there was a "*more imminent danger*" than the deterministic forecast alone, while others found the amount of information to be off-putting: *"I wouldn't really take the time to decide what this chart means. I'd probably just glance at it and like, you know.., I could understand if I wanted to, but I'm not going to take time to actually look at it."* Others indicated they would use this as a secondary product once something else, like a rain forecast, alerted them to risk, and suggested that it would be helpful to have it paired with a rain forecast to clarify when it was time to begin preparing if needed.

Participants, as in the other sessions, requested more information about the elements driving the probabilities to determine how confident they are in the forecast: *"It makes people feel more secure in the decision that they're making, because they're not just going, ok, I saw this, so this is gospel, I have to believe this."*

Residents in this group were very familiar with briefings from the NWS WFO and said information from these briefings is shared in many formats, including the local fire wire. They noted that in-person visits from the NWS office after major flooding in 2011 was important and memorable and built trust in the forecast process and relationship with the local office.

Response to the vertical bar Maximum Chance of Exceedance graph was mixed, with many people preferring that format and others preferring the main river level graphical presentation. Overall, most agreed that a combination of the two products presented together as was shown in the focus group would be most helpful.

Residents in this group were very familiar with briefings from the NWS WFO and said information from these briefings is shared in many formats, including the local fire wire. They noted that in-person visits from the NWS office after major flooding in 2011 was important and memorable and built trust in the forecast process and relationship with the local office. Participants said impact information was helpful to include in briefings, along with soil saturation information, but that for residential users, limiting information to as few pages as possible and not repeating information (such as multiple graphics for snow details) would help reduce the frustration associated with low internet bandwidth that makes managing longer, high-image-based documents difficult and slow. Participants suggested sharing an abbreviated 2-page briefing for residents and reserving more detailed information for professionals.

When probabilistic and deterministic forecasts diverged on the HEFS, several participants indicated they would follow the deterministic forecast, and suggested that the steadily increasing probability of flooding from previous days would encourage them to be more cautious and to prepare.

Colorado - Gunnison

Water Resource and Emergency Management Professionals

Participants in this session were shown the same scenario as in Round 1, but with revised products for the HEFS (Figure 18) and hydrographs. They were familiar with the hydrograph but noted that the version shown in this session was much "cleaner" than what they had seen previously.

Initially, professionals received the ensemble information favorably with positive descriptions of it: *"Visually, I think it's pretty good ... everything is right there, not hard to decipher."* They also gave specific suggestions for improving understandability, such as using a solid line for the deterministic forecast in the first few days of the forecast, and then transitioning to a dotted line for subsequent days to indicate increasing uncertainty.

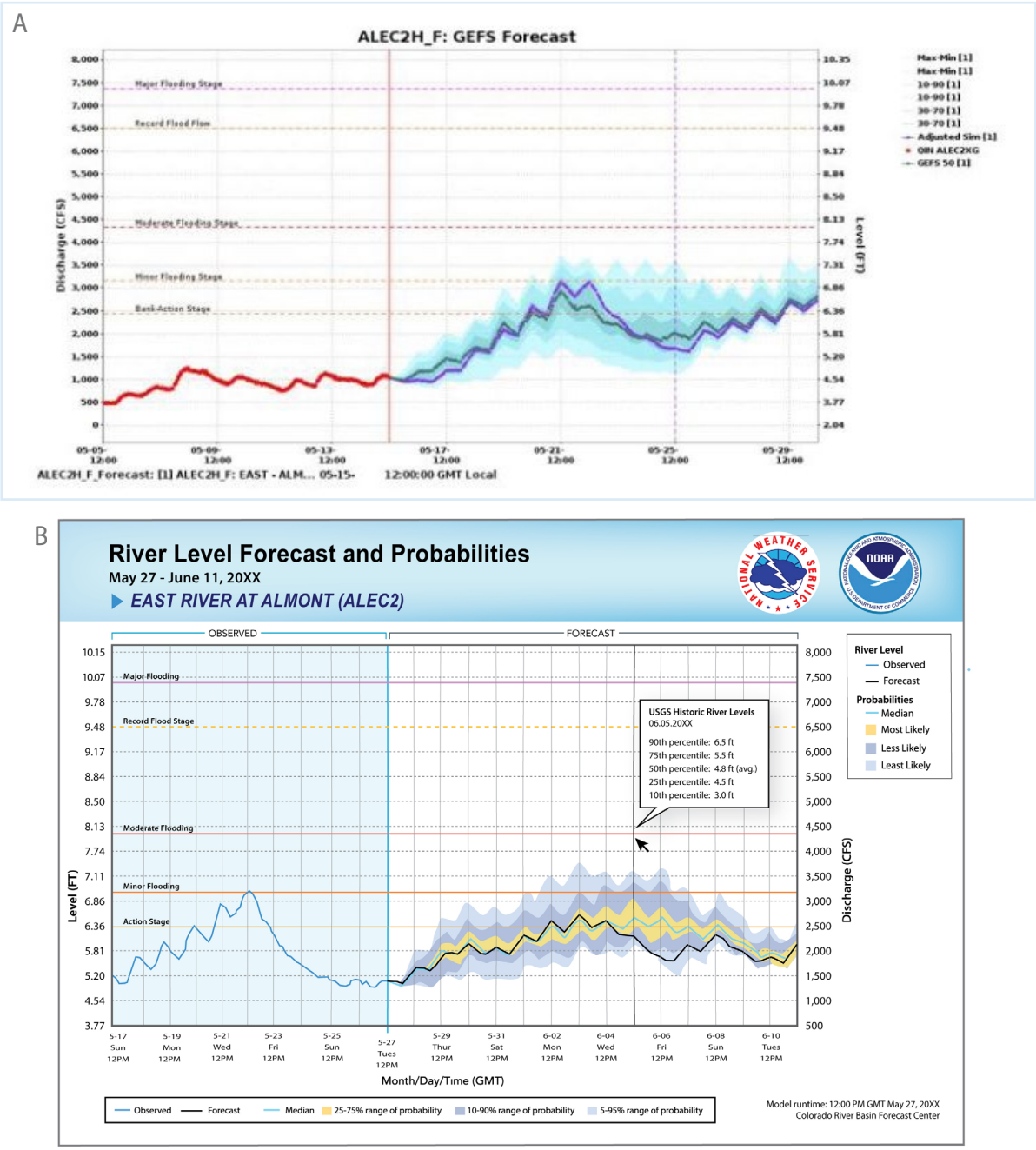


Figure 18. Regional HEFS product shown during the Gunnison, CO focus group scenario in Round 1 (A) and Round 2 (B). Durango had similarly designed graphics.

As the scenario unfolded, participants had questions about what was driving the ensemble forecast, especially when trying to understand why it diverged from the deterministic forecast. They asked for information to understand if the ensemble was based on historical data or weather models, with one noting, *"Otherwise... you're not quite sure what it's really telling you with all the probabilities."* As in other sessions, participants indicated they would like to know the past performance of the model to understand its reliability. One participant asked directly: *"It's almost like, why are we using these models to do this forecasting, if then the deterministic forecast is so much different than the models?"* Another said showing a product that had a divergence in forecasts to their stakeholders would cause a lack of trust and suggested his audiences would say: *"Well, that's why you shouldn't use those damn models."* Another indicated that a different sort of risk product that showed a maximum potential along with the deterministic might be less confusing, with one participant noting: *"It would seem if you show this to like five different people, each one could come out with a different interpretation of it."* It was suggested that a product that showed the deterministic with a high end and low end probability attached might be simpler.

Some participants indicated that if this product were available to them, they would refer to it to understand the probabilities of various scenarios; some indicated they would use the deterministic line as their primary go-to for decision-making, knowing that the forecasters had "*picked a black line*" and indicated that they would call the RFC and WFO when the ensemble showed any information that called the deterministic into question for any reason.

Professionals expressed concern that the product might be difficult for public audiences and questioned the feasibility and usefulness of a "one-size fits all" product. They responded favorably to an interactive feature on the ensemble that would allow users to see historical levels for a given date, to compare the forecast to historical data, and indicated that seeing percentiles in this feature was more helpful than merely showing maximum flows for that date. Overall, feedback on an interactive product that showed historical and forecast data together was favorable.

Overall, feedback on an interactive product that showed historical and forecast data together was favorable.

Residential Users

Participant response to the probabilistic forecast was mixed, with some initially finding the probabilities helpful. When the forecasts diverged, participants were confused and sought understanding and more information, and at least one participant found that watching the progression of ensemble forecasts over a period of days was helpful in building trust in the product. Participants felt more trusting of the product when the ensemble and deterministic forecasts began to move into closer alignment. Some participants indicated they would rely more on probabilities, with one noting they would be *"less likely to trust the human if there is a human aspect that goes into the forecast line."*

Participants in this session indicated that they used several sources of information to determine the weather, which they felt was different than surrounding regions – suggesting that a "Gunnison donut" or "Gunnison triangle" changed weather patterns and also made radar less effective. As a result, participants indicated relying on information from several sources, including social media, emergency managers and TV. They suggested that impact information, such as would be released in briefings, was helpful.

Participants appreciated having historical data and suggested that showing past major floods would be helpful, but noted that with a changing climate, historical data may not be as valuable as it once was considered. Interactive data was appreciated.

Colorado - Durango

Water Resource and Emergency Management Professionals

Participants in the Durango group were shown the same scenario as in Round 1, but with revised HEFS and hydrographs. They were familiar with the hydrograph and found it useful for monitoring high flows, as well as low flows, citing that inexperienced water recreationalists can be at risk during low as well as high flows. They reported that they do not share the hydrograph directly but rather translate it for audiences, such as river outfitters.

Participants observed that recent weather trends did not seem to correspond to historical averages and that the period when streams would be running at their highest points are coming earlier in the season. They discussed that what's "normal" seems to be changing, and less relevant when using forecast products than assessing what is upcoming. The terms "future" and "outlook" were not immediately clear, and participants requested a relabeling of those terms.

Viewing the HEFS, participants had mixed familiarity with ensemble forecasts, with one recalling seeing a similar product earlier in the year and the others encountering this product for the first time. Response was favorable, with participants suggesting that they tried to understand different potential outcomes on their own already. They worried that the information might be too complicated and confusing for inexperienced users, based on past experience with people monitoring reservoir data: *"Everybody thinks they know what the hell is going on and they don't: they're clueless,"* and *"I don't know that I'm all jazzed about having this all out for everybody."*

Participants did indicate that they would use the probabilistic forecasts and also share it with others, including colleagues in other agencies, such as sheriff's offices, road and bridge departments, and elected officials. Noting that radar is not effective in their region, participants said that they would use these products for planning, but that during acute events, they must rely on on-the-ground observations and try to communicate that information back to the local NWS offices. Participants explained that probabilities would be helpful for focusing them on when to pay attention, but that even high probabilities were taken with some doubt: *"We watched 80, 90 percent chance of precipitation yield nothing, you know. And so again, it is voodoo. I read something coming out of the weather guys that says 80 or 90 percent, you gotta watch it close. But at the same time, there's a good chance that it may go on one side or the other."* Participants said these forecasts would be used as tools for being "vigilant" in monitoring weather, which they characterized as difficult to accurately predict and anticipate: *"You've got to be on the program constantly. It's a poker game. And you got to know that Mother Nature holds all the aces."*

Participants provided focused feedback on design of the HEFS, noting that understanding the percentiles was important for translating descriptions such as "least likely" and "most likely."

Examples of HEFS outputs showing interactive historical data were well received, with one participant stating that *"That's great, it saves another, how many minutes for me to track that other information down. The comparisons, um, while they don't tell you everything, it definitely can help to ... formulate your plan of action or if there needs to be one."*

Participants also indicated that when NWS shares information from other agencies in briefings, such as the NRCS' Snow Telemetry (SNOTEL) data, they need to translate that information clearly for people to avoid confusion, such as when a particular SNOTEL site has stopped functioning and residents misread the data, not understanding it is out of date.

Residential Users

Residential participants in this session were shown the same scenario as the professionals above. They had limited familiarity with the hydrograph and required a description of the product to understand that it was showing observed and forecast river levels. Terms, including action stage, were unfamiliar to some participants. Initial response was favorable with participants noting that the product could motivate them to start looking for more information and begin planning. As one said: *"... Maybe I should start thinking about what I should be doing,"* and another *"Inquiring to figure out what the heck is going on."*

Participants found the HEFS graphic readable and were mixed on its utility. Reactions reflected a lack of experience with the product, with one participant saying they would use them over time to determine their accuracy. Other comments reflected a range of interest in the product, with one suggesting the graphic provided "*too much information for something so uncertain – basic is great,*" while another appreciated getting a "*worst-case scenario*." While river flows were very low in the scenario, participants discussed the need for something like an "action stage" for drought, so they could understand the level at which the river was low enough to trigger needed actions like catching rainwater for household use, or preparing for possible fire: *"We're looking at the extreme of flooding now and we're also looking at the extremes of drought. I use the river for all kinds of things. I'm thinking ok, if the river is low it affects me."* Another participant suggested that in drought situations, it is not clear which actions people should take, and that the product might also include information about how to prepare for droughts.

Participants requested to have historical average data on the chart, because the river levels alone were insufficient for understanding what is "normal" or when action is needed. *"It currently supposed I know what these numbers mean...the levels. I don't know what normal level is,"* one participant explained.

It was also noted that as a standalone product, the hydrograph or HEFS may be difficult to decipher, but in context with the other products in the scenario, *"I can start to get a bigger picture. If I hadn't been following this for the past few weeks, and I just saw that (HEFS)...I don't know, but we happen to know that the river level's dropping because we have more information than what was on the graph."* One participant suggested arranging the graphics so they show progress over time, to let users know how the situation was changing, because a flat line during a low-flow season doesn't trigger much response, even if it reflects a risk situation.

When presented an interactive hover box that would provide historical levels, participants responded with enthusiasm and some confusion about what the percentiles meant, with one person stating: *"Now we're talking about math, I thought we were talking about the river."*

While river flows were very low in the scenario, participants discussed the need for something like an "action stage" for drought, so they could understand the level at which the river was low enough to trigger needed actions like catching rainwater for household use, or preparing for possible fire.

Impact statements provided as part of flood warning products were helpful and liked for being "specific."

Summary

In sum, the focus groups yielded a wide range of perspectives that varied within and across user types and regions. Certain elements in product design emerged as important, and trends in usage can be seen, but preferences for various products and the way they were displayed varied widely. Professional users, perhaps not surprisingly, often sought more detailed information than residents, but not always; conversely, residential users frequently had to work harder to extract information from probabilistic forecasts, but the information was also new and difficult for many professionals. Colorado residents expressed more desire for historical data to calibrate forecasts against a changing sense of "normal," and were familiar with this data coming from USGS; in New York, residents and professionals alike wanted to understand flood forecasts in the context of the NOAA flood data for recent memorable events. Most users wanted to see gage information presented in terms of river level, while in Colorado, water resource and recreation uses require water information be expressed in discharge or cfs. All groups emphasized that experience with the products would sharpen their ability to use the information, as would clearer understanding of what the legend elements were displaying.

Discussion

The purpose of this study was to learn the needs of professional and residential users for probabilistic information and to identify ways to improve delivery of probabilistic information using HEFS, hydrographs and emergency briefings. Research questions for the project were designed to elucidate needs for communication related to the timing of information, expression of forecast confidence, the influence of changes in probabilities on user confidence, display needs, and importantly, to identify whether and how the presentation of deterministic and probabilistic forecasts simultaneously can best be achieved to reduce confusion.

This section addresses these research questions and draws from focus group and survey data to highlight trends and important considerations that emerged from the audiences.

How to time briefings for probabilistic vs. deterministic information

Discussion in sessions revealed that participants were very interested in receiving information such as is contained in emergency briefings and appreciated having a combination of impact statements and graphics in one package. Both professionals and residents said they would use them if available. Generally, participants understood that uncertainty increases as forecasts stretch into the future, and as such, used longer lead times, such as five days out, to monitor the situation and assess previous conditions, like *"how much water we've had,"* but began relying on forecasts for action in the period closer to two days prior to an event. Participants reported that they "*watch the trends*" to build confidence in the forecast, suggesting that showing the changes in forecast over a period of days is helpful for people to determine action steps. Multiple participants revealed that information about events affecting weekends need earlier attention because *"people who are watching things aren't working on the weekends."*

Discussion also revealed that for professionals, lead times are different for internal planning than external communication. For instance, one professional suggested that they would talk with emergency managers about a possible risk five days in advance but would wait to alert the public: *"So you need to start preparing for it, but you need to think about when you're actually gonna reach out to the public to let them know, and five days, you know, because things, that forecast is going to shift a lot over five days, so you just need to be careful about that part."* This sense was reflected by multiple participants across sessions, that longer lead times and the probabilities provided in briefing materials would be used as a "heads-up" and to plan for a worst-case scenario, while those briefings issued closer to an event occurring would be used to disseminate messages to the public and trigger action. Some participants found probabilistic information important until close to an event, to prepare for various impacts, but as one participant indicated, by two days prior to an event they need more certain information: *"It's a story – it's done. We gotta release information."* Participants also suggested that highlighting changes since previous forecasts would be helpful.

How to express varying levels of confidence across different forecast types, (low/medium/high flows) and geographic regions

Participants indicated that they welcomed direct expressions of confidence in forecasts, such as are sometimes included in forecast discussions, as one participant noted: *"When you read the weather discussion now it'll say, 'we have poor run-to-run agreement on the model. So forecast certainty on Sunday is low, but there's a potential for a [high] flood stage.' Whereas with other systems, they'll say, 'This is very widespread. We have high confidence in this.' So, it's more of a narrative thing - I haven't seen them present error bars on it, but it really gives me a better idea. And then I do my own looking at modeling results to see like, oh here's, here's the inconsistency and see what they're talking about."*

Another echoed that when discussing uncertainty, statements of confidence can be direct: *"When talking about that, just be really upfront about when they're confident and when they're just going (sound effect implying uncertainty)."*

One participant expressed frustration at the idea of a 50 percent chance, which he interpreted as a lack of information, and suggested that in areas of high uncertainty, indicating so is better than presenting uncertain data without explanation: *"If they don't know, it's better to say that, but yeah, it's like I'm looking for the forecast. 'I don't know' is not a good answer."*

Some participants felt that the utility of the hydrograph was decreased by the geography of their region, including the influence of snowmelt, which can significantly affect river levels. To address this, a professional said he sought out more information about snowmelt than the hydrograph provides, suggesting that forecasts could link to ancillary information to improve user trust in the product: *"You can start giving yourself some more confidence and they're just running through a model and it does not handle the geography here very well."* Additionally, longer-term forecasts, considered important for planning seasonally, should also be explicit about the level of confidence. For instance, referencing an integrated product for fall river flows, participants said expressions of "pattern shifts" indicated in the product were helpful cues about how to follow the forecasts for the season. Participants also said they applied their own understanding of meteorology to forecasts when determining confidence; for instance, one participant indicated variable confidence in historical trace information when applied to low-flow events vs. event-driven precipitation, suggesting that historical traces are not trusted as well for heavy precipitation. This tendency to interpret products based on user understanding may suggest a need for forecasters to be explicit in describing the relative level of certainty in products.

Participants expressed understanding that forecasts increase in uncertainty as they extend into the future, but said they needed more clarity on the difference between terms like "forecast" and "outlook" and "guidance," and needed the products to contain clear explanations to distinguish between portions displaying near-term forecasts with one level of certainty and extended forecasts with decreasing certainty.

Overall, participant feedback suggested that they relied on personal experience as well as environmental cues to develop confidence in the products, and that direct explanations of confidence in forecasts would be welcome information. Specifically, one participant suggested that the forecaster's note as shown on mocked-up HEFS products could be a location for a direct expression of confidence, or a location to identify significant changes since past forecasts for those who are following trends. Additionally, a participant noted that a clear impact statement could help influence the reader's perspective on how likely a risk is to occur, and overcome a tendency to ignore out-of-sight risks: *"Well, even knowing that houses and businesses are being inundated kind of gives a sense. Even if you're nowhere near any of this, it's kind of like, oh, god, this is actually, it's happening, like it literally is right now happening."*

How changes in forecast probabilities over time affect user confidence

Participant discussion in focus groups revealed that both professionals and residents prefer to monitor forecasts for a series of days to determine confidence, and that watching products change over the course of days influences their concern level more than seeing just one stand-alone forecast. Many expressed sentiments such as stated by one participant: *"I also watch the trends, the changes. Even though I'm not sure if it's going to happen or not. I still watch the trends."*

Watching a series of products was frequently noted as a way to improve one's confidence in the likelihood of a forecast: *"Yeah, now I'm starting to see that trend of steadily increasing flows. And it's not tapering off within this forecast. That's definitely getting my attention."* And further: *"I mean, I've been aware of the next day or two days at this point, but now seeing the further trend, ... eleven, twelve, thirteen days out. And it's not getting any better. And that's definitely getting my attention."*

Monitoring trends on hydrographs, a participant indicated that consistent peaks from day to day "*makes me more confident*." And noting the probability of reaching peak stages on an early iteration of a probabilistic forecast in Eureka, one participant followed the changes from day to day to determine his confidence that risk was increasing.

Participants also indicated that, when faced with changes in forecast information, they are inclined to seek out more information to determine what is happening: *"I mean when there's a big storm event coming, I look at multiple sources to try to figure out what everybody's talking about it because nobody knows that 100% for sure. But if you've got, you know, the front, looking at the weather channel and my radar and the National Weather Service and I sort of get a better picture when I put lots of things together because I, I, I don't know that any one of these graphs is—really the one I want, I want to pick to look at, there's still uncertainty. I just want to look at everything."*

Some professional participants suggested that their experience with forecasts that did not materialize as indicated eroded trust in current forecasts, while others looked to model consistency to develop confidence. *"I look at our run-to-run consistency. You look at the model runs and then if your next day, it's completely different, the next day it changes back again, I'm like – Ok, this is really low confidence."*

Residential audiences less familiar with the products saw consistency in forecasts from day to day as verification of the forecast accuracy: *"It's getting more serious,"* said one upon watching increasing trends, while others weighed in, *"It seems to be verifying what the previous day was"* and *"this sort of reinforces what we saw before."* As such, it may be important for forecasters to acknowledge and explain any significant changes in forecast trends and, following the previous suggestions for direct communication about confidence, find opportunities to explain changes. Lastly, some suggested that discrepancies in forecasts were most important when the risk was large, but in smaller, flashy areas where small floods come and go quickly, sudden changes were better understood and tolerated.

How display needs of these products vary for different users (i.e., water managers vs. public)

Needs of residents and professionals for product information varied widely. Generally, residents favored simpler information with an emphasis on expected impacts. For instance, residents asked that flood levels be clearly linked to expected impacts on hydrographs and HEFS products, *"so that when they see the color, the graph or whatever, they're really already thinking about the specifics as opposed to just watching the numbers."* Direct statements of expected impacts, presented in various ways across the focus groups, were valued by residential participants: *"Those kind of, that verbiage, is very helpful. Be able to anticipate things. Rather than just looking at a graph"* and *"I'd like to have a specific of where... they explain what they're expecting to happen and where."* Participants expressed that geographic regions are important and that terms, such as "Upper Colorado," needed to be clearly defined so users could locate themselves within products.

For both sets of users, design characteristics were critical to conveying the information. For instance, one draft product used the color red to indicate the range of probability of reaching flood levels, but residential users misunderstood the color to mean danger, rather than confidence in a lower river level: "We look at red, and we think risk."

Professionals had specific needs, including requesting that the 'monitor' and 'action' levels be clearly indicated on hydrographs, as well as tidal information, where appropriate, which can combine with high rainfall to create increased flooding. Professionals also suggested that text information *"in a couple of sentences in clear language"* that would accompany graphical data would be very helpful.

Knowing which elements are included in the creation of forecast data was critical to professional users, who asked in many sessions what was included in a probabilistic forecast, with one participant asking a question representative of many throughout the sessions: *"Is there a dam on the system? And does this account for dam operations? Because they might be kicking into some kind of emergency, and kicking up the flow, so does this account for those types of observations?"*

For both sets of users, design characteristics were critical to conveying the information. For instance, one draft product used the color red to indicate the range of probability of reaching flood levels, but residential users misunderstood the color to mean danger, rather than confidence in a lower river level: *"We look at red, and we think risk."* Further, the use of color in products needs to be consistent across products and periods of time: *"I would point out that those colors change all the time depending on the map. And you have to look at things and be like, oh it's red. And you're like, oh well today red's only over one inch. And other maps they'll be like, oh red means eight inches."* Other comments emphasized that word choice in product design could help understanding or could distract users with unfamiliar concepts. For instance, one participant noted with support from the room that the phrase "river level exceed-

ance" was strange and that "*exceedance is a word nobody, absolutely nobody, uses.*" Conversation centered on this terminology for some time, slowing understanding of the product data. Variants of HEFS with many different colors caused some confusion for participants who described the graphics as looking, for instance, "*Like a tie-dyed shirt*," distracting from understanding One cleverly explained how the complexity of the information affected his decisions to take action when presented a probabilistic product showing potential flooding: *"If you really want to catch my attention, they have to get a lot, a lot more simplified and more cartoony. At this point, I would still be playing video games."*

Describing the probabilistic products as complex, residential participants and professionals alike favored any information that would instruct users how to read and understand probabilistic information, and suggested that absent that information, they may just skip over the product because they are uncertain how to use it in decision-making. One experienced professional explained that without a description of the HEFS, *"I'm not sure I would have sussed it out on my own."* Participants requested tutorials, including text and videos, to explain how the forecasts are developed and how to understand the graphics.

More advanced users requested advanced product development, with one professional asking if the HEFS could show different scenarios based on dam management models or show a spatial display of probabilities across a watershed rather than only gage-specific. Participants also requested to see multiple gages at the same time, as they frequently used multiple gages to assess risk. Professionals noted that emergency managers often use data from the field on a mobile device, and that data needs to be easy to use via cell phone, and that graphics also need to be easy to capture for sharing with others.

As demonstrated in the survey results as well as focus group data, the forecaster's note was a welcome addition to products, with one professional saying: *"I think it's a quick way to analyze the data. Because... a lot of people aren't gonna look at this graph and necessarily understand it, so they can just read that note - oh, then we should probably you know, consider this."* Others noted that it was also a good way to communicate with trusted forecasters *"I think it's a good opportunity to have the forecasters...sort of personalize and customize it to what they're really saying."* Another requested that such a note also be included in an interactive platform for probabilistic data, to help users understand the key information as they set their own parameters.

When trying to portray probabilities, adding text categories to percentiles, such as "more likely, less likely, least likely," was helpful for many residential users, though some professionals worried that the idea of "most likely" could confuse users who are also viewing the deterministic forecast, and may opt to consider the "most likely" as the perceived intended forecast. Professionals frequently but not exclusively favored use of percentiles, with one suggesting: "*(F)or what we're doing, for our line of work, percentile is more interesting and more understandable.*" Combining percentiles and categories worked to meet the needs of both users.

In addition to distinctions between professional and residential users, needs among the regions varied as well. For instance, in Colorado, which included a low-flow scenario, participants requested action thresholds for a drought phase, similar to that provided for flooding, and further mentioned that users need information about how to prepare for impacts from sustained low flows. As one user explained, in their region *"it's not just high flow conditions, low flow conditions can cross an ecological threshold, they could cross an ecological threshold or some kind of infrastructure threshold or just, the river's going dry. So, if those thresholds are known, then we should also be shown."* Users in Colorado also expressed a preference for hydrologic information expressed in cfs, compared to California and New York, where users strongly preferred receiving information about river levels/stages. Historical data was important for many users, especially in Colorado, where users expressed the most familiarity with receiving historical river flow information. Presented an HEFS showing low flows, a user described challenges in deciding whether they were at risk: *"It currently supposes that I would know what these numbers, mean... the levels. I don't know what a normal level is so...I appreciate the information, but I don't know how to read it. So when you say historical river levels, record flood stage,... can you just give me one like what's the highest it's ever been, you know?"*

Across all regions, both professionals and residents expressed a desire to "ground-truth" the accuracy of probabilistic forecasts...

Across all regions, both professionals and residents expressed a desire to "ground-truth" the accuracy of probabilistic forecasts, and suggested that seeing the past performance of probabilistic forecasts would help ascertain confidence in current probabilistic forecasts: *"... I would like to see past history of how the probabilistic versus the deterministic forecasts perform, before I would say, I trust one or the other. So really this doesn't, for me doesn't do a whole lot, because it just shows and from the public, I think it probably is confusing because, they're gonna, they're gonna, they, many of them understand less about statistical and modeling than those of us do, are going to be like, why is it so? Because I understand now, but it's like, I understand maybe they're trying to show that, you know, this is all a crapshoot. I mean forecasting the weather is not something that is easy to do."*

Overall, participants expressed that help in learning what data is available, and organizing how it is presented, would be helpful for users trying to digest information. Information overload and the confusion from too much visual data was identified as a challenge. Participants in one location wondered how they would find flood watches and warnings in their remote region because they have limited access to broadcast media, while others suggested that all-digital dissemination (through TV and internet platforms) was insufficient, and that local officials need to post physical kiosks and signs to warn neighborhoods of impending risk. The idea of a "one-stop shop" came up several times to help people organize information, as well as a system that could organize various data sets by participant type, such as a portal for emergency managers designed with the key data they might require. Another participant suggested *"you could even make a forecast for natural hazards that could kind of summarize in narrative what the data is out there."*

How users tolerate divergence in probabilistic and deterministic forecasts

When probabilistic and deterministic forecasts diverged, residential and professional participants responded in a variety of ways, based on experience and their level of understanding of product information. Almost always, the HEFS forecast products had to be explained to participants, as well as the difference between the black deterministic forecast line and the probabilities described in detail. With repeated use, participants' sense of the utility of the product generally increased.

Professionals expressed an expectation that the deterministic and probabilistic would converge and struggled to understand why the deterministic forecast and 50 percent line weren't in agreement: *"Why on this graph does the deterministic exceed the most likely? Is it because of some setting you just change?"* Another said: *"I can't quite figure that. It doesn't make sense to me that the black line doesn't jive with, all the, all the fancy colors that are in there."* One experienced professional found the forecast very confusing when the deterministic forecast didn't align with the median: *"Now when I'm looking at this, I'm like, everything I knew was wrong. I don't know what they're doing."*

Some suggested that large divergences can cause them to believe the forecast is incorrect, as said one participant when probabilities diverged from the forecast, *"So like, they say that it (river level) has a low percent chance of being true, why should I believe the official forecast?"*

As mentioned earlier, if previous experience suggests that the probabilities are reliable, people will favor those instead of the forecast. When one participant noted that the deterministic seemed not to match the actual impacts occurring in the scenario, he said, *"The prediction hasn't been so good. That's what I'm saying. But the probabilities have been really good. They have been very consistent with reality so I'm feeling really good about it."*

If given information about the reason for the divergence, users expressed increased confidence in the products. *"(S)o you, you made the point that the deterministic is different*

than the probabilistic, and that the, the black line is not following the average of the probabilistic, so you're actually in two different methods here to calculate those two things. And so it would be useful to just have a button or something that describes how each was calculated. And so that you understand that there actually, the black line is not the average of the probabilistic, it's a different method." Another echoed: *"And so, um, is yellow, so the middle of the yellow zone, is fifty percent probability. So according to fifty percent probability, you're not even gonna hit your monitor stage or you're nowhere close, but your deterministic is saying that you're going to be in the flood stage. And so, um, at this point, you need to understand, as a professional you need to understand the difference, the, why, why is that difference there? What is that indicating? So you need to understand the methods behind it, and maybe in that information, like I've talked about earlier you have some description of why, why you might see those differences. Just so you can interpret it."*

Another suggested that people "*are going to freak out*" if the forecasts diverge, and that the divergence must be explained to avoid panic. Participants suggested that forecasters could "flag" forecast information that doesn't immediately appear sensible, such as a probabilistic forecast that diverges from deterministic data. One said: *"...I mean if there is something that is suspect on a gage or in a forecast, then it would be good for it to be flagged as yes, the model is showing this, but for whatever reasons, you know, so that the information is suspect, you know...."* Another said, *"I think uncertainty is good to display and communicate...better than not knowing that cause they're being hesitant and pulling back because I don't want to freak people out but I'd prefer to know about the uncertainty in the forecasts."* Still another suggested that without explanation of divergence, it would be hard to make decisions: *"Yeah, I think the first question would be, why is the black line so far out of all the probabilities? And if that's not explained on the page anywhere, ...I don't know what to do."*

As with other decisions, users sometimes relied on experience to decide which of the divergent forecasts to follow. One participant when faced with a divergence said *"The deterministic doesn't make sense to me knowing our river because that's, I don't think that's when we'd have peak flow so... I would throw that one out and look at the trend on the other line as being more realistic."*

As demonstrated in the survey data, both professional and residential participants across all regions acknowledged overwhelmingly that when faced with a discrepancy, they would seek more information. One said, "This would make me come back and check it three days later and see what the trend's doing."

As demonstrated in the survey data, both professional and residential participants across all regions acknowledged overwhelmingly that when faced with a discrepancy, they would seek more information. One said, *"This would make me come back and check it three days later and see what the trend's doing."* Participants suggested adding a phone number for the issuing office directly on the product so users can call the forecasters to ask questions, "*Cuz that's what I'm gonna do,*" said one professional participant. One said he would start looking to other products and forecasts to decide how to proceed: *"This would make me want to look for other information. So I look at the um, uh, forecast models for precipitation and really just start following those and seeing are those lining up. And then also really talking with... Like I would talk with the forecaster at National Weather Service and just try to get more information. You get an idea of their confidence."* Another echoed that without explanation, the divergent forecasts were not viewed as trustworthy: *"I'm going to be skeptical. I'm going to look at it... I'm not going to do much until I talked to somebody who's in this equation. What's this forecast process?"*

Whether people favored the probabilistic or deterministic when they diverged depended on several factors, with some relying on probabilities because they afford more information or because they felt like models with *"all of the different data points"* would be more trustworthy than the "*human aspect that goes into the [deterministic] forecast line.*" Perceiving this data to be more reliable, one user said: *"I would trust that a little bit more than the forecast."* Others suggested a growing preference for probabilistic as their familiarity grew with them during the scenario: *"The probability is always nice now, since like now that they're on there, we've seen them, I don't*

really trust the black line." A professional with experience with forecasters said they would favor the deterministic, knowing that forecasters are behind the product and *"they have picked a black line."* Other professionals suggested they would simply refer to the deterministic forecast on a daily basis, to reduce complication in the face of so much data: *"I mean, you could run a million scenarios in a model, but at some point that becomes somewhat useless."* Some participants expressed a tendency to prepare for the higher forecast if flooding is a risk, to be ready *"So I'm not gonna go with the forecast,"* said one. *"I'm gonna go with higher than the forecast."*

Some users favored the longer time horizon the probabilistic models provide. One noted that the uncertainty in the deterministic forecast is already there, but that the probabilistic models "*makes it more easy to find, I guess."*

Nonetheless, users reported that a very large divergence can cause a loss of faith in the models running the forecast: *"It's almost like why are we using these models to do this forecasting, if then the deterministic forecast is so much different than the models? Because typically you would, you're using the models to help you make the forecast, so your deterministic might be a little bit different than the models. But if your model is that bad, why are you?"*

As such, professionals indicated they would be hesitant to share such an example with the public because it would be hard to explain, noting that the *"kind of people that call"* them to discuss weather would see a divergence and say *"well that's why you shouldn't use those damn models."* Presenting explanations of the reason for the discrepancy was an important request to counter this concern.

How deterministic and probabilistic river level forecasts can be presented simultaneously without causing confusion for the user

Even as they struggled to understand the occasion of divergence between probabilistic and deterministic forecasts, participants overall welcomed the presence of probabilistic forecasts alongside deterministic and sought information to help make them usable and more understandable. As noted above, users requested clear explanation of any divergence, noting *"Just the explanation behind why there's that much uncertainty would be really helpful."*

Even as they struggled to understand the occasion of divergence between probabilistic and deterministic forecasts, participants overall welcomed the presence of probabilistic forecasts alongside deterministic and sought information to help make them usable and more understandable.

Product descriptions that added text explanations were also proposed to help the user take in the data from the graph: *"Maybe summarize what we're looking at here. We're not just looking at a graph. Okay. What's happening tomorrow? Like you know, you want to have a brief understanding of what you are looking at before you look at it."* Participants requested user tutorials that explain the use of colors, the forecaster's note, the percentiles and other legend details, with one stating that it would make people *"feel more confidence in what they were reading and looking at."*

Other considerations

Differing geographic regions had varying levels of familiarity with probabilistic information and hydrologic forecasts in general. In New York, for example, users were much more familiar with and trusting of the hydrograph's deterministic forecast, which appeared to make interpretation of probabilistic data around the forecast easier for new users. In contrast, participants in Colorado tended to rely upon historical data rather than forecasts, making use of probabilistic forecasts slightly less familiar upon introduction. Getting users to adopt HEFS products, therefore, may require different approaches by region. In places where the hydrograph is familiar and trusted by public and professional users, the probabilities could be easily absorbed into the data flows people use for personal and professional use. In places where the hydrograph is less well known and trusted because of geographic factors, the probabilities could be presented to new users as helpful tools to decipher the range of possible outcomes in a region where people already expect uncertainty.

Recommendations

Our recommendations are organized in three tiers: national product, regional products, and general decision support service best practices.

National Product

Based on the findings from the Round 3 survey, we propose that a prototype (Figure 19) as tested in that survey will be suited for meeting the needs of both residential and professional users.

This graphic was developed with the most favored elements of the products tested in each of the three regions, and with strategies designed to improve user understanding. Recognizing that a one-size-fits-all approach is impossible, this product nonetheless aims to provide maximum utility to the broadest set of users – combining, for instance, preferences for cfs and river level into one product as well as numerical representations of probability along with "likely" categories, and adding a vertical side bar graph showing river level exceedances to help interpret the graph. A forecaster's note, which ranked high in all survey data, is prominent, and formatting is designed to be standard and easy-to-use across all regions.

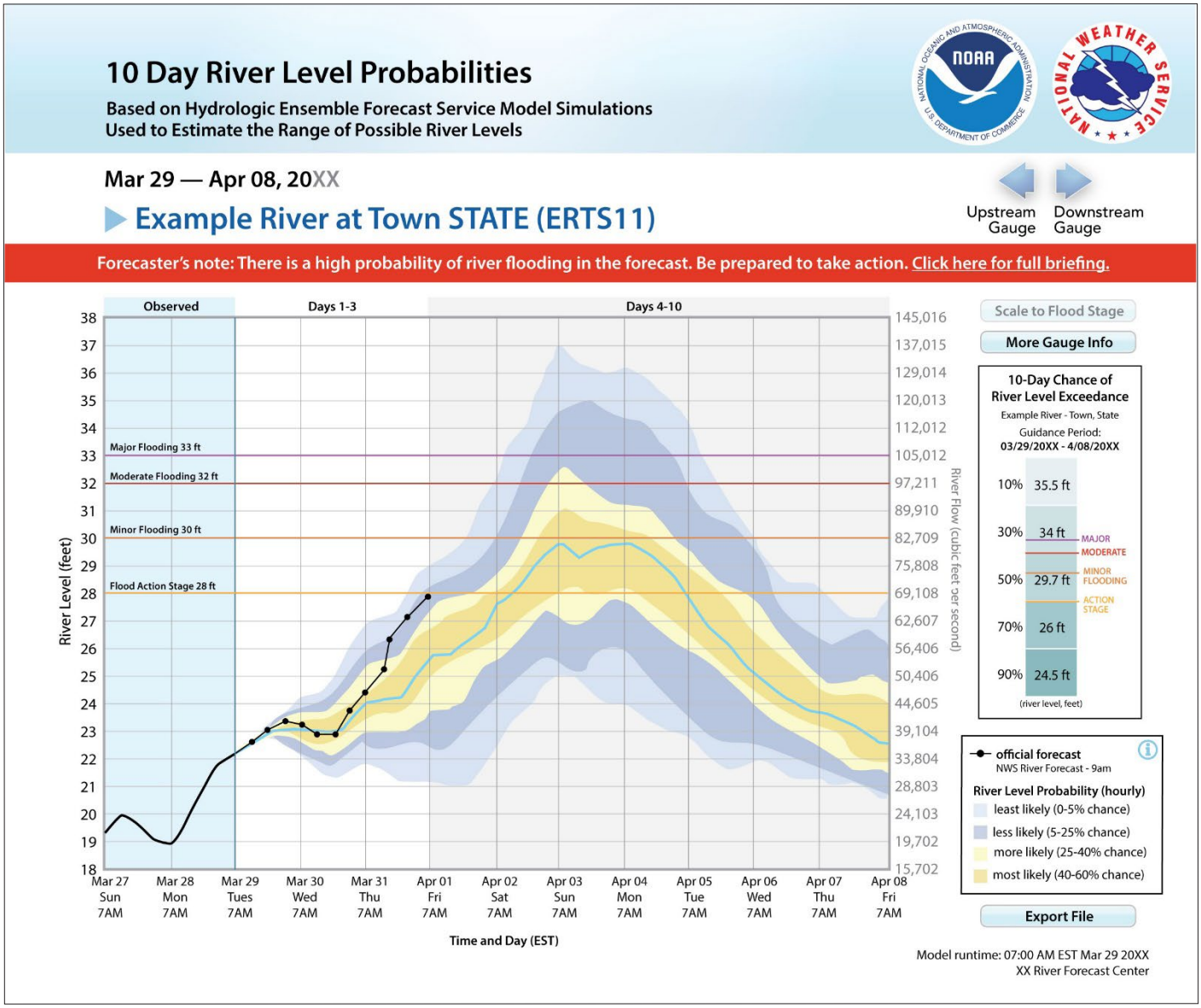


Figure 19. Proposed national HEFS product tested in Round 3 online survey.

As part of the final online survey, participants ranked their favored elements in this national product. We provide that data here in the graphic below (Figure 20) to help illustrate the most critical components. (Note that one element, the "Scale to Flood Stage" button on the top right, ranked last in the survey, but was considered important information during the focus groups; we expect that the fact that the survey product was already scaled to flood stage rendered this option moot in the rankings, and nonetheless suggest that a national product should have a way to showcase river levels relative to flood levels, as this is frequently needed and requested information).

This product includes a proposed method for sharing historic river level data gathered from USGS, which serves to situate a given day's forecast river level into context of the low, average and high data from that date compared to the previous 30 years. Other approaches for sharing a fuller range of historic information data were considered and dismissed in an effort to streamline and simplify the national product to meet the needs of the greatest number of users. However, the HEFS platform could also develop a complementary product that shares the probabilistic forecast levels in conjunction with a more complete display of the historic river levels for the same period (with the historical levels demarcated by patterns as an overlay to the colorized probabilities.)

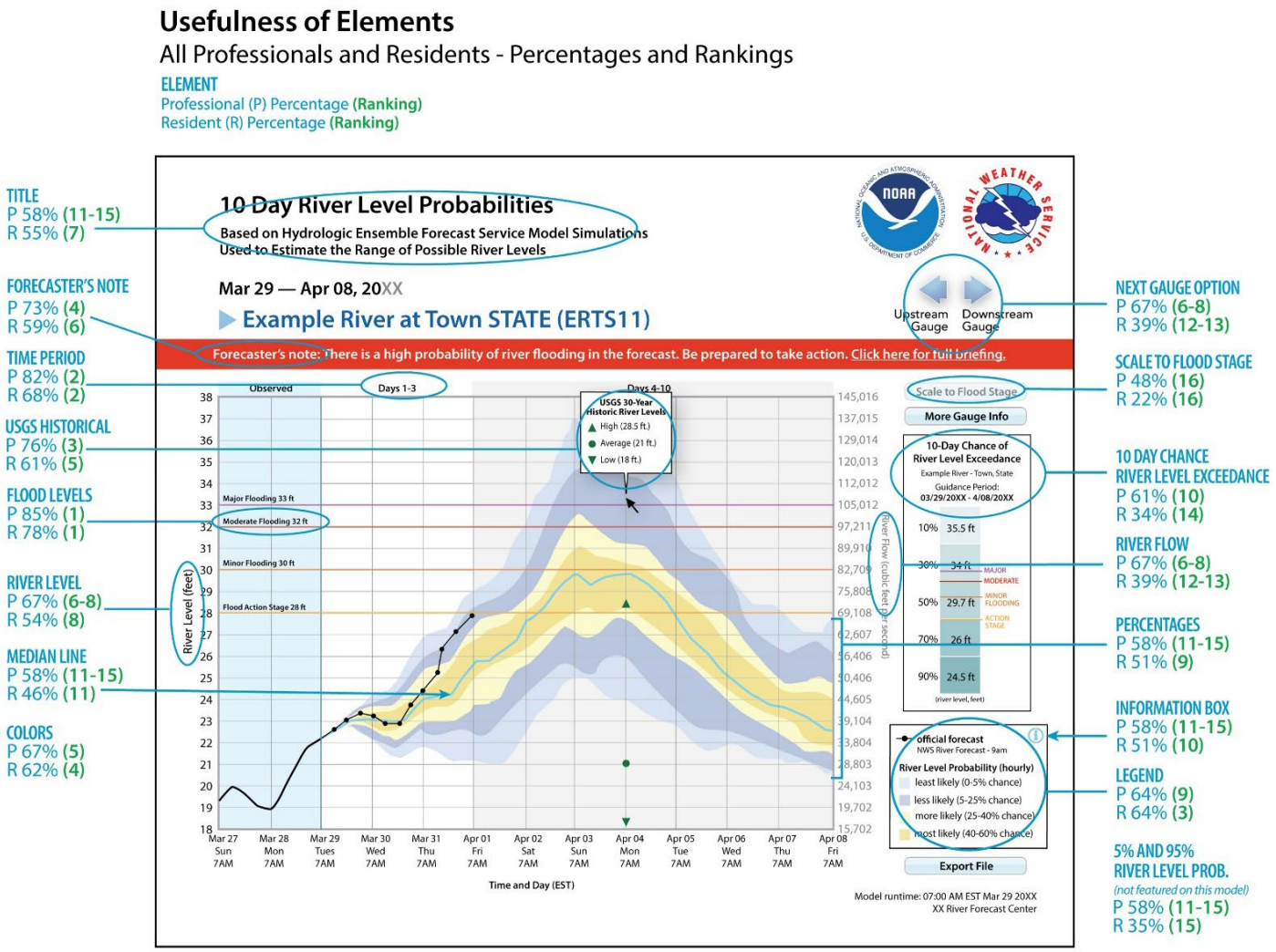


Figure 20. Graphic showing usefulness of various elements: percentage of professionals (P) and residential (R) participants indicating the element was useful is demarcated in blue, while overall ranking of the elements with 1 being the most preferred is shown in green in parentheses for each. (Note: The annotation on the legend indicating hourly model runs can be adjusted as needed for operations; this is placeholder text.)

Regional Products

While a national product will help provide a standard for delivery of information across the country, feedback from focus groups in each region nonetheless revealed a need for region-specific information, delivered in formats that are comfortable and familiar to users in the area. During focus group conversation, participants relayed stories revealing that each community had a unique and important culture of cooperation with local NWS offices and established patterns of communication that had developed over many years. As such, regional offices working to communicate probabilistic information may require specific modifications to probabilistic data products to meet regional needs.

Many factors, including physical ones such as geography and population density, and social factors, including the history of a community's interaction with government agencies, will influence the amount and types of information needed. As presented below, for each region, a "regional product" was shown and tested in the Round 3 final survey. These products incorporated the feedback from both Rounds 1 and 2 and aimed to retain the specific elements that were critical to each region. Provided here are variants of a probabilistic forecast product developed for each region.

Colorado

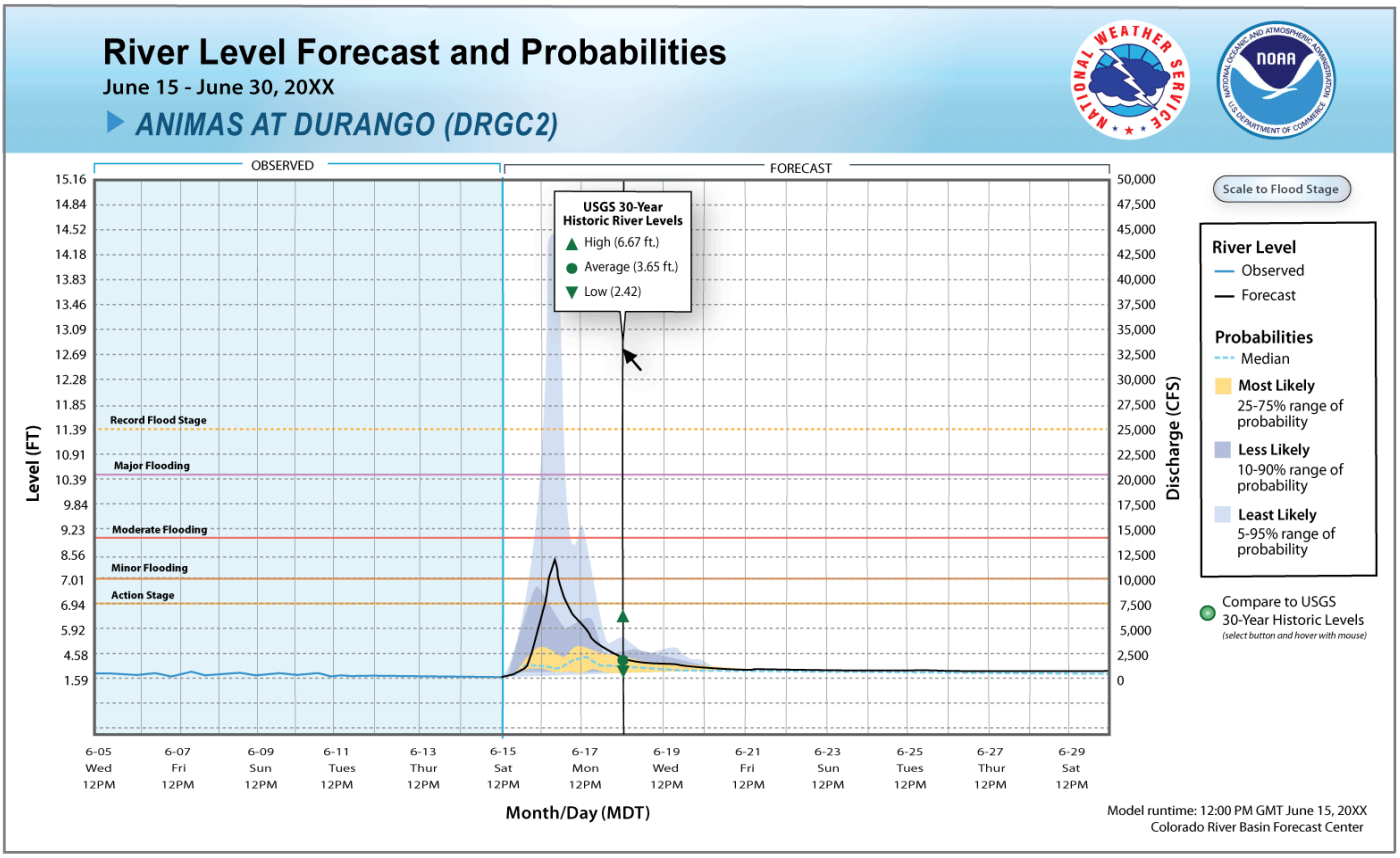


Figure 21. Final regional HEFS product shown to Colorado participants in the Round 3 online survey.

In Colorado, audiences frequently reported using historical river data from the USGS in planning for use of area rivers, whether for festivals or individual use, or flood or drought planning. This variant, therefore, displays this data in an interactive pop-up box, to help orient users to how forecast probabilities relate to historical high, normal, or low levels. Participants from this region expressed a special need for this information and therefore it should be considered in any regional variants.

New York

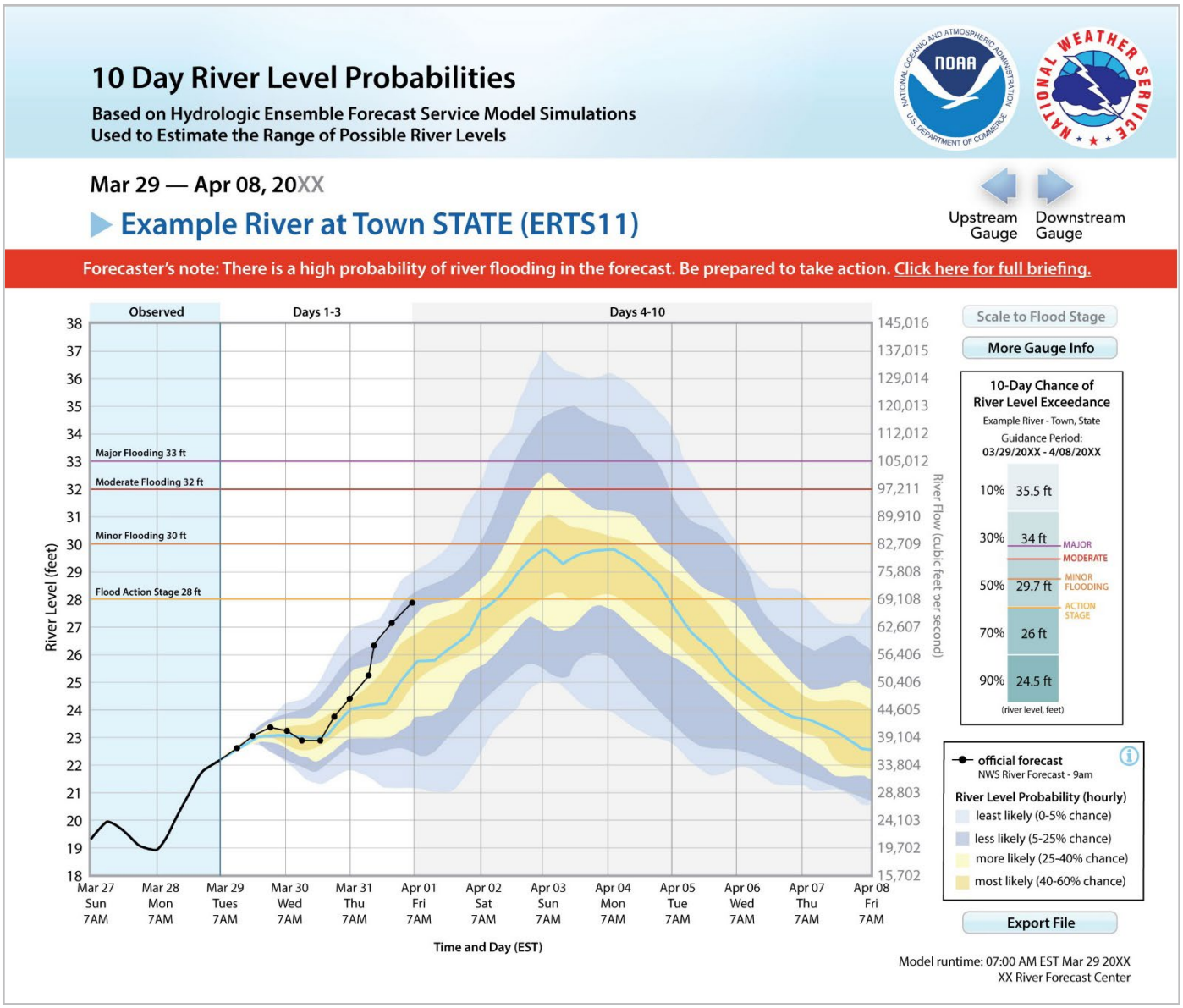


Figure 22. Final regional HEFS product shown to New York participants in the Round 3 online survey.

New York audiences particularly reported a familiarity with deterministic river level forecasts and relied upon those for planning, while also welcoming probabilistic data. Professional and residential audiences alike were concerned about frequent flooding and wanted to understand anticipated river levels. They expressed strong support for a tabular set of data that indicated probabilities for river level exceedance which was shown as a vertical bar graph on the revised graphic. This data was considered important for flood planning and also advanced understanding of the range of probabilities shown on the HEFS output.

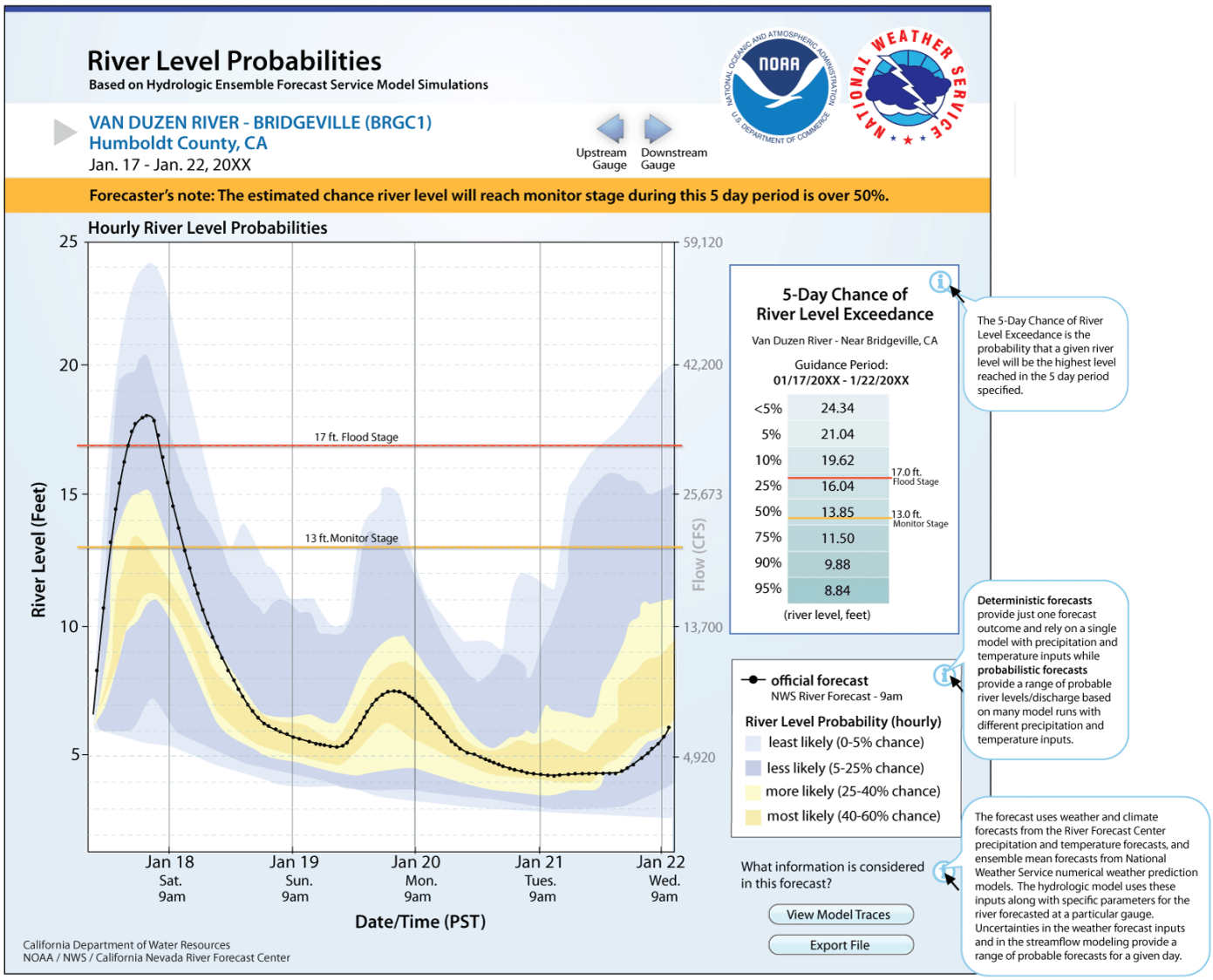


Figure 23. Final regional HEFS product shown to California participants in the Round 3 online survey.

As with New York audiences, residents and professionals in California were concerned with frequent flooding. In California, audiences had less familiarity and trust in deterministic river level forecasts than New York, but wanted to understand the probability of flooding. California audiences also expressed strong support for the vertical bar graph river level exceedance information.

Other Regional Products

In each region, the scenarios included other products used by forecasters during acute weather events. For instance, New York's scenario included information about snowmelt, soil saturation, and river levels at gages adjacent to the scenario location, as well as a spatial flood warning polygon map and a Significant River Flood Outlook product. In Colorado, the scenario was opened with drought information from NRCS and included a specific focus on a "Peak Flow Forecast" product that is shared by the CBRFC. Discrete focus group feedback on these particular products has been shared with project partners outside of this report, but lessons learned from communication about these elements helps to inform the decision support recommendations that follow.

Decision Support Recommendations

Product Presentation

In all communication, including products and briefing information, the need for titles, labeling and legends to clearly convey information is critical to allowing users to quickly and easily understand what they are reading. Our product recommendations reflect the need for careful use of color, legends and labeling, and also reflect extensive user testing.

- Avoid the use of acronyms, wherever possible and where they are essential, ensure that legend or title information clearly defines what the acronyms are and what they mean. For instance, if referencing a particular weather model such as the GEFS, this information should be explained in a legend, and the primary title should use plain language to describe what the product is showing (i.e., Observed and Forecast River Levels instead of GAGENAME: GEFS forecast).
- Eliminate or define any legacy coding text that does not help users understand what they are looking at. Users will work to understand such codes, and they may come to false conclusions or exhaust their interest and energy in the product while trying to decipher unknown and unimportant details.
- Explore opportunities for inviting user feedback into new products to ensure that messages are being clearly received. This is especially important for WFOs as they ‹‹£work with partners and others in their regions.

Interactivity

Users welcome interactivity in products and request the ability to define their own parameters and set their own categories for information. Professional users have expressed the importance of being able to define timeframes and regions, and to input data from NWS systems into their own platforms. Residential users are interested in being able to set only those data components that are relevant to them, to simplify, rather than expand, information. Both groups find interactivity engaging, and interactive platforms appear likely to encourage both sets of users to spend more time with data. Interactivity can also advance incrementally with the addition of information buttons as described below.

- Consider building interactive platforms of the probabilistic products that default to the simplest displays and most basic components of information, and which allow experienced users to add more complex data.
- Include the ability to preserve data choices so that the product can be frequently revisited by a user without having to be redefined each time. Toggle options could include the deterministic forecast, fewer or more percentile breakdowns (i.e., only extremes, or 25-50 percent ranges, etc.), median line, and traces. Other parameters could include a user-established forecast period (3 days, 7 days, 10 days, longer periods, etc.) and the possibility of selecting numerous gages for simultaneous display, allowing for an area comparison.
- Consider a default setting for near-term forecasts that could be used in briefings or other dissemination. Standalone products reflecting the forecast will continue to be important and need to be easily captured so they can be exported from an interactive platform for sharing by professional users.
- Include a base level of interactivity with buttons on products that provide information about how to understand and read the forecast product (see below for more information on sharing what's in the forecast).

Sharing: What's in the Forecast?

Participants overwhelmingly reported that they want to understand what the forecast contains, especially when faced with information that is not easily understood or that seems incongruous for any reason. To this end, we provide the following recommendations.

- Consider methods, such as expanding legends or providing pop-up information boxes for more information, to elaborate on how forecast information was derived.

- For hydrographs and probabilistic forecasts, include information about whether forecasts contain historical data, current weather and precipitation information, or a combination of both, as well as whether the forecasts incorporate other factors, such as snowmelt, soil saturation and dam management regimes. Emergency briefings can be an excellent method of providing ancillary information about these factors to help users understand what is driving the probabilistic forecasts.
- Recognize needs of different users. For instance, participants primarily requested a description of the elements used to generate the forecast, rather than the data itself (i.e., they wanted to know it contained quantitative precipitation forecast data, but did not request to see the actual QPF data specifically). However, some professional users indicated that interactive systems that allowed them to pull raw data for use in their modeling systems would be helpful generally.

Product performance and experience - building trust with users

Users report a need to build experience with ensemble forecasts to determine their utility and to assess their confidence in the products.

- Consider mechanisms for sharing the past performance of probabilistic forecasts to help new users understand how well the forecasts have performed, through visual and/or narrative explanations.
- Consider providing links to relevant information as part of product dissemination wherever possible. We know that uncertainty causes people to seek additional information to confirm a forecast and to consider actions they should take. Providing additional information along with any uncertainty information will help the user find supporting forecast details quickly to inform their decision-making. For instance, when presenting a flood watch and warning, links to help users quickly find the hydrograph or probabilistic forecast could be included. Similarly, linking precipitation forecasts to hydrologic forecasts when possible will help users quickly assess the situation and understand their confidence in the forecasts.
- Build interactivity between and across products to direct users to relevant information. New and nonprofessional users of probabilistic forecast information will often be unaware of how to find additional information and this interactivity can strengthen user understanding of probabilistic forecasts.

How to handle divergence in ensemble and deterministic forecasts

As noted above, users report the potential for lost faith in forecasts when probabilistic and deterministic forecasts diverge, but they overwhelmingly indicate that they will look for more information to explain the divergence in order to understand and decide how to take action.

- Consider methods for directly identifying and explaining meaningful divergences within product dissemination to avoid confusion. Sharing inputs and drivers into the forecast can help explain why deterministic forecasts may come to different outcomes than the median of the probabilities.
- If there are key factors in the deterministic forecast that are important to consider, and which are missing from the probabilistic, explain these to the audience through mechanisms such as forecaster's notes, forecast discussions or emergency briefings.

Use emergency briefings to convey complex information and to focus on impacts

As the amount and type of available weather information increases, users consistently request information on anticipated impacts and actions they should take. Forecast products frequently do not provide an outlet for this information, but emergency briefings can be used to share this information in conjunction with forecast products to create a robust, one-stop location for information during and prior to severe hydrologic events such as floods or droughts.

The challenge for briefing development is balancing important information with brevity while meeting the needs of diverse users. Professional users are looking for more detailed storm information and hydrologic detail along with information about impacts. Residential users suggest keeping briefings short to avoid challenges with downloading large files on the internet, noting that large 10 or 12 page documents would be cumbersome and likely left unread.

- Consider developing briefings that place critical impact information up front which can be condensed for broad dissemination, and which include a link to longer, more complete versions with additional storm details for professional users.
- If probabilistic forecasts are being disseminated in advance of an acute event, consider using briefings to describe the products and help instruct users in following the data.

A Note About Forecaster's Notes

Participants consistently responded favorably toward the inclusion of a special "Forecaster's Note" on probabilistic forecasts that could serve to provide additional information or product interpretation. Several tiers of functionality could be considered for this function. The forecaster's note could be a customizable field to be completed by individual forecasters responding to data for a specific gage at a moment in time, for instance, when a significant river event was anticipated. It is recognized that custom messages could become cumbersome if a large region has many gages approaching or in flood stage at the same time. An alternative approach would allow the forecaster's note box to be automated, for instance, with standardized text alerting when specific thresholds were forecast to be reached. The forecaster's note field could also be used as a way to link to an existing emergency briefing package, or to become activated when a Flood Watch or Flood Warning is in effect.

Conclusions and Future Research

Participants in this project suggested that probabilistic forecasts introduce a tremendous amount of new information into a weather enterprise that already offers much data and many products. Users can be quickly overwhelmed by information and not know how to sort and prioritize. Conversely, lay users may be unaware of valuable resources that are available, and if they are aware, may not know how to find them if located in a website that contains a lot of information. Future research should explore presentation and dissemination strategies to help NWS design websites, social media and other mechanisms to 1) alert users to the availability of probabilistic information, 2) help them locate it easily, and 3) to direct them to "self-briefing" interactive platforms that would let users set up their own customized data pages.

Respondents also indicated that time spent "ground-truthing" the products would be helpful in determining their confidence in the products. There are multiple methods by which a probabilistic forecast could share past performance, for instance, showing the previous days of probabilities along with the observed information, to illustrate how closely the probabilities matched actual outcomes, or to show results over a longer period of time, including seasonal results. But such approaches risk creating new confusion for users and should be studied to identify the best ways to share this information clearly.

Further study into regional needs may also identify the limitations of relying solely on a national product, and may elucidate ways in which a national product can be successfully modified by regions to meet the specific needs of their local audiences. Research can examine whether a national product should be combined with a regional variant, or otherwise augmented with regional information, to communicate risk. Testing in other regions could be useful in understanding the advantages and hurdles associated with a combined presentation as well as revealing further kinds of regional distinctions and needs.

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Appendix A.

Round 2 Focus Group Scenarios in ESRI Story Map

Eureka, CA : https://www.arcgis.com/apps/Cascade/index.html?appid=c0ff5177d1b04437b36f8991db81ff52

Owego, NY: https://www.arcgis.com/apps/Cascade/index.html?appid=af2e0ccbd25f4d939c6261b19df99e39

Gunnison, CO: https://www.arcgis.com/apps/Cascade/index.html?appid=864c921aae3f4f37822778be673dba0c

Durango, CO: https://www.arcgis.com/apps/Cascade/index.html?appid=89a9b349fead4496a13514a7d0b74925

Appendix B.

Focus Group Questions/Protocol

Note: Only one location is shown as an example

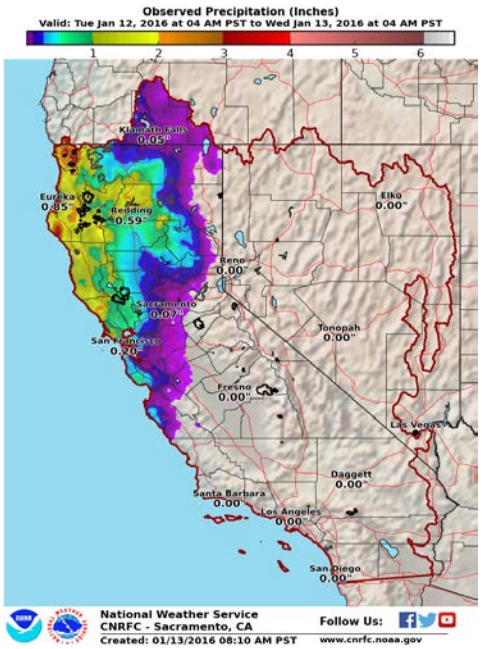
Eureka, California Focus Groups, Round 2
Residential audiences
November 4th, 6 p.m.

HIGH FLOW SCENARIO

Day T-5 – January 13th Wet Weather Patterns Return

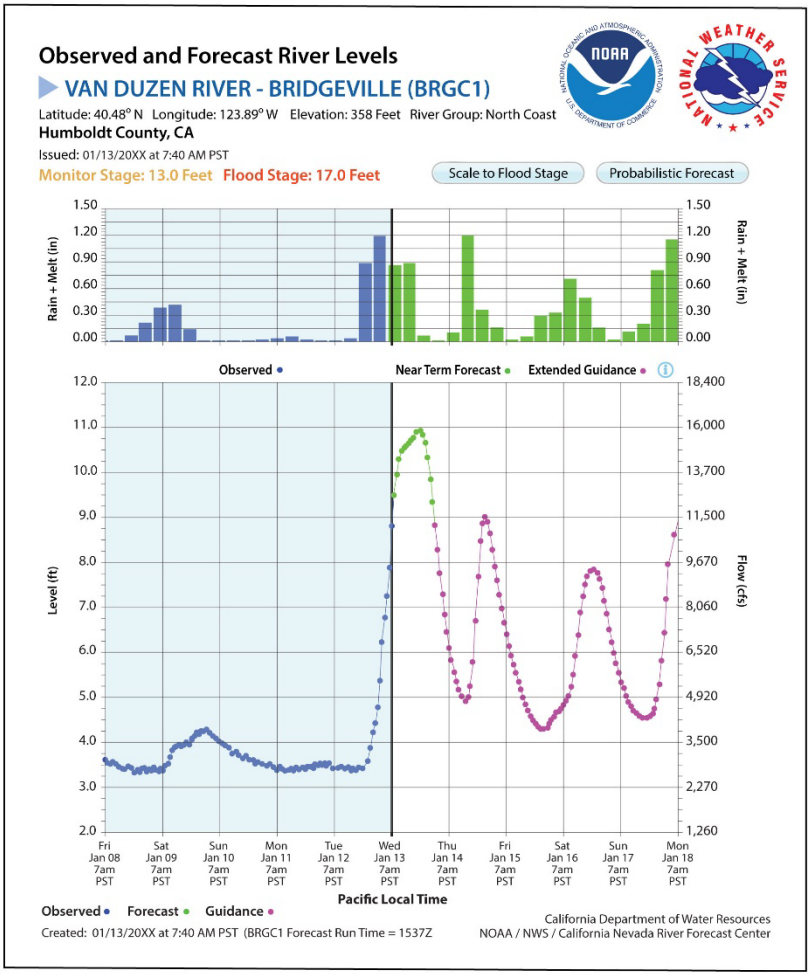
Forecast Summary:

After a brief dry period, wet weather will return to northwest California for the next several days. An approaching storm system will bring multiple inches of rain to the region through this weekend and into early next week. Persistent rainfall will cause rapid rises on mainstem rivers but there are no flooding concerns at this time. Temperatures will be in the 40s and 50s across Humboldt County with no impacts from snow expected. Folks should use the forecast to make travel plans and avoid commuting during the heaviest rainfall.



Facilitator: Move through all 5 days of QPF

Explain to group: We'll see a total of about 3 inches of rain in the next few days



Questions:

Have you seen this graphic, or one like it before?

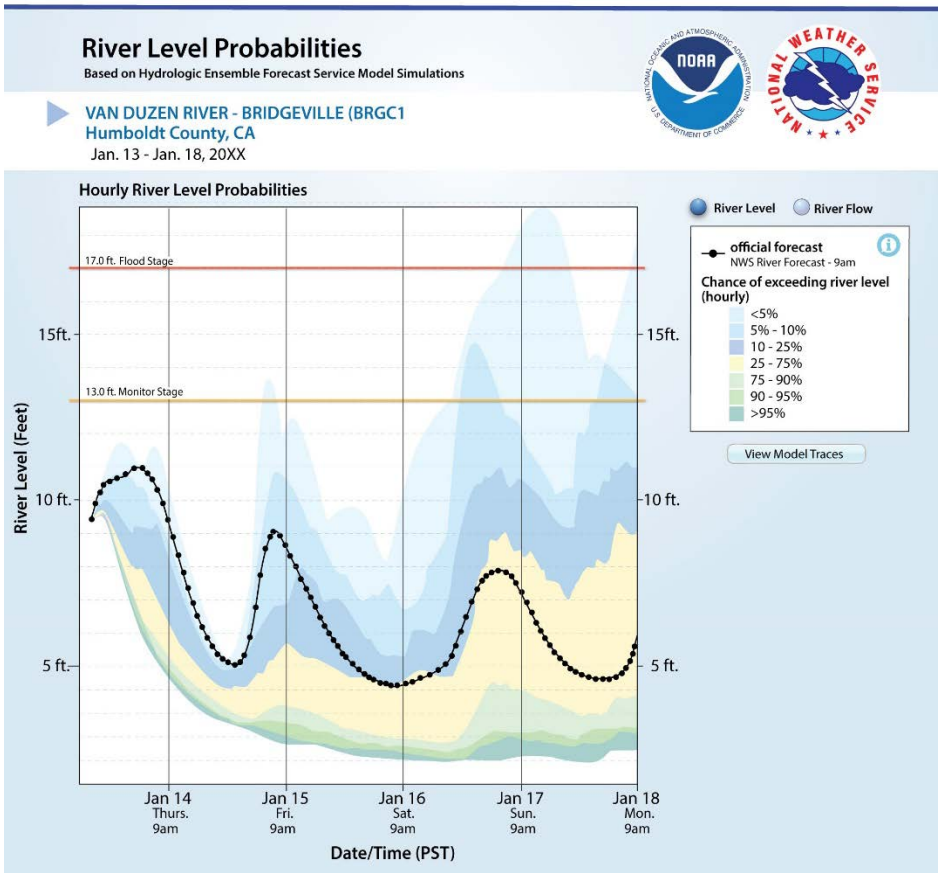
What does this graphic suggest to you?

What are you thinking about your situation?

What actions would you be taking?

Are you talking to anyone?

Are the three time periods useful? Make sense? Near Term and Extended Guidance terminology?



Questions:

What does this product tell you?

How might you use it?

Let's talk about ensemble and deterministic – what do those words mean to you? How helpful is it to have both on the same graphic? On Jan 15th – the deterministic is higher than the median – does this concern you? Would you have less confidence in either forecast?

Would you share this with others?

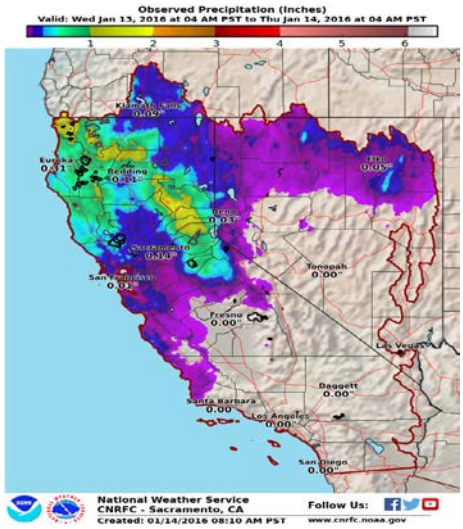
How confident are you in this forecast at this point?

Ask about Peak Flow – useful? Toggle with separate graphs or together on one?

Day T-4 January 14th Wet Weather Patterns continue over the next 7 days

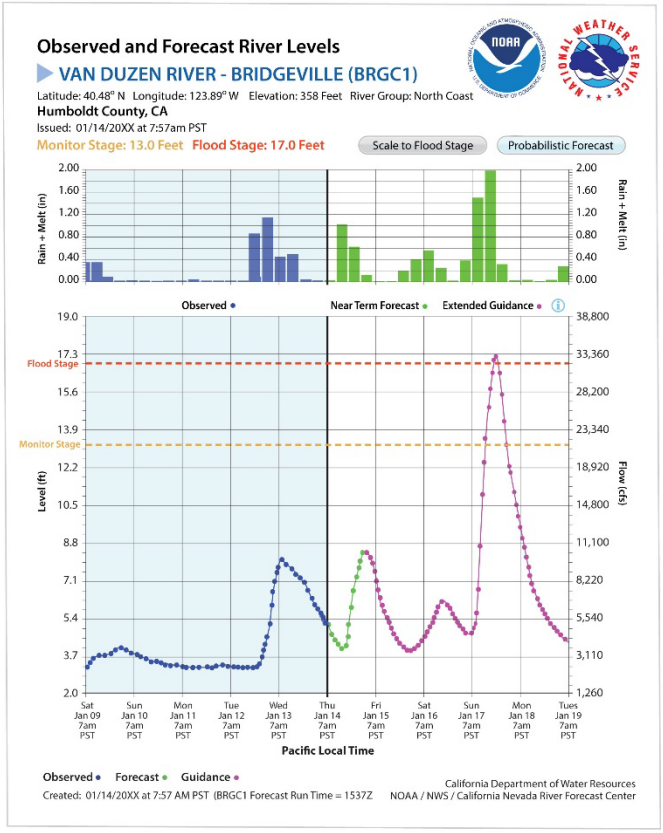
Update:

Wet weather conditions remain on track through the weekend, but it looks like potentially heavy rainfall will directly impact northwest California Sunday through early Monday morning. This change in rainfall could result in minor river flooding and greater flood impacts around small streams and urban areas. We are confident in wet weather but there is still some uncertainty in the details related to timing and intensity of the rainfall. Please stay tuned to the forecast.



Show Observed Precipitation only.

Comment: So far, about .31" has fallen since yesterday.



Questions:

OK, here is this hydrograph again.

How do you see your situation now? Does this change anything for you?

What preparations are you taking now?

<u>Day T-3 – January 15th Heavy Rain and Flooding Early Next Week</u>

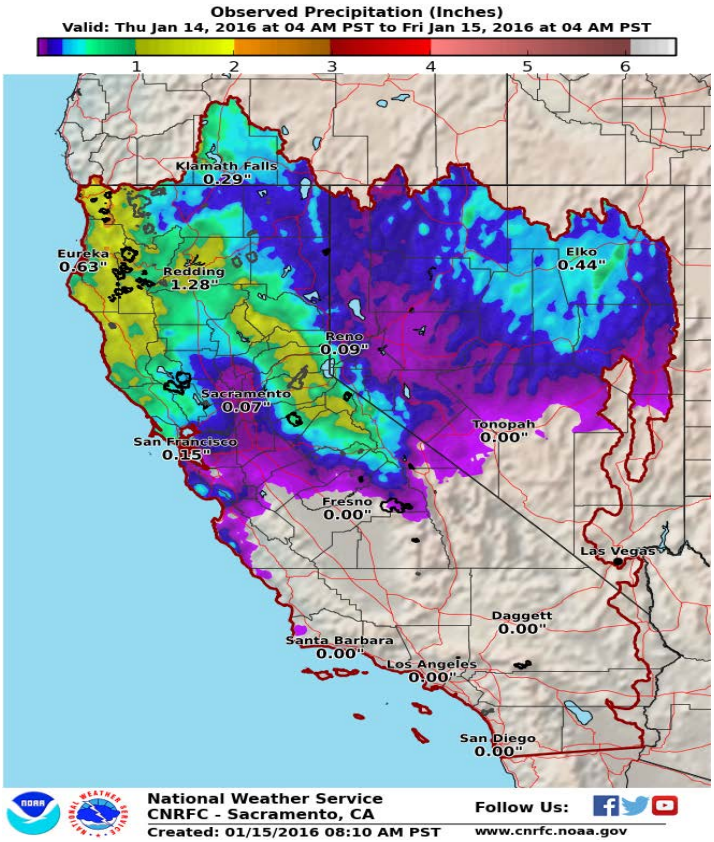
A significant storm system will bring rain to northwest California through next week with the heaviest rain expected on Sunday.

Moderate confidence for rainfall

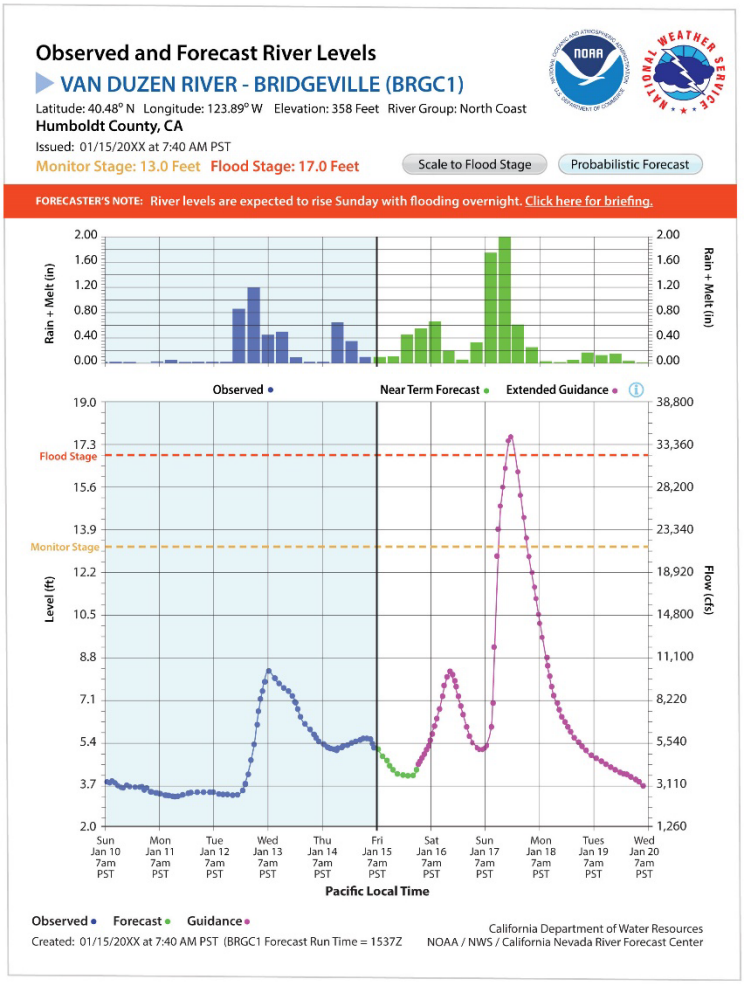
Moderate confidence for flooding

<u>Impacts</u>

- Mud/rock slides
- Small stream flooding & pond in areas of poor drainage
- Minor river flooding on the Van Duzen
    - Grizzly Creek State Park
    - River Bar Road



Go through QPF Day 3 up to T



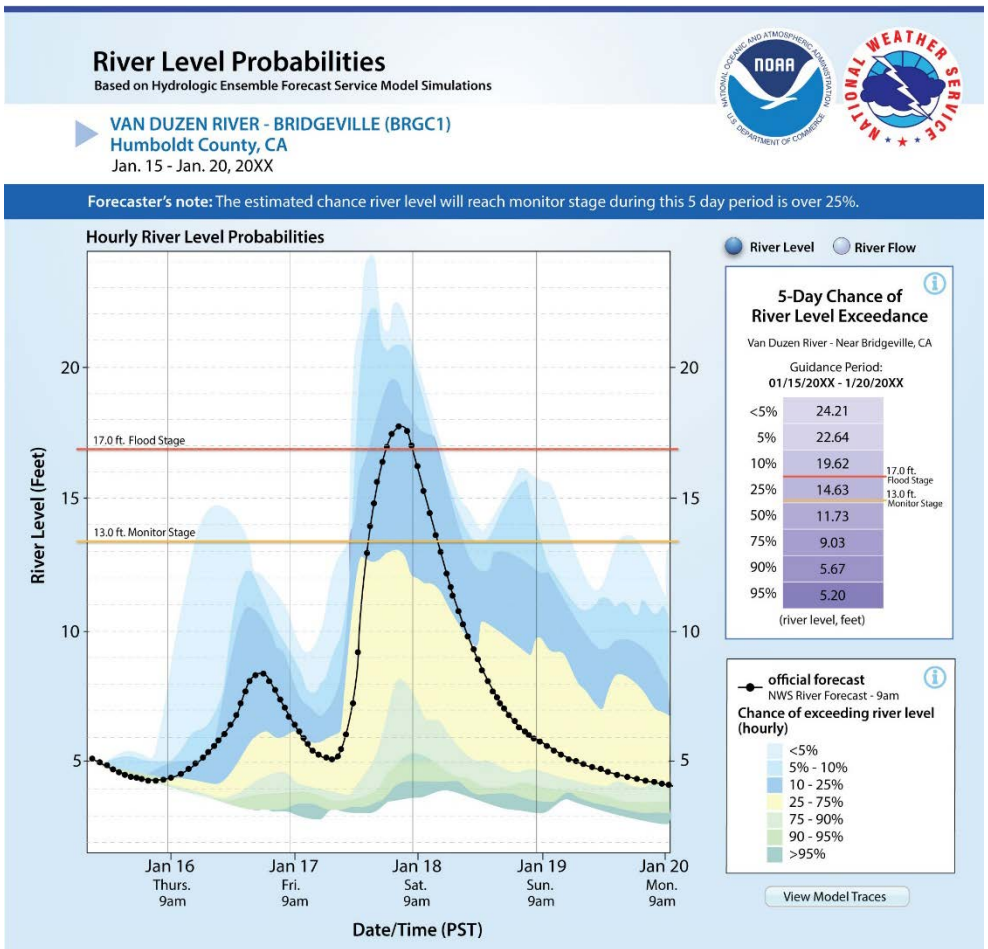
Questions:

And again, a new hydrograph

How do you see your situation now? Does this change anything for you?

What preparations are you taking now?

Note: Additional of Forecaster's Note – useful?



Questions:

Note addition of right side box with 5-Day Chance of River Level Exceedance – useful? Do they understand what it is saying?

New forecaster's note added here too.

How do you understand the situation now?

Does this change your understanding of your risk? How?

Are you taking preparations based on this graphic? If so, what? If not, why not?

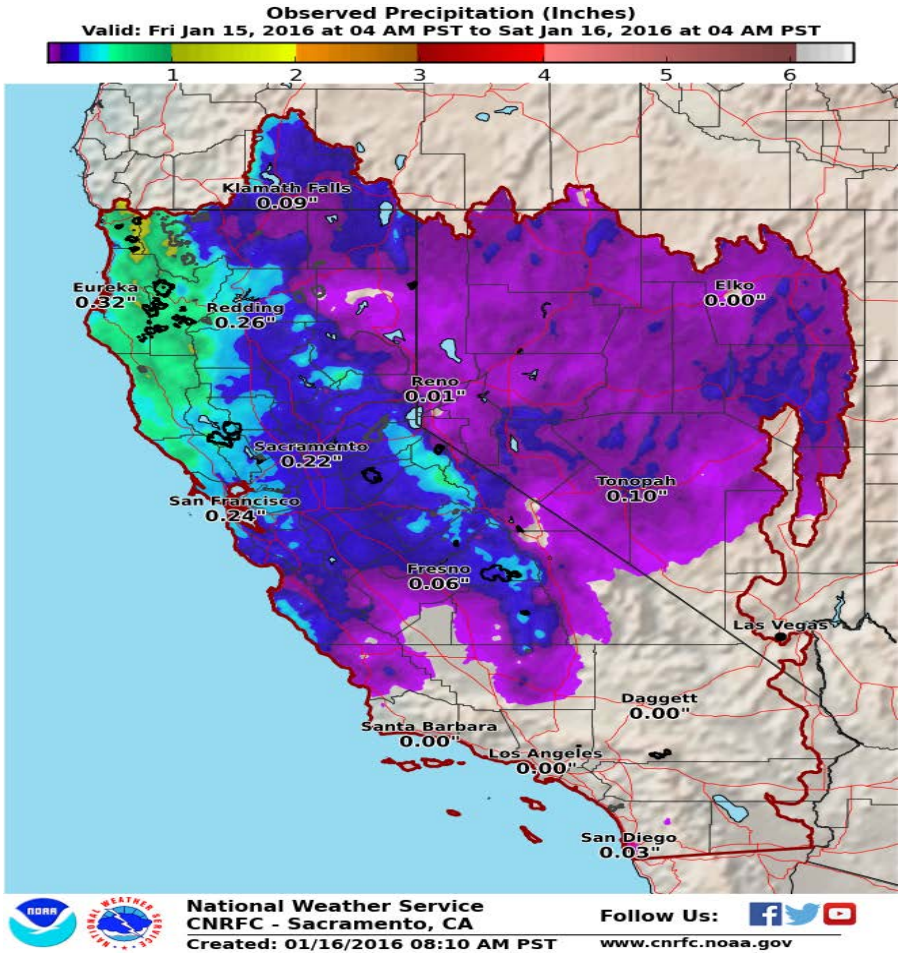
Does this change your confidence level compared to the previous one? How? For better or for worse? Why?

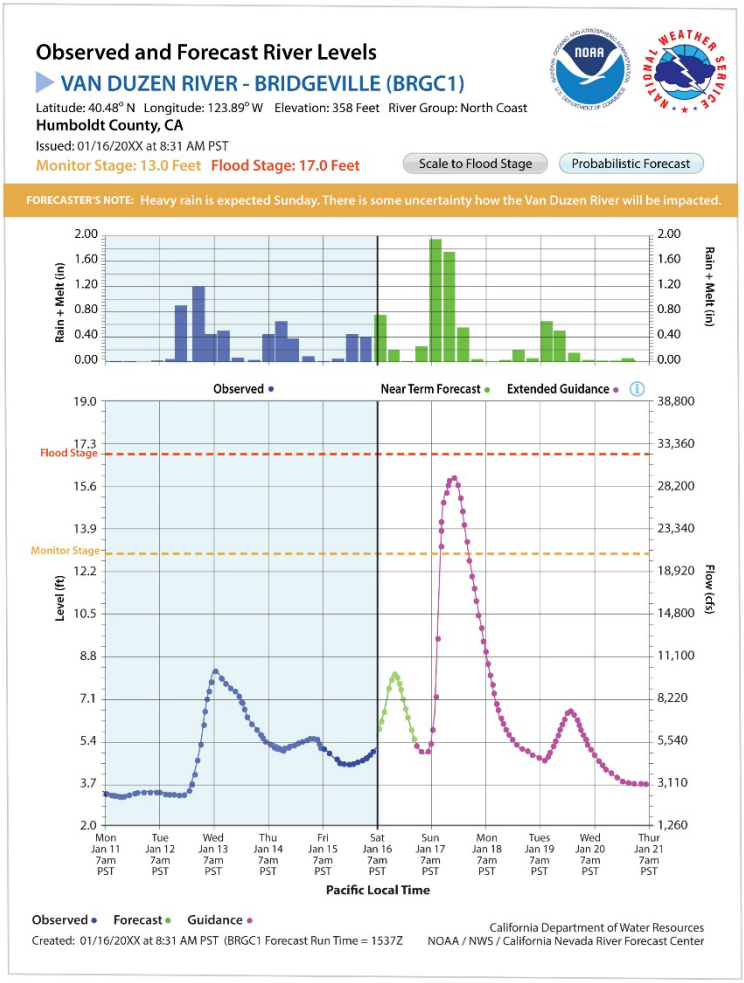
Would you share this with anyone?

Would you be confident enough in the information at this stage to take action? If not, what more do you need? If so, why – on what are you basing your confidence?

Day T-2 – January 16th Heavy Rain and Flooding Early Next Week

Northwest California is still on track to observe heavy rain on Sunday but there is uncertainty in where exactly the heaviest rain will impact. This uncertainty means the difference between minor flooding or no flooding on the Van Duzen River. Nevertheless, we are still confident in widespread, heavy rain across northwest California that could cause some small stream flooding. Stay tuned to the forecast for any flood concerns.





Questions:

Anything new here?

What other information are you looking for right now?

How confident are you at this point in the forecast?

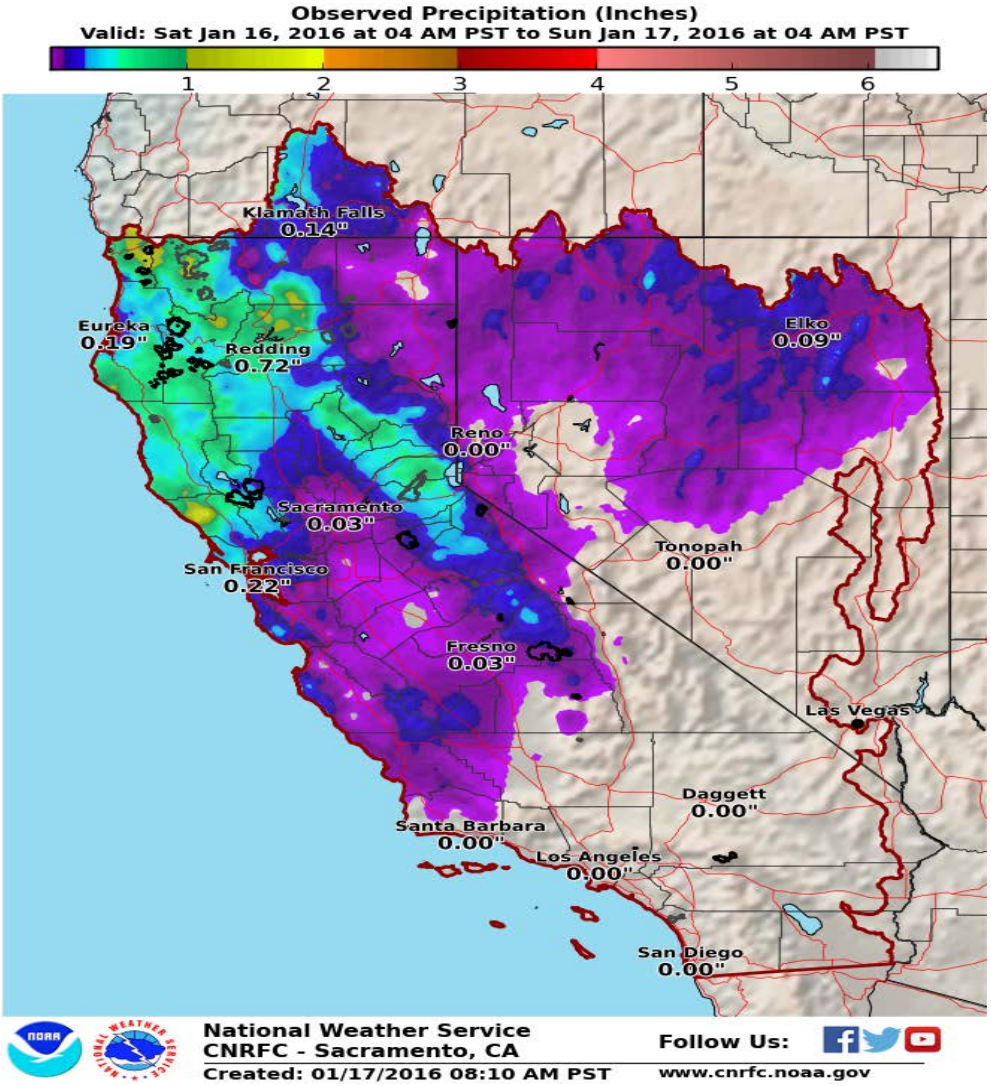
<u>Day T-1 January 17th Heavy Rain and Flooding</u>

The forecast is on track for heavy rain on Sunday that will result in river flooding and small stream flooding across the region.

Moderate confidence for rainfall

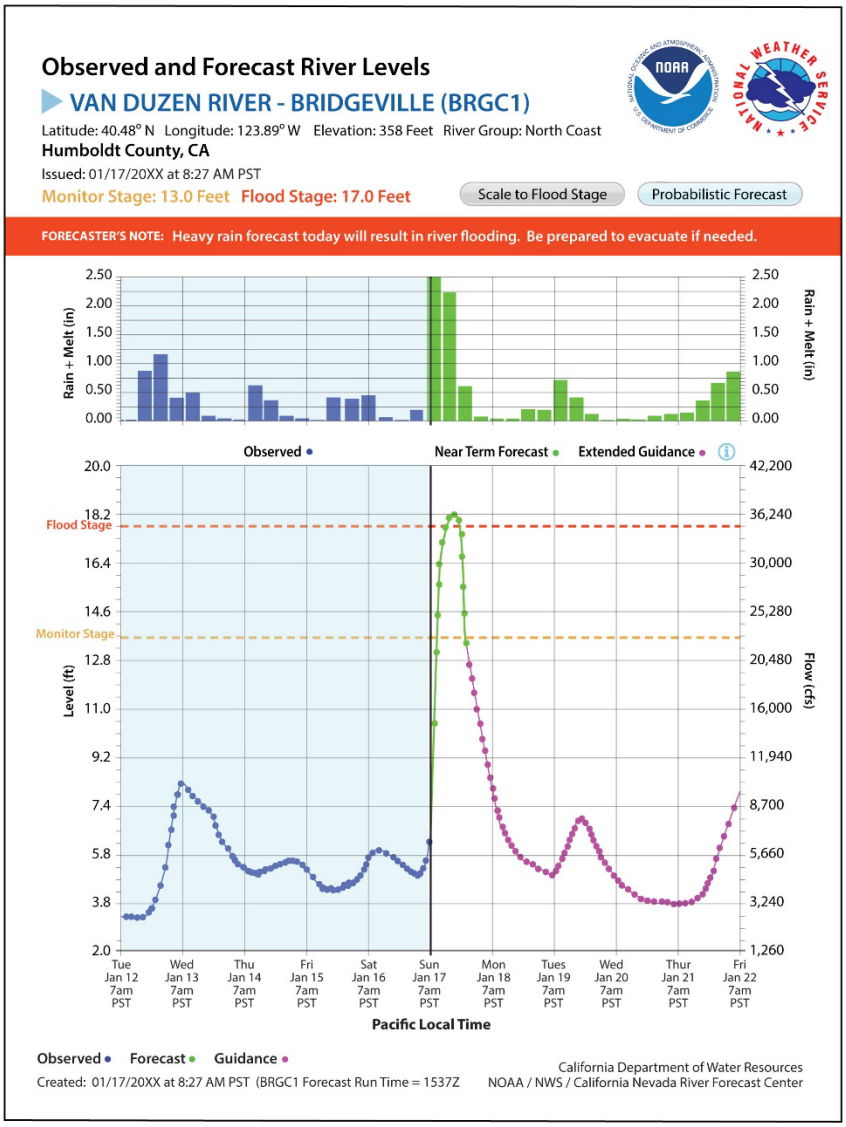
Impacts

- Minor flooding of Highway 36 near Grizzly Creek State Park and in lower portions of the State Park itself.
- Moderate flooding of River Bar Road in the Starvation Flats area.
- Mud/rock slides
- Small stream flooding & ponding in areas of poor drainage



Show QPF 5

Comment - .8 inches still to come

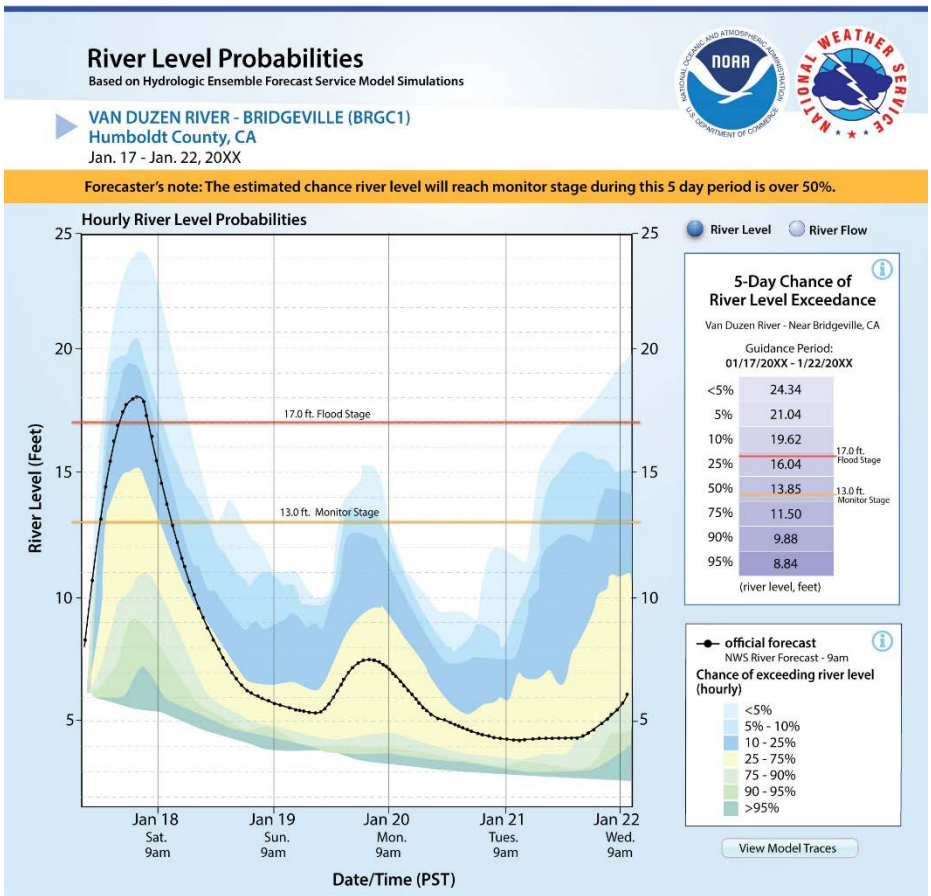


Questions:

What is this product telling you now?

What are you doing in response?

Are you seeking out more information?



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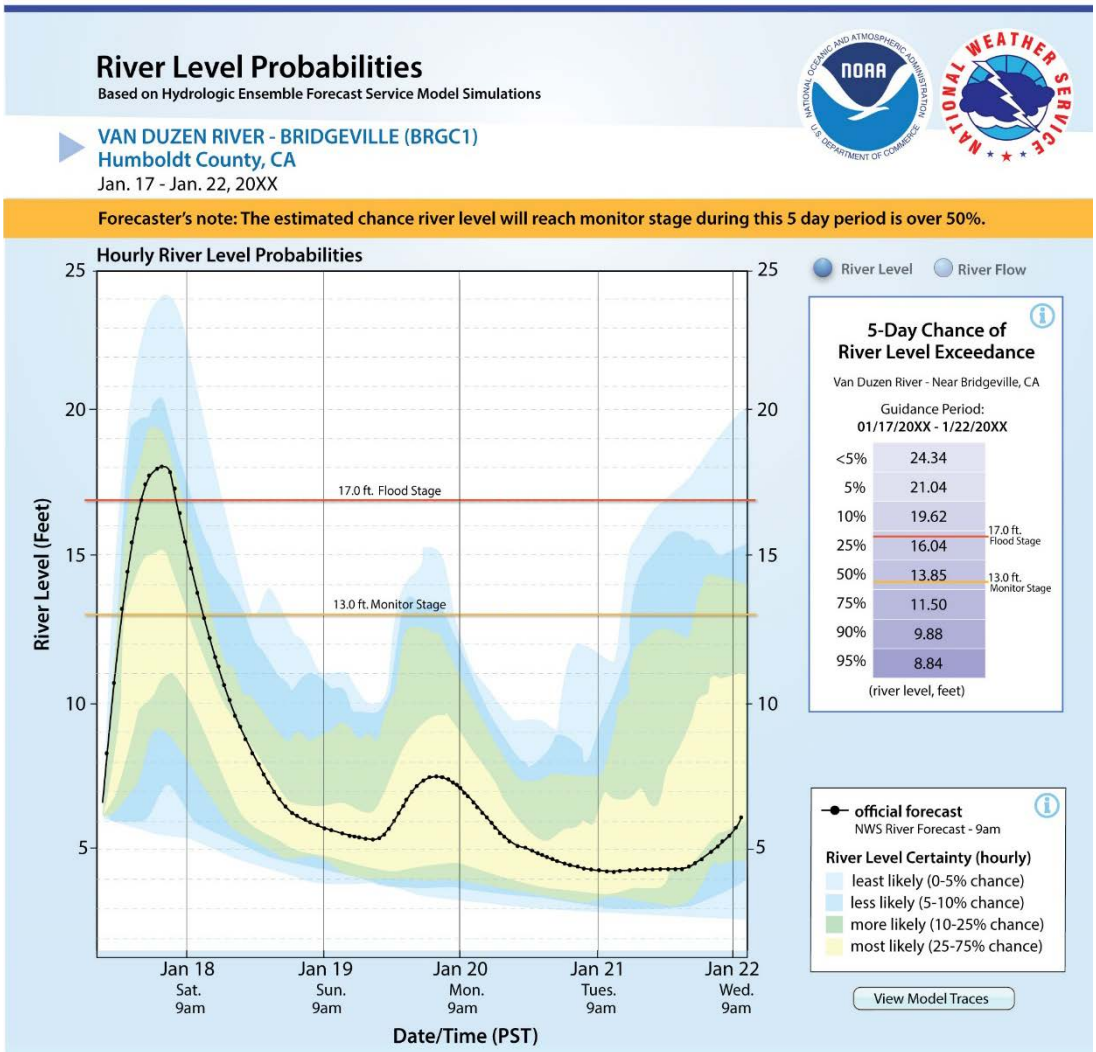


Questions:

NEW LEGEND – least likely to most likely language – is this preferred over the previous percentages only legend?

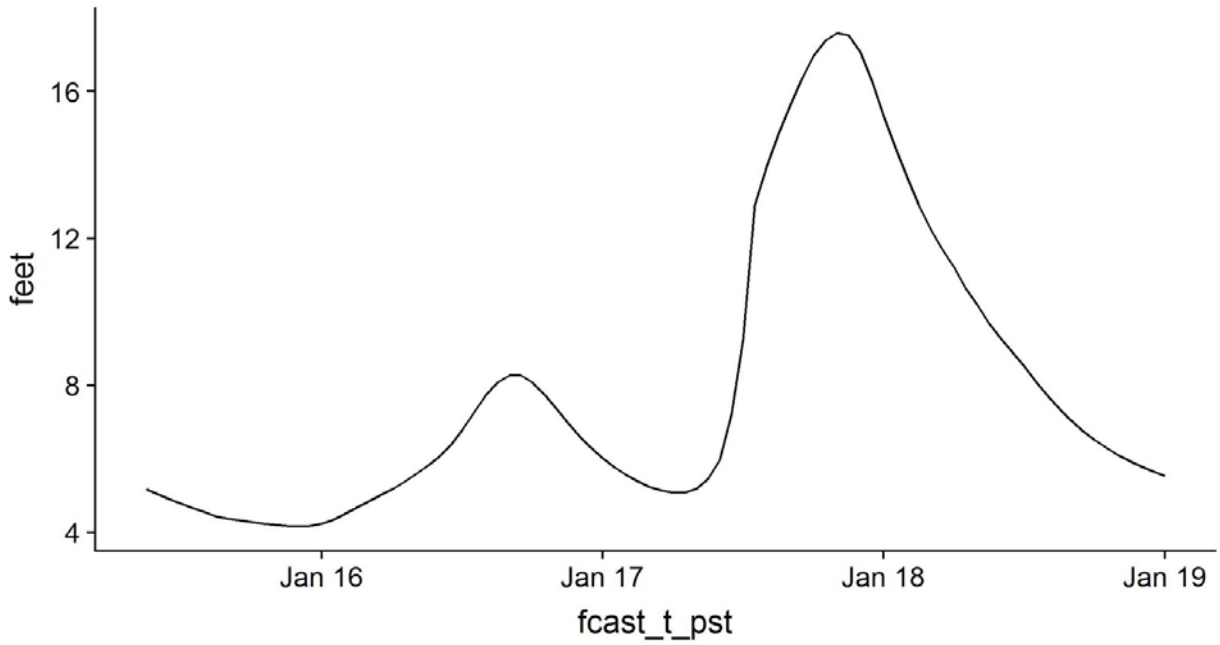
Interactive

https://dbo99.shinyapps.io/thresholdevent_jan16/

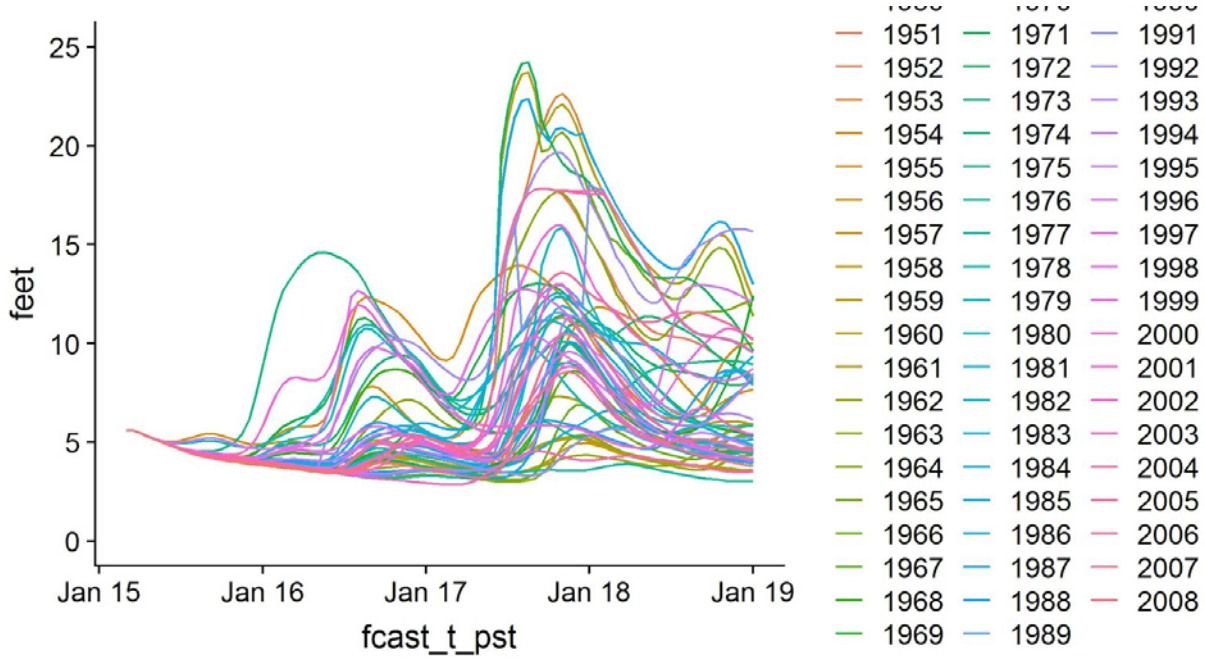
Is this useful? Would you use this?

ADDITIONAL ITEMS FOR DISCUSSION IF NEEDED

Deterministic



Ensemble



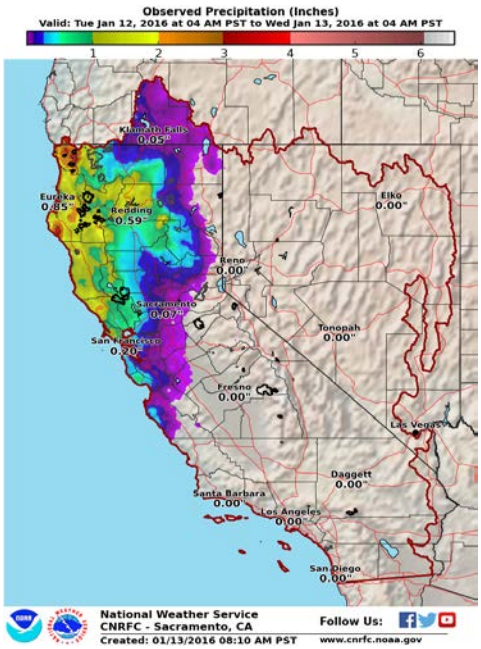
Eureka, California Focus Groups, Round 2
Water Resource Professionals
November 4th, 10 am

HIGH FLOW SCENARIO

Day T-5 – January 13th Wet Weather Patterns Return

Forecast Summary:

After a brief dry period, wet weather will return to northwest California for the next several days. An approaching storm system will bring multiple inches of rain to the region through this weekend and into early next week. Persistent rainfall will cause rapid rises on mainstem rivers but there are no flooding concerns at this time. Temperatures will be in the 40s and 50s across Humboldt County with no impacts from snow expected. Folks should use the forecast to make travel plans and avoid commuting during the heaviest rainfall.



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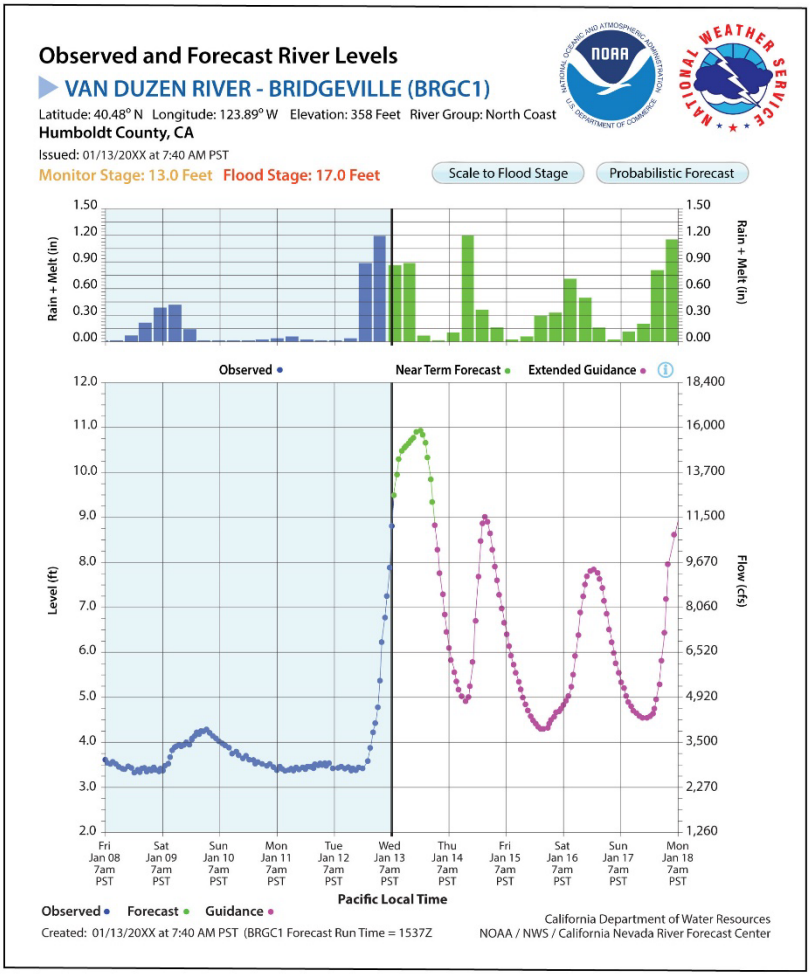

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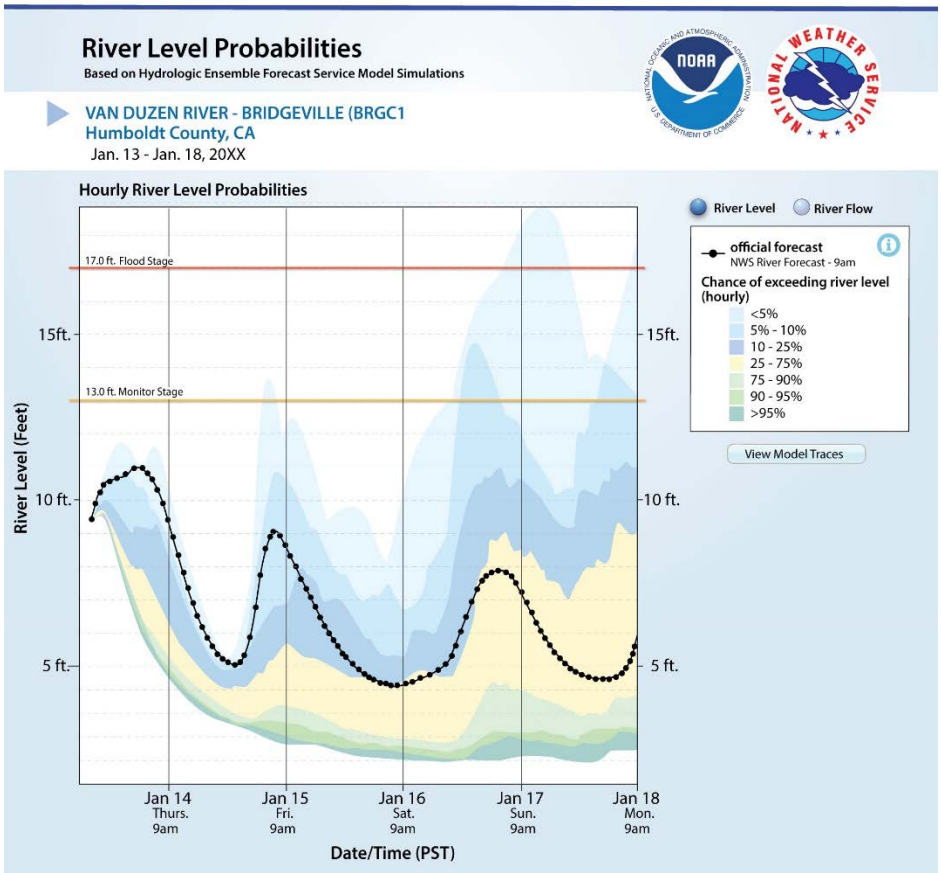

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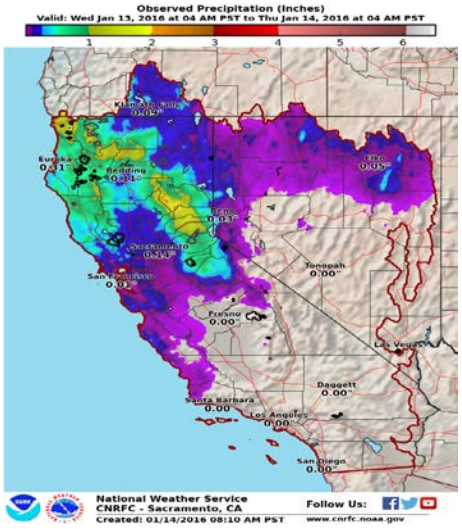

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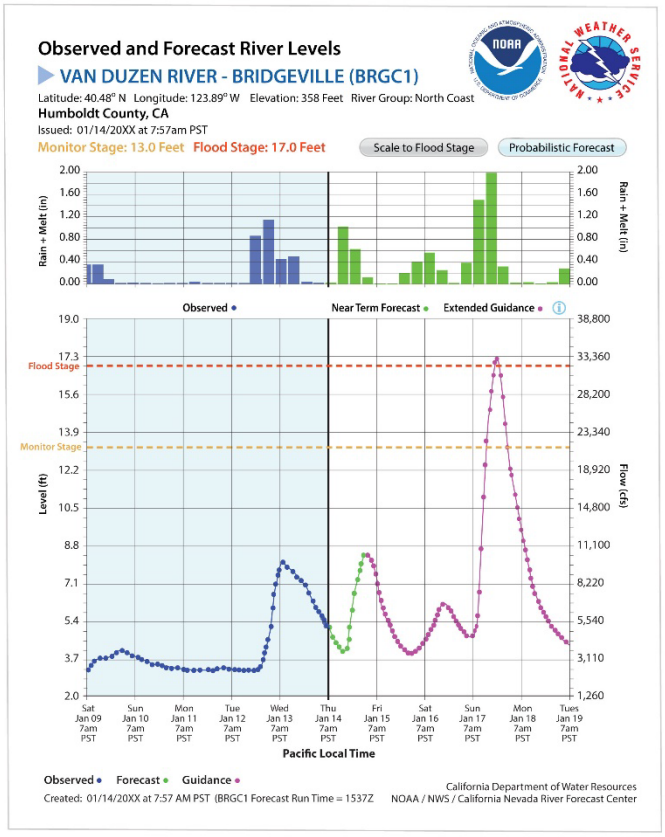

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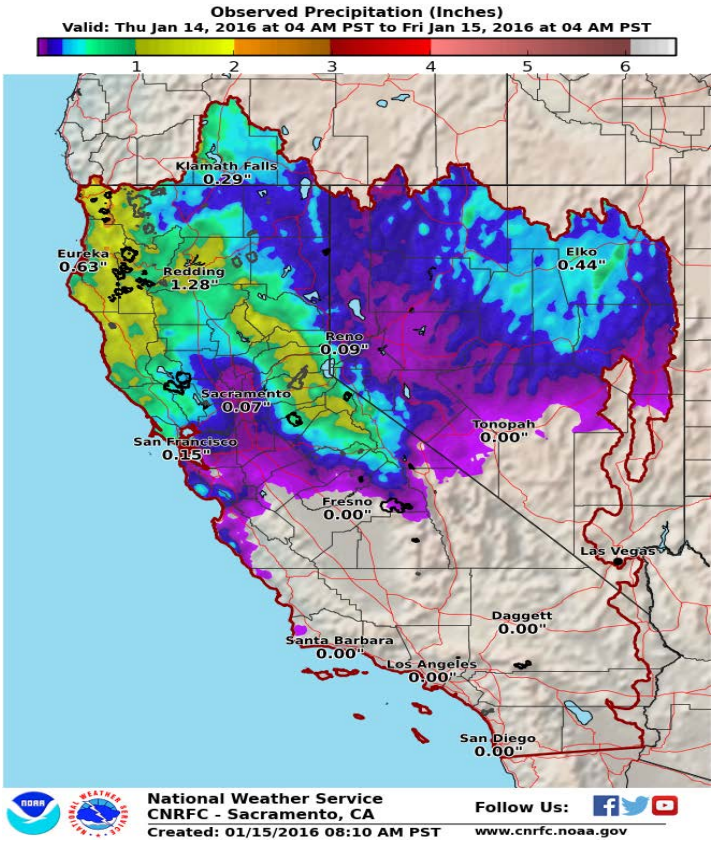

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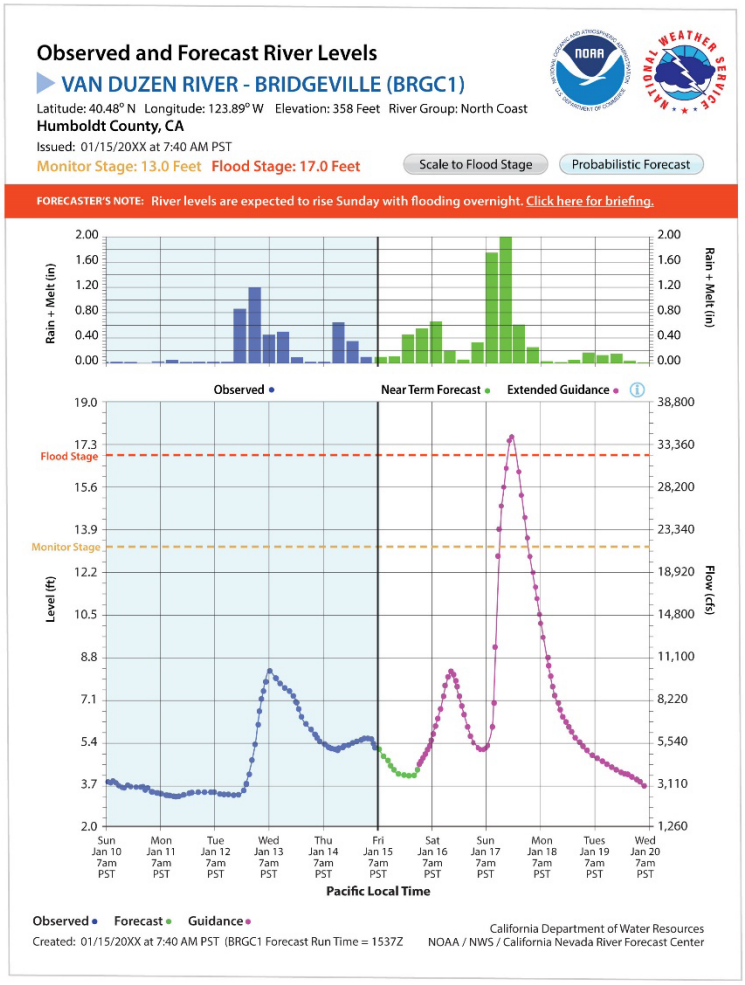

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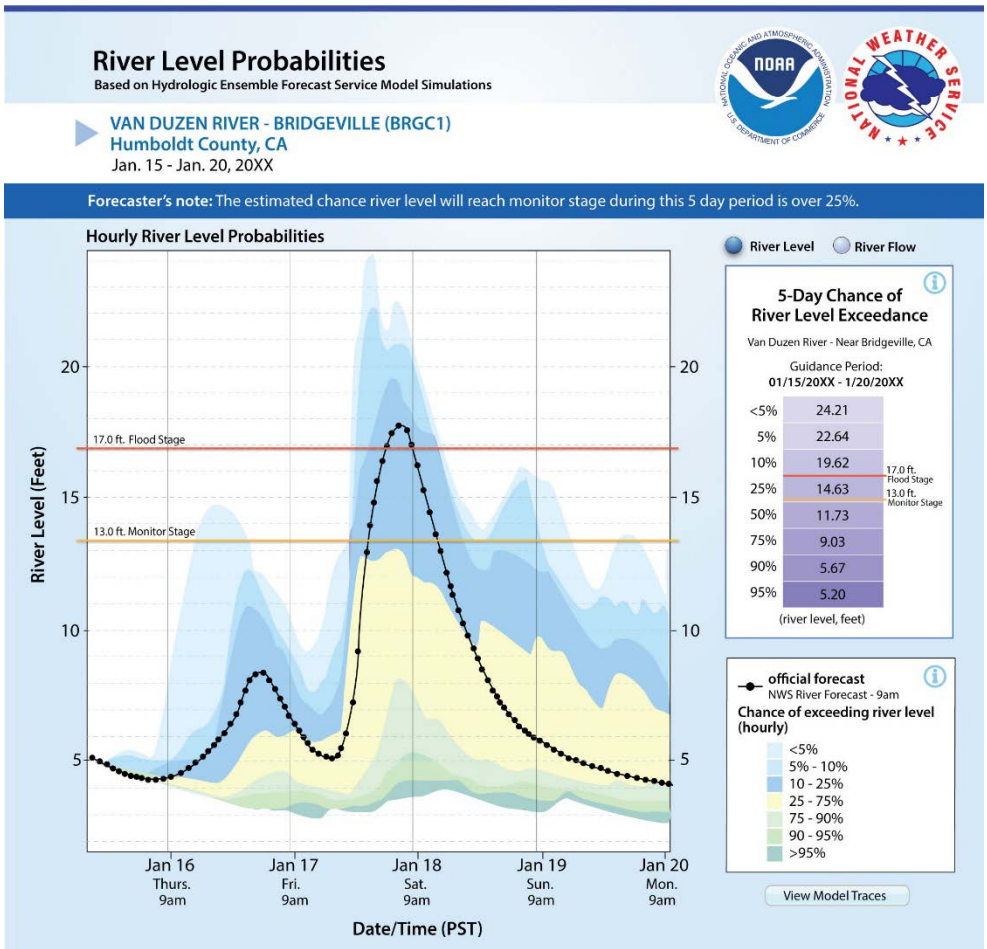

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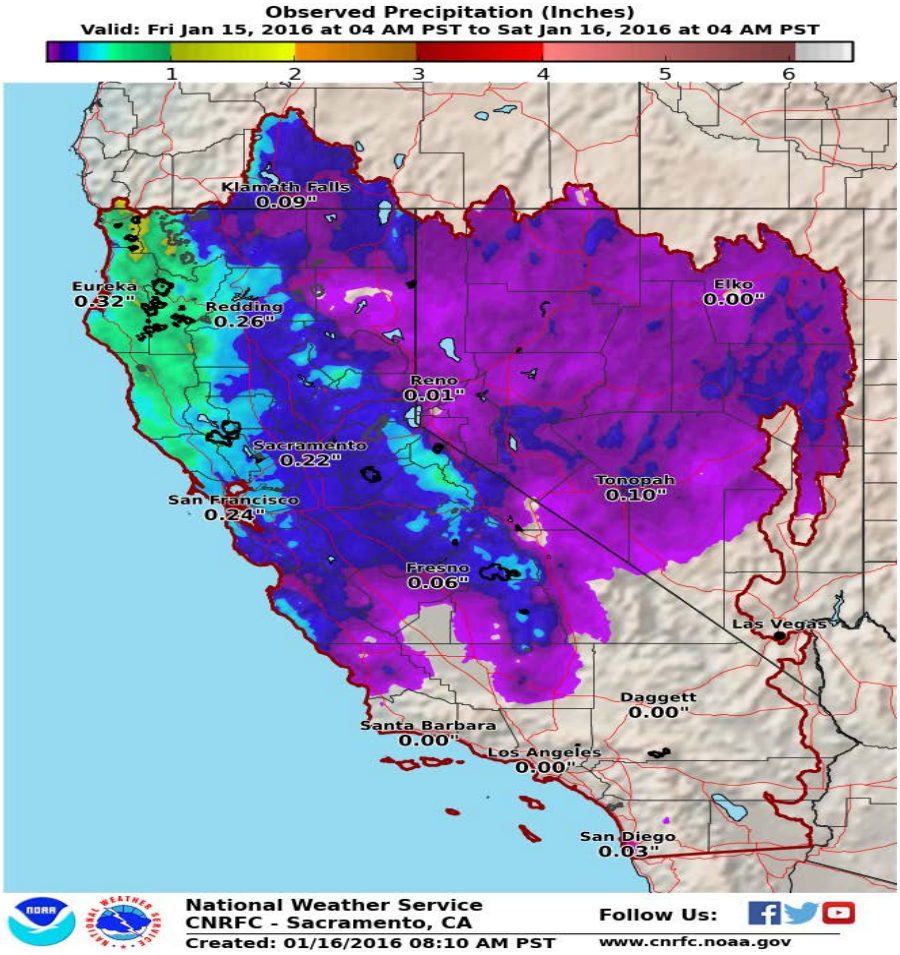

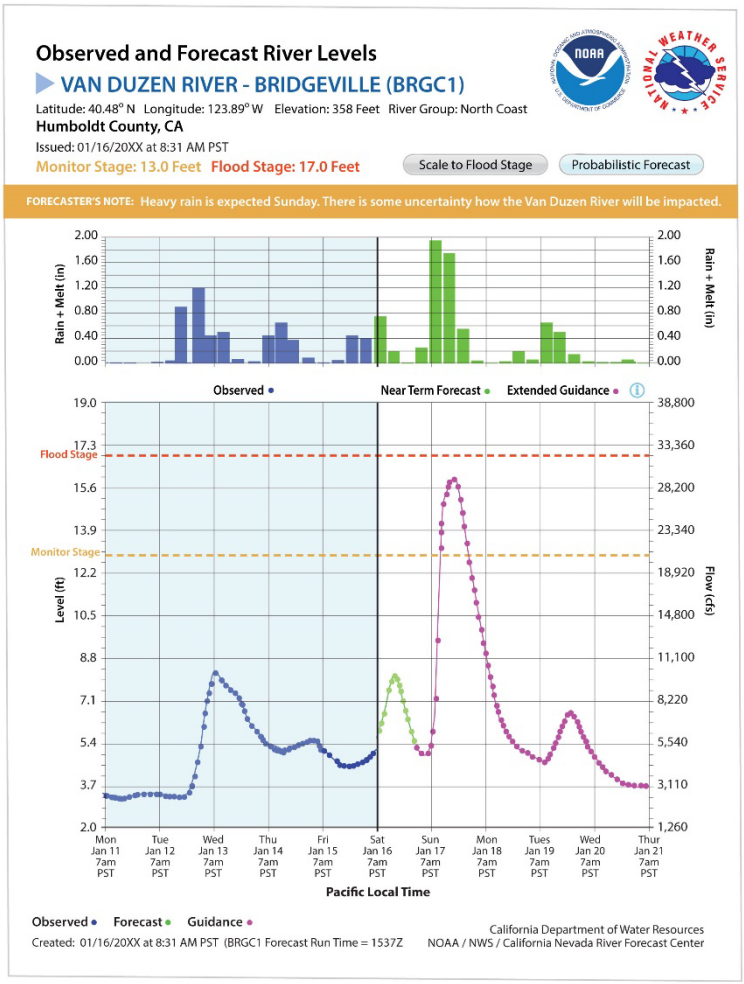

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<u>Day T-1 January 17th Heavy Rain and Flooding</u>

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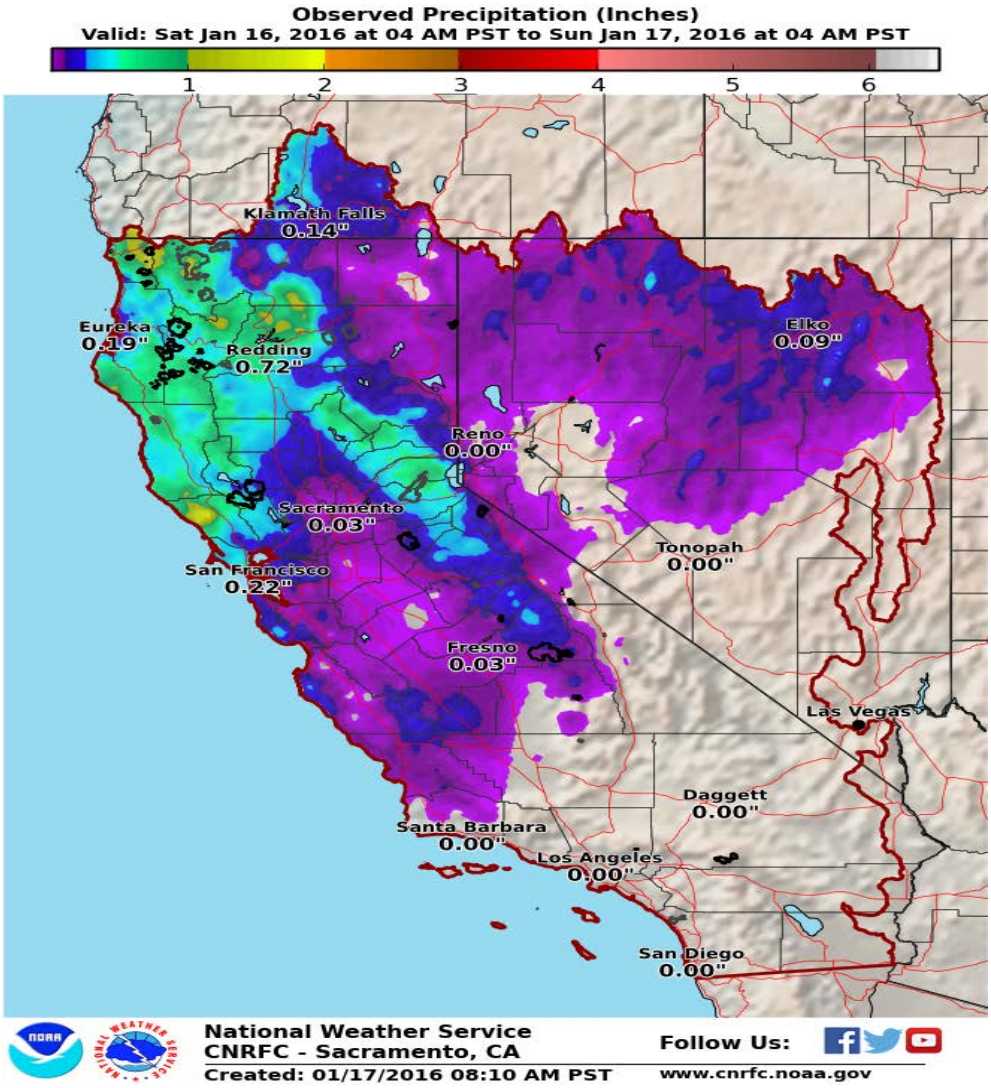
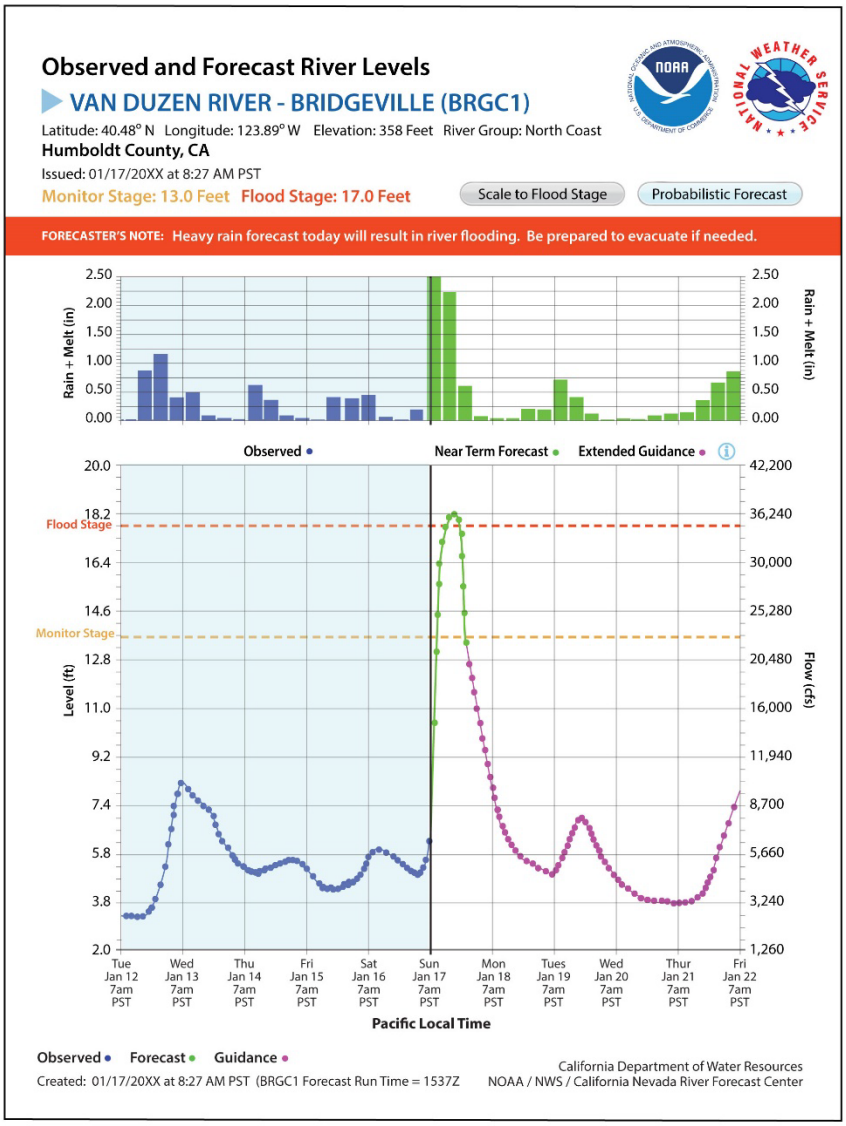
Impacts

- Minor flooding of Highway 36 near Grizzly Creek State Park and in lower portions of the State Park itself.
- Moderate flooding of River Bar Road in the Starvation Flats area.
- Mud/rock slides
- Small stream flooding & ponding in areas of poor drainage



Show QPF 5

Comment - .8 inches still to come

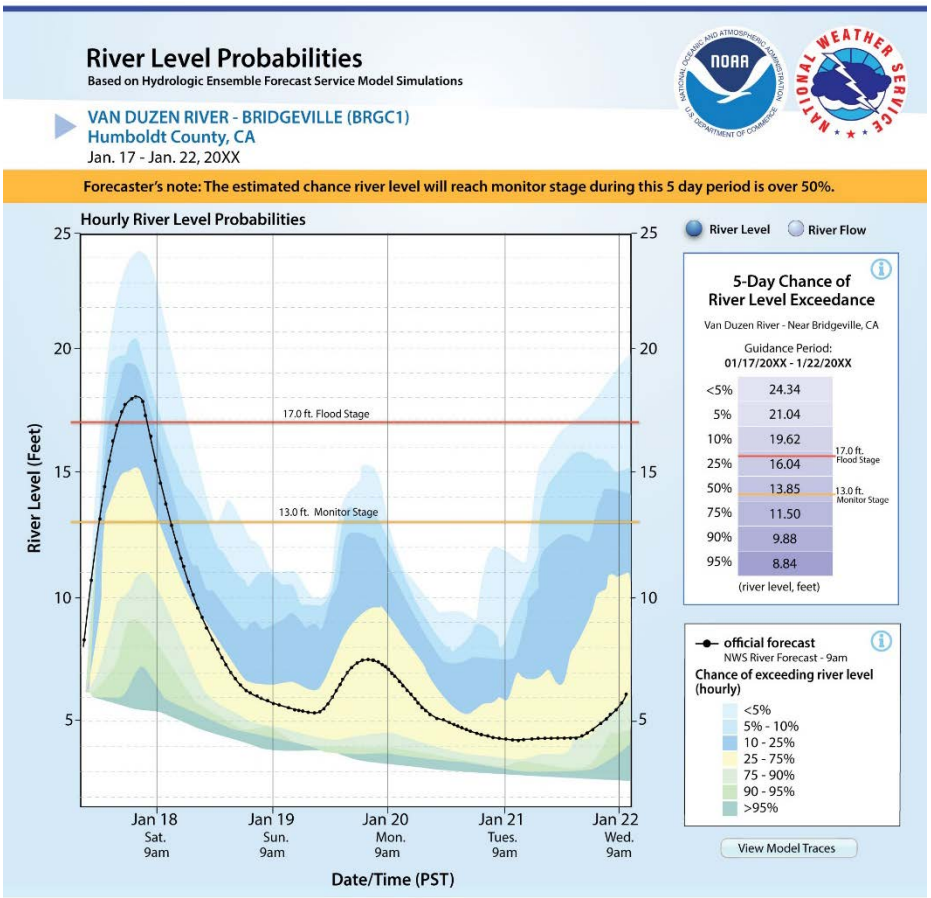


Questions:

What is this product telling you now?

What are you doing in response?

Are you seeking out more information?



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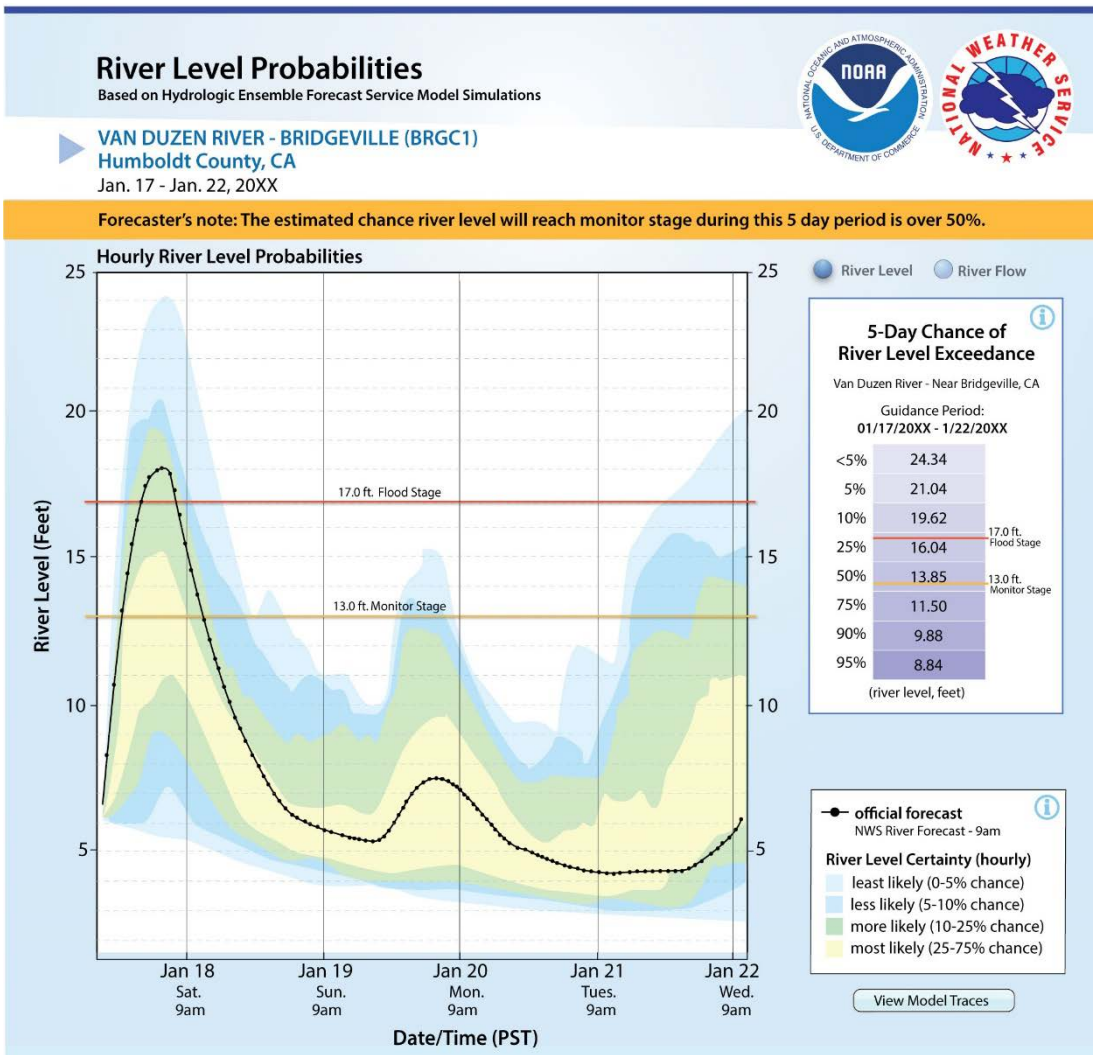
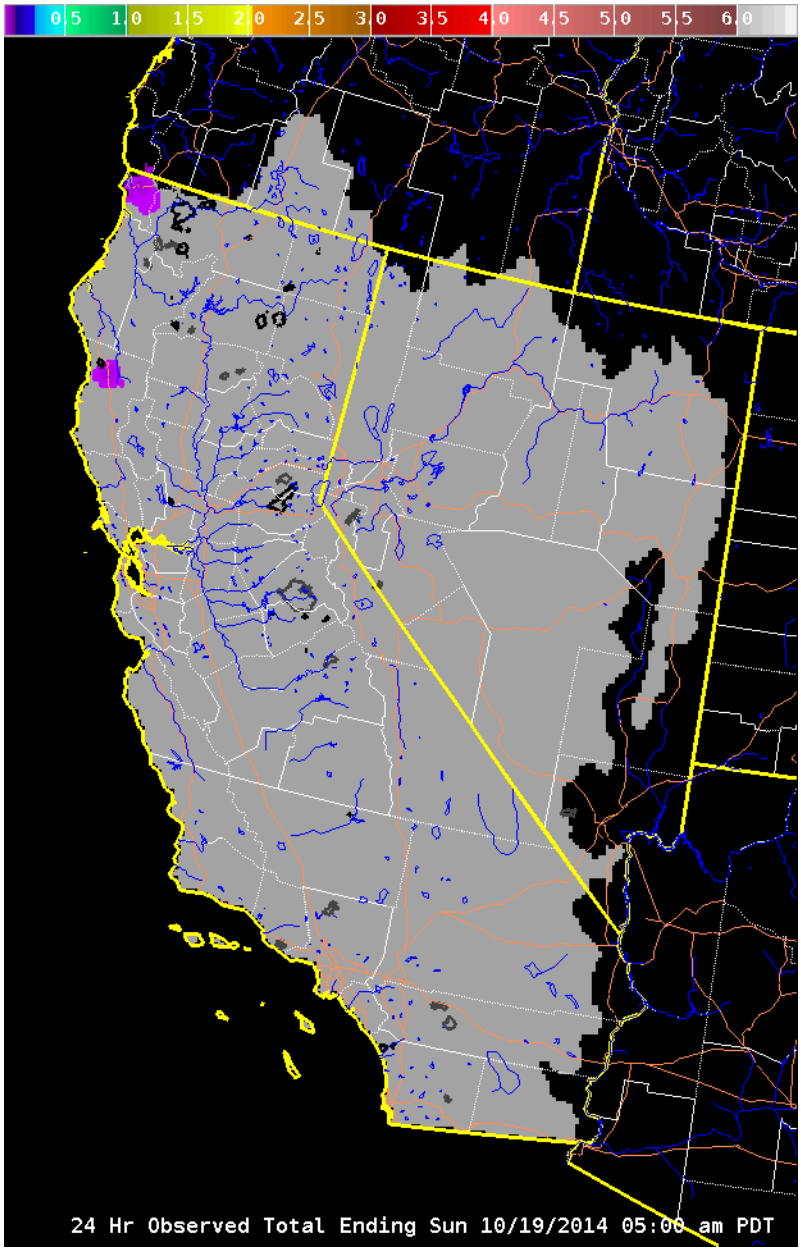


Questions:

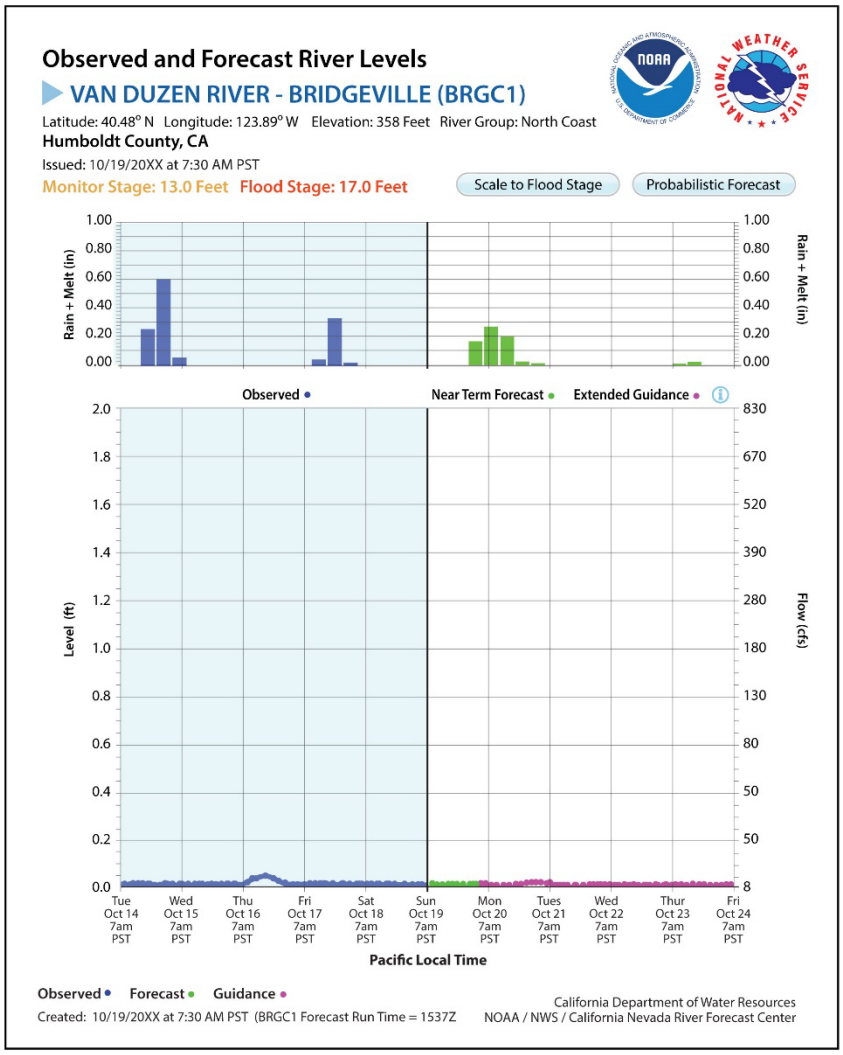
NEW LEGEND – least likely to most likely language – is this preferred over the previous percentages only legend?

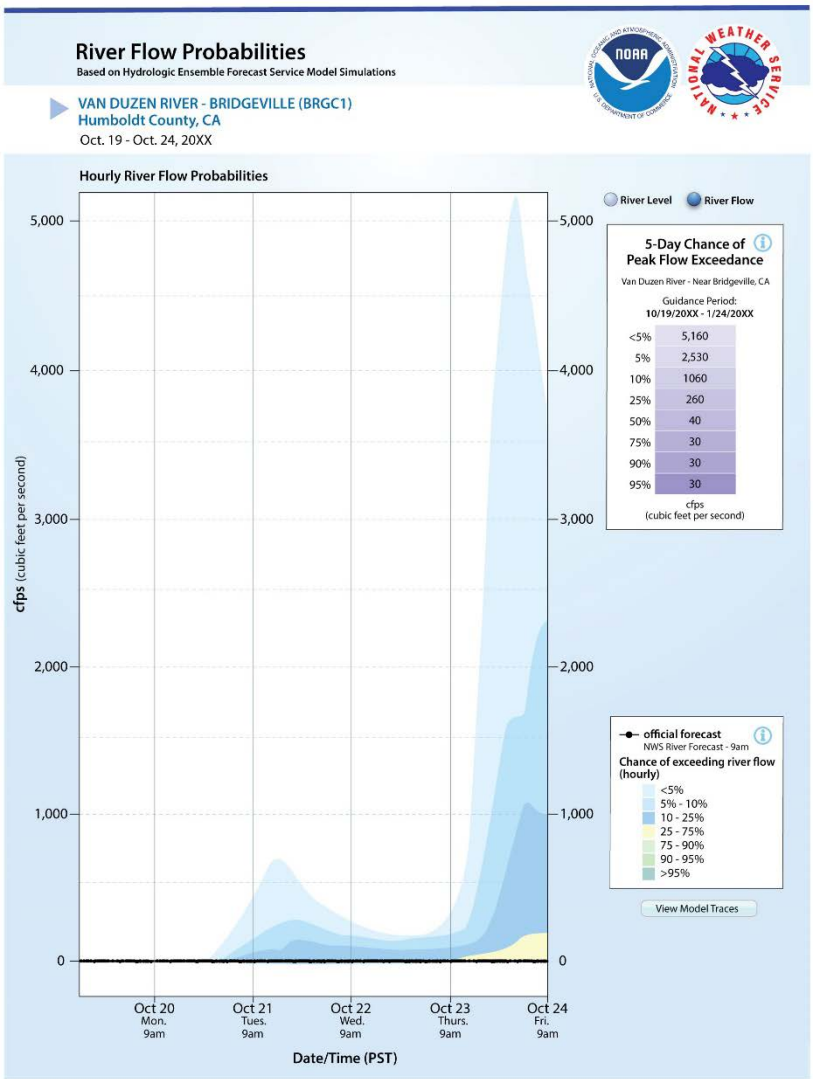
LOW FLOW SCENARIO

T-5 October 19th



Observed plus QPF for each day.


Observed and Forecast River Levels
VAN DUZEN RIVER - BRIDGEVILLE (BRGC1)
Latitude: 40.48° N Longitude: 123.89° W Elevation: 358 Feet River Group: North Coast
Humboldt County, CA
Issued: 10/19/20XX at 7:30 AM PST
Monitor Stage: 13.0 Feet Flood Stage: 17.0 Feet
Scale to Flood Stage
Probabilistic Forecast
Rain + Melt (in)
Observed
Near Term Forecast
Extended Guidance
Level (ft)
Flow (cfs)
Tue Oct 14 7am PST
Wed Oct 15 7am PST
Thu Oct 16 7am PST
Fri Oct 17 7am PST
Sat Oct 18 7am PST
Sun Oct 19 7am PST
Mon Oct 20 7am PST
Tues Oct 21 7am PST
Wed Oct 22 7am PST
Thur Oct 23 7am PST
Fri Oct 24 7am PST
Pacific Local Time
Observed Forecast Guidance
Created: 10/19/20XX at 7:30 AM PST (BRGC1 Forecast Run Time = 1537Z
California Department of Water Resources
NOAA / NWS / California Nevada River Forecast Center



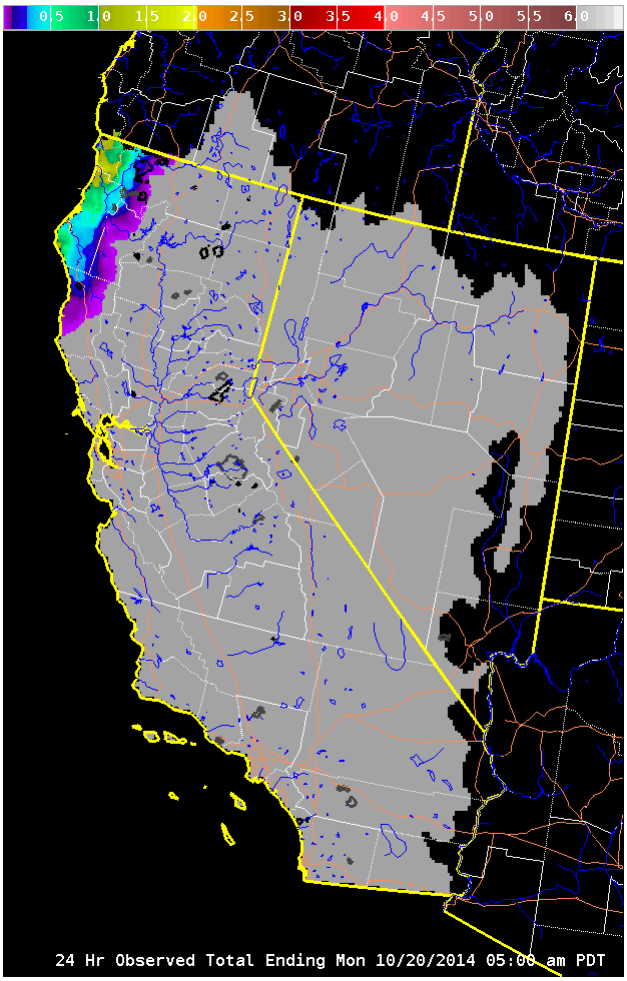
This is the 5-Day Peak Flow Probabilities Product – Useful? Separate or together on the same graph with levels?

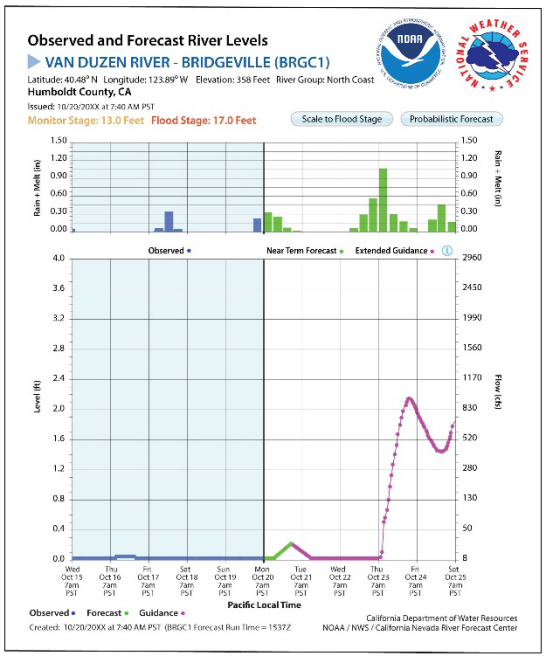
Right box Peak Flow Exceedance useful?

Day T-4 October 20th

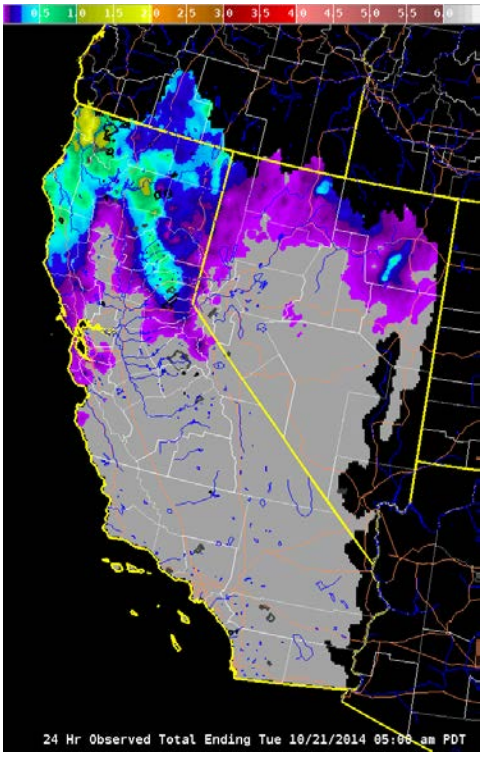
The forecast looks on track for rain impacting northwest California early this week but weather models shifted the storm track farther south for Thursday and Friday. As a result, an additional 2 to 3 inches of rain is expected late in the work week. The first round of rain will have little to no impacts on rivers but the second round of rain will cause mainstem rivers to rise more

significantly on Thursday and reach nearly 1000 cfs. These high discharges could impact temporary bridges set up for low flow during the summer months.

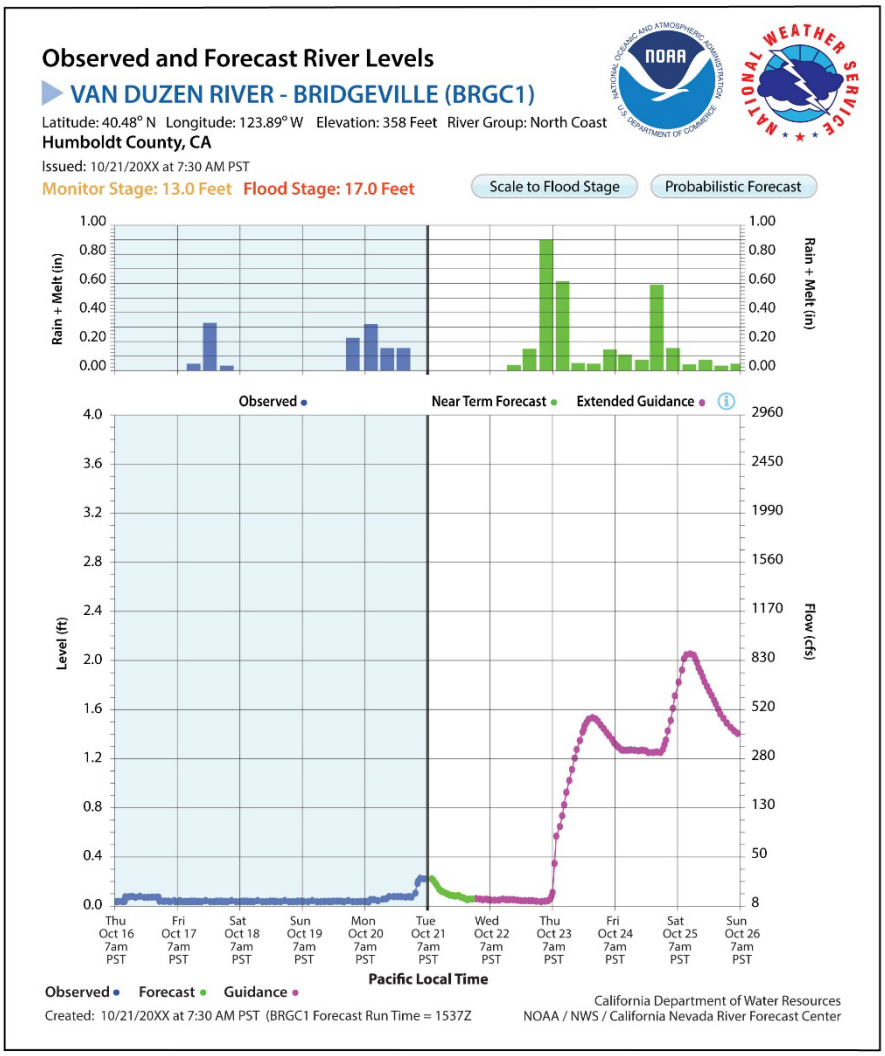


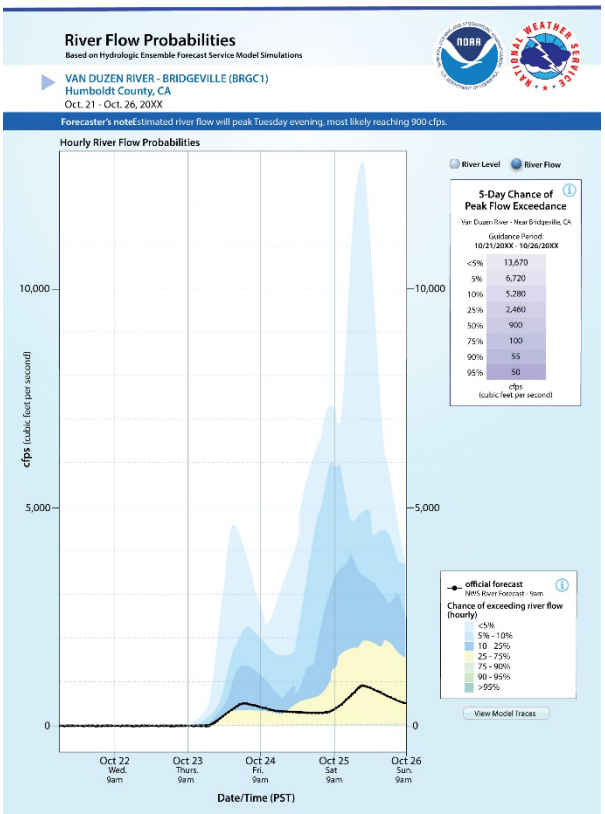


Day T-3 October 21st



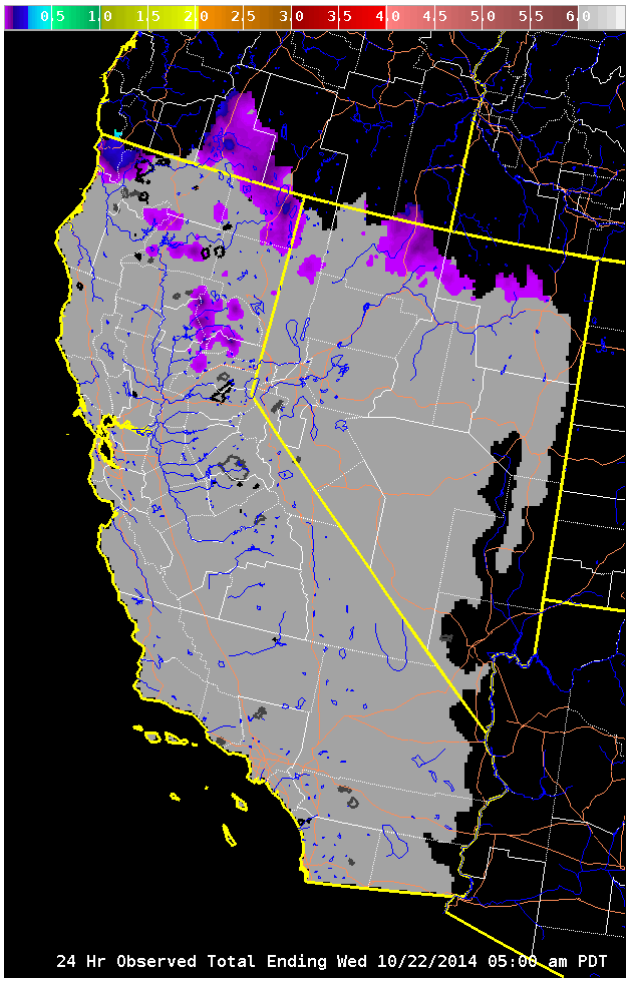
Observed plus QPF for 3 days leading to T.

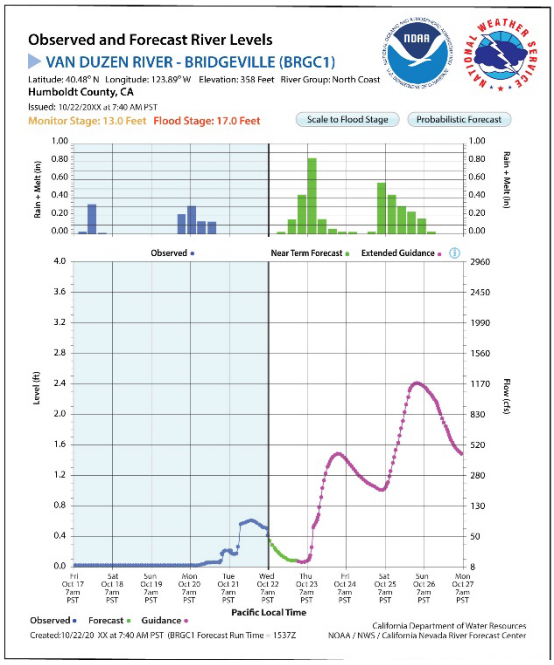

Observed and Forecast River Levels
VAN DUZEN RIVER - BRIDGEVILLE (BRGC1)
Latitude: 40.48° N Longitude: 123.89° W Elevation: 358 Feet River Group: North Coast
Humboldt County, CA
Issued: 10/21/20XX at 7:30 AM PST
Monitor Stage: 13.0 Feet Flood Stage: 17.0 Feet
Scale to Flood Stage
Probabilistic Forecast
Rain + Melt (in)
Observed
Near Term Forecast
Extended Guidance
Level (ft)
Flow (cfs)
Thu Oct 16 7am PST
Fri Oct 17 7am PST
Sat Oct 18 7am PST
Sun Oct 19 7am PST
Mon Oct 20 7am PST
Tue Oct 21 7am PST
Wed Oct 22 7am PST
Thu Oct 23 7am PST
Fri Oct 24 7am PST
Sat Oct 25 7am PST
Sun Oct 26 7am PST
Pacific Local Time
Observed Forecast Guidance
Created: 10/21/20XX at 7:30 AM PST (BRGC1 Forecast Run Time = 1537Z
California Department of Water Resources
NOAA / NWS / California Nevada River Forecast Center



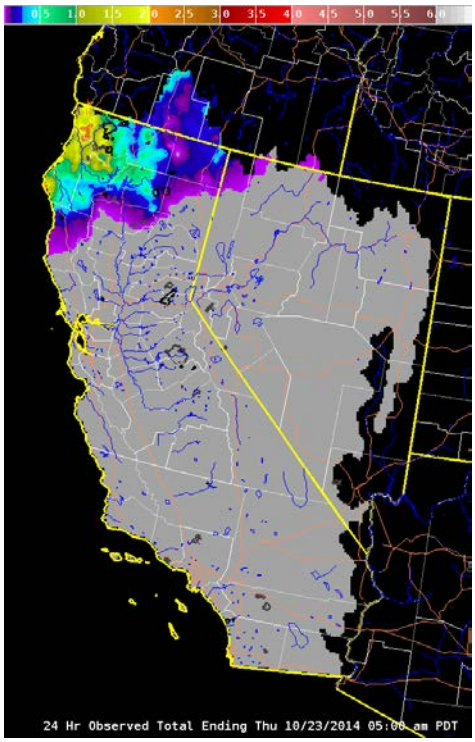
Day T-2 October 22nd

Despite some subtle changes in rainfall totals, the weather forecast looks on track for additional rain starting Thursday through the weekend. This will cause rapid rises on mainstem rivers on Thursday with a secondary river rise over the weekend. No river flooding is expected but temporary low-flow bridges could be impacted.

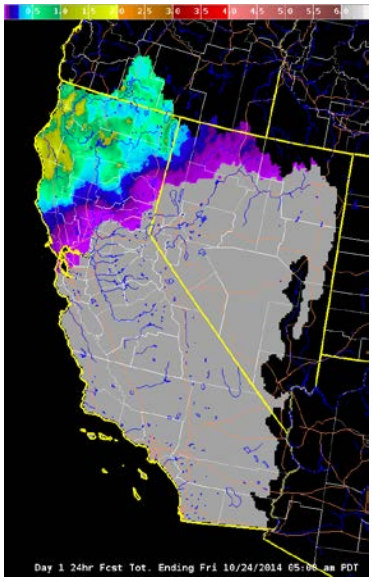

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
24 Hr Observed Total Ending Wed 10/22/2014 05:00 am PDT

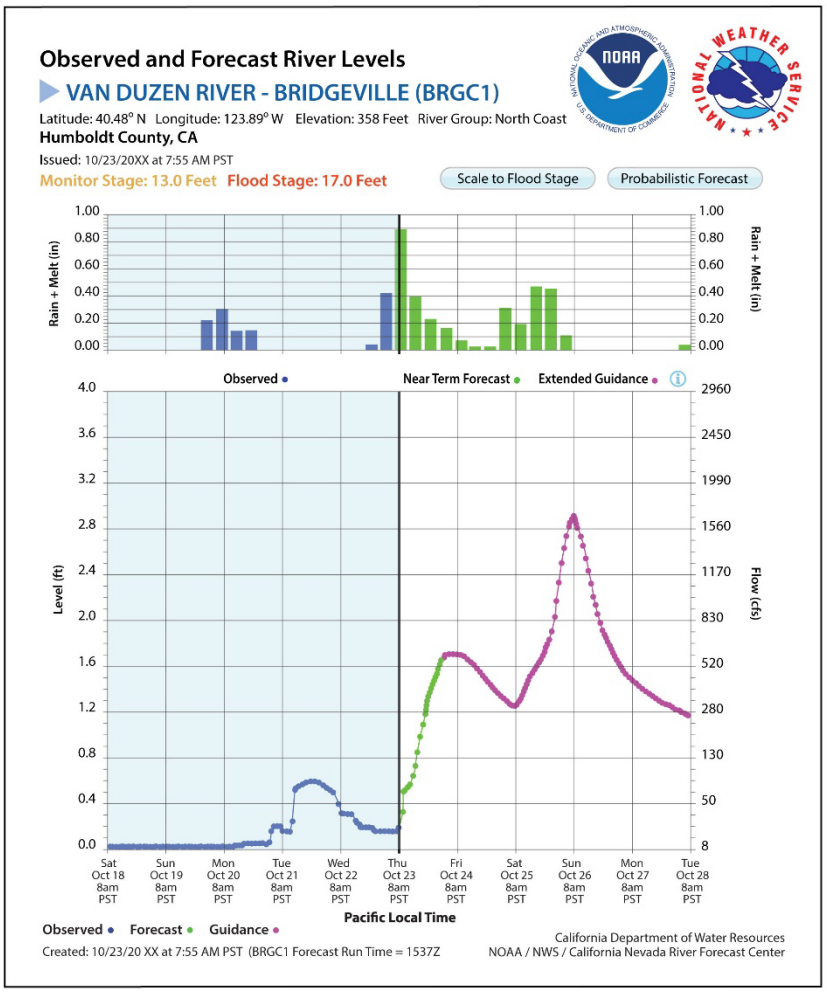

Observed and Forecast River Levels
VAN DUZEN RIVER - BRIDGEVILLE (BRGC1)
Latitude: 40.48° N Longitude: 123.80° W Elevation: 358 Feet River Group: North Coast
Humboldt County, CA
Issued: 10/22/20XX at 7:40 AM PST
Monitor Stage: 13.0 Feet Flood Stage: 17.0 Feet
Scale to Flood Stage
Probabilistic Forecast
Rain + Melt (in)
Observed
Near Term Forecast
Extended Guidance
Level (ft)
Flow (cfs)
Fri Oct 17 7am PST
Sat Oct 18 7am PST
Sun Oct 19 7am PST
Mon Oct 20 7am PST
Tue Oct 21 7am PST
Wed Oct 22 7am PST
Thu Oct 23 7am PST
Fri Oct 24 7am PST
Sat Oct 25 7am PST
Sun Oct 26 7am PST
Mon Oct 27 7am PST
Pacific Local Time
Observed Forecast Guidance
Created:10/22/20 XX at 7:40 AM PST (BRGC1 Forecast Run Time – 1537Z
California Department of Water Resources
NOAA / NWS / California Nevada River Forecast Center

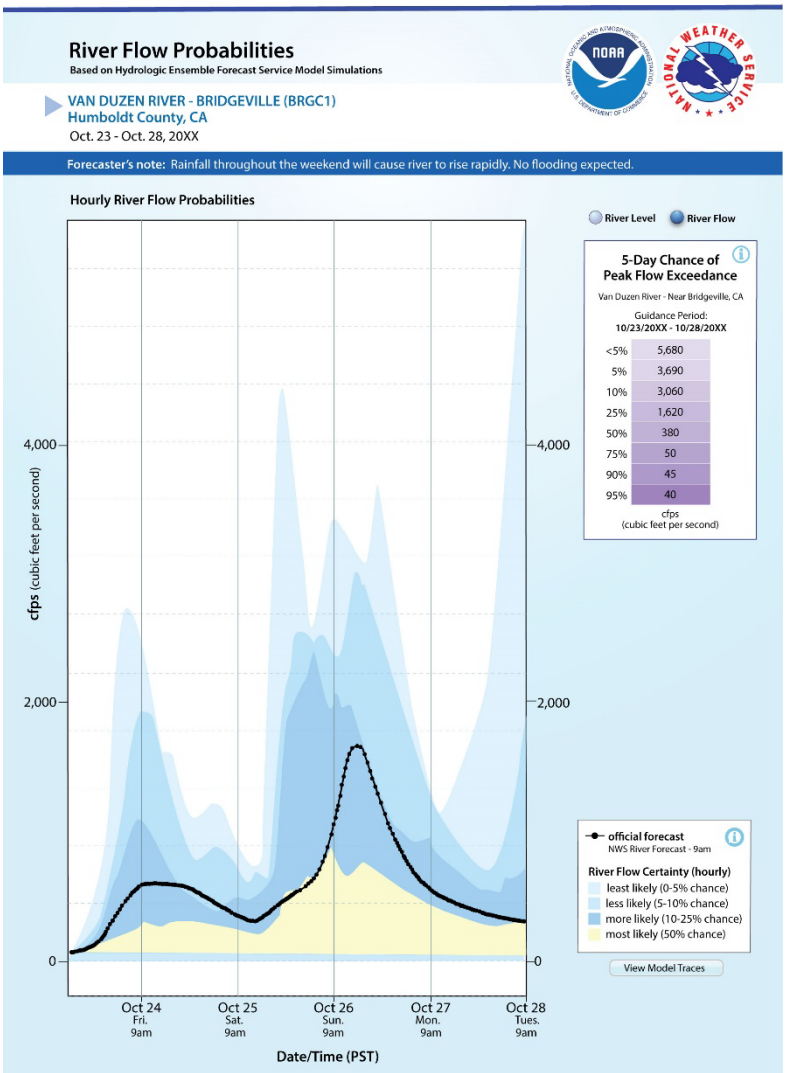
Day T-1 October 23rd



Show observed and QPF 1




Observed and Forecast River Levels
VAN DUZEN RIVER - BRIDGEVILLE (BRGC1)
Latitude: 40.48° N Longitude: 123.89° W Elevation: 358 Feet River Group: North Coast
Humboldt County, CA
Issued: 10/23/20XX at 7:55 AM PST
Monitor Stage: 13.0 Feet Flood Stage: 17.0 Feet
Scale to Flood Stage
Probabilistic Forecast
Rain + Melt (in)
Observed
Near Term Forecast
Extended Guidance
Level (ft)
Flow (cfs)
Sat Oct 18 8am PST
Sun Oct 19 8am PST
Mon Oct 20 8am PST
Tue Oct 21 8am PST
Wed Oct 22 8am PST
Thu Oct 23 8am PST
Fri Oct 24 8am PST
Sat Oct 25 8am PST
Sun Oct 26 8am PST
Mon Oct 27 8am PST
Tue Oct 28 8am PST
Pacific Local Time
Observed Forecast Guidance
Created: 10/23/20 XX at 7:55 AM PST (BRGC1 Forecast Run Time = 1537Z
California Department of Water Resources
NOAA / NWS / California Nevada River Forecast Center



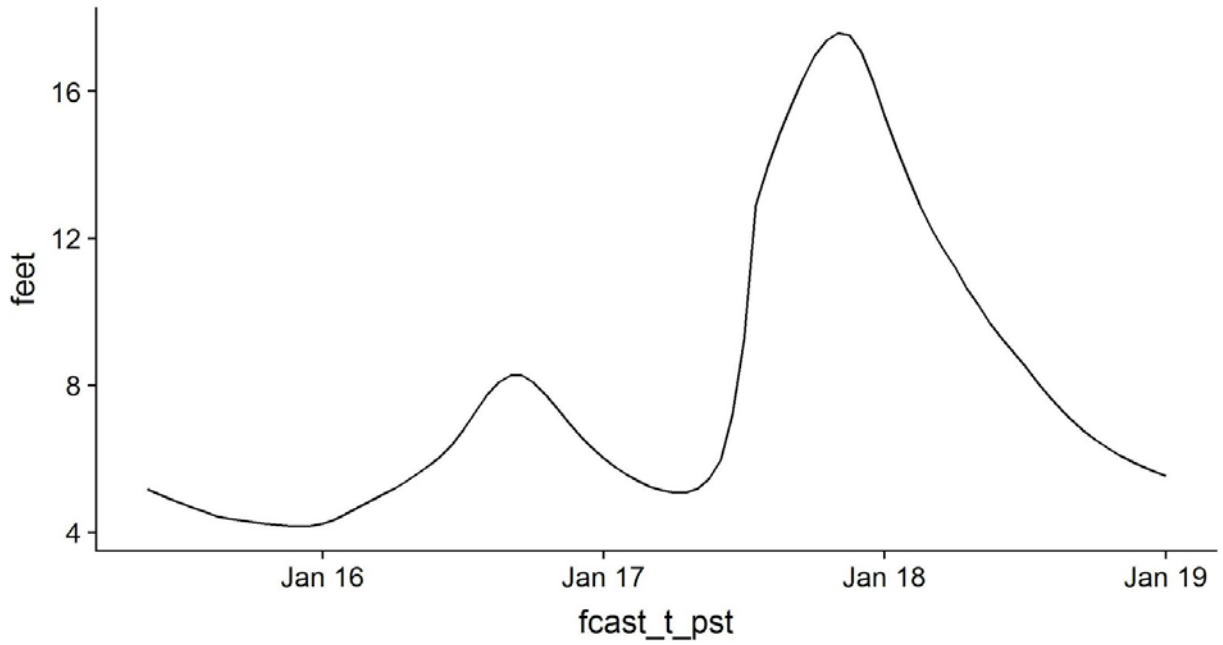
Interactive

https://dbo99.shinyapps.io/thresholdevent_jan16/

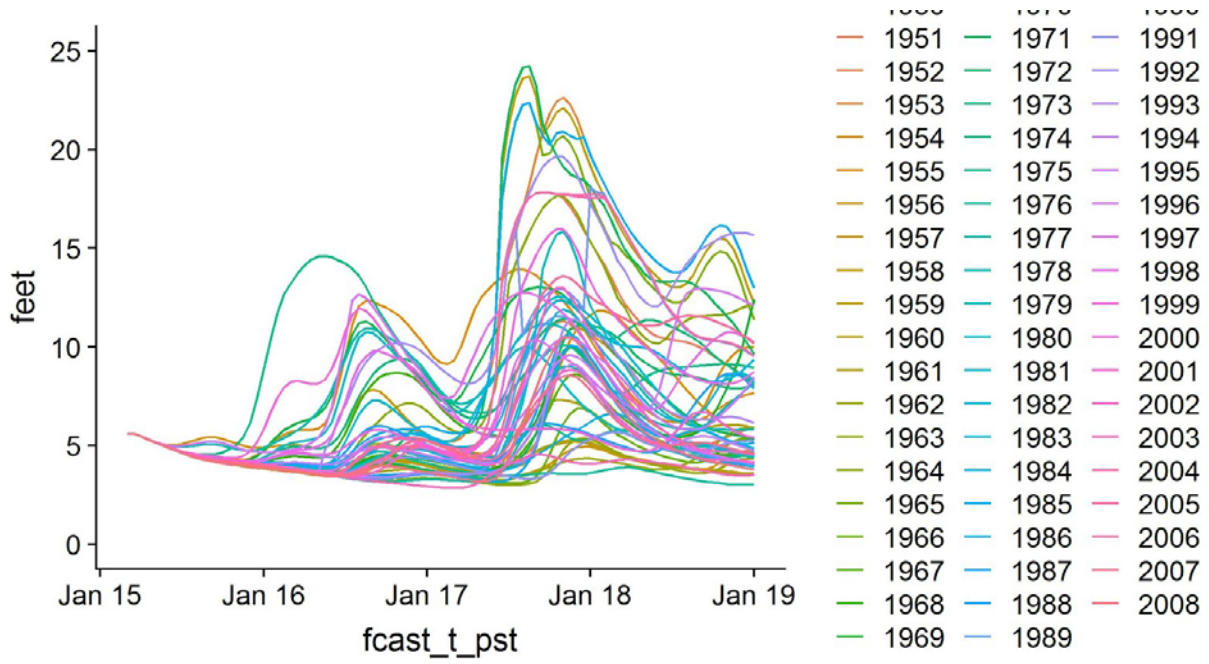
Is this useful?

Background Explanations

Deterministic



Ensemble



Appendix C.

Survey Instruments for Focus Group

Pre-Session Survey

Post-Session Survey (note that these were customized for each location, but only one is shown as an example)

Pre-Session Survey (Residents)

Thank you for participating in this focus group. Please take a few minutes to answer some questions before we get started.

* Required

1. 1. How did you learn about this focus group? *

2. 2. What was your reason for attending? *

3. 3. Do you live in a floodplain?

Mark only one oval.

- Yes
- No
- Unsure

4. 4. Please tell us about your experience with extreme weather/flood events. Have you, a family member, or close friend experienced one or more significant flood events (e.g., experienced damage, loss, evacuation)? *

Mark only one oval.

- Yes
- No

5. 4a. If yes, please indicate:

Mark only one oval.

- within the last 2 years
- 2-5 years ago
- more than 5 years ago

6. 5. If you have experienced a flood, did you respond to official flood warning messages? *

Mark only one oval.

- Yes
- No
- Not applicable

7. 6. How do you rate your own chance of being flooded at your home or business? *

Mark only one oval.

- Extremely High Risk
- Somewhat High Risk
- Some Risk
- Very Little Risk
- No Risk

8. 7. Have you ever prepared for an anticipated flood? *

Mark only one oval.

- Yes
- No

9. 8. How much advance notice do you need to prepare for an extreme event (i.e. flooding)? *

Mark only one oval.

- 1 day
- 2 days
- 3-4 days
- 5 or more days
- Other: _____

10. 9. How do you get information about imminent extreme weather events, such as flooding? Please check all that apply and identify sources in the blank 'Other' line. *

Check all that apply.

- [ ] TV
- [ ] Radio
- [ ] Smartphone
- [ ] Internet
- [ ] Twitter
- [ ] Facebook

Other: [ ] _____

11. 10. How do you get information about how to prepare for extreme weather events? Please check all that apply and identify sources. *

Check all that apply.

- [ ] TV
- [ ] Radio
- [ ] Smartphone
- [ ] Internet
- [ ] Twitter
- [ ] Facebook

Other: [ ] _____

12. 11. If you learn that a significant weather hazard is approaching your area, what do you typically do with that information? (Please check all that apply.) *

Check all that apply.

- [ ] Discuss with friends and family
- [ ] Seek further information
- [ ] Contact local officials

Other: [ ] _____

13. 12. What is your age? *

Mark only one oval.

- Under 20
- 20-29
- 30-39
- 40-49
- 50-59
- 60-69
- 70+

14. 13. What is your gender? *

Mark only one oval.

- Female
- Male
- Prefer not to say
- Other: _____

15. 14. In what Municipality do you live? *

_____

16. 15. In what County do you live? *

_____

17. 16. How long have you lived at your current residence? *

Mark only one oval.

- under 1 year
- 1-2 years
- 3-5 years
- 6-8 years
- 8 or more years

18. 17. What is your highest level of education completed? *

Mark only one oval.

- High School/GED
- Associate's degree or 2-year college degree
- Bachelor's degree or other 4-year college degree
- Post graduate work

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Post-Session Survey (Residents)

* Required

1. 1. Please rate your agreement with the following statements about the forum. *

Mark only one oval per row.

	Strongly Agree	Agree	Disagree	Strongly Disagree
The information was clearly presented.				
I felt comfortable voicing my opinion.				
I know more about the National Weather Service (NWS) resources.				
I feel I could use NWS resources to judge my risk in an extreme weather event.				
I understand the difference between probabilistic and deterministic forecast products.				

2. 2. What is the biggest barrier you face in using NWS flood forecast and warning products? *

3. 3. Our goal today was to gather feedback to improve NWS flood forecast and warning tools, including the River Level Probabilities. Beyond the questions asked today, what else would be important for us to know about how you gather information about extreme weather risks and your intended actions? *

4. 4. After attending today's session, how likely are you to: *

Mark only one oval per row.

	Very likely	Somewhat likely	Somewhat unlikely	Unlikely
Create or revise plans to deal with extreme weather events.				
Share what I learned today with others.				
Seek NWS information about extreme weather risks.				
Seek out uncertainty information				
Use uncertainty forecasts in your decision-making				

5. 5. Which do you prefer in trying to understand your level of risk from flooding? *

Mark only one oval.

- Text-based products
- Graphic/visual products
- Combined text and graphics

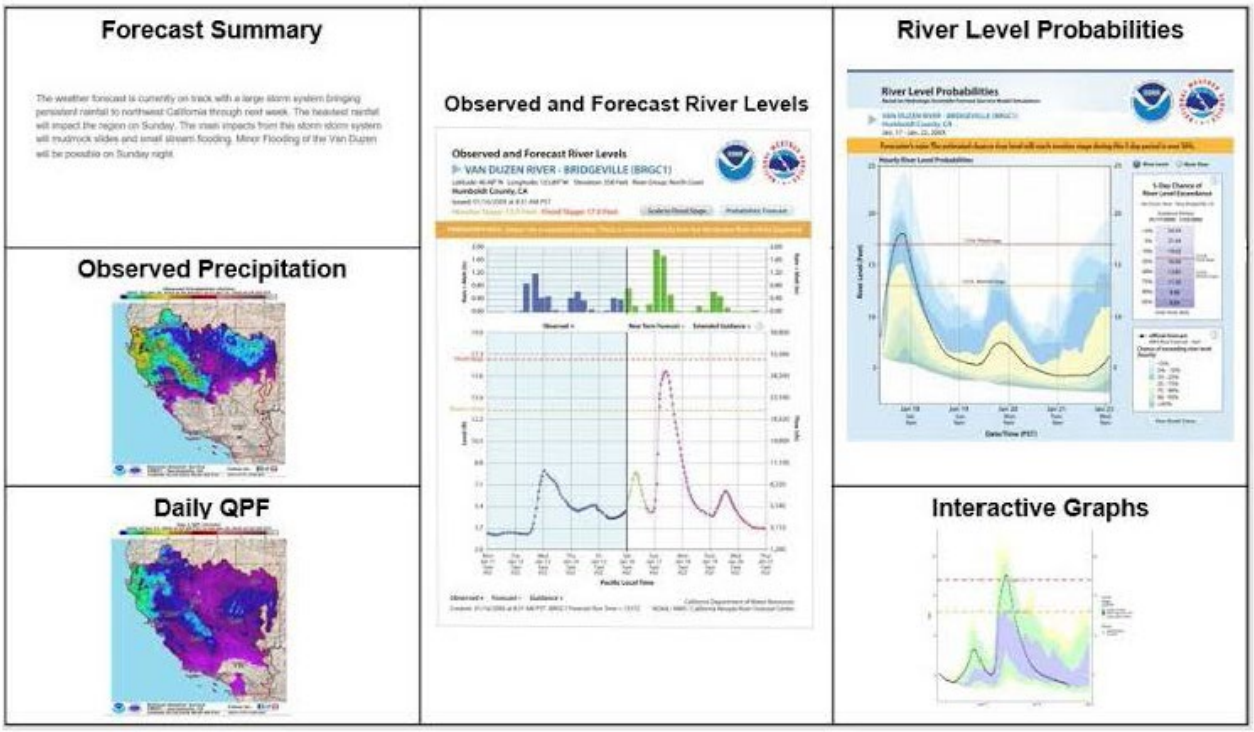
6. 5a. Please explain why: *

7. 6. Please rate the weather products discussed today based on their usefulness to you in assessing your water level situation. See thumbnail images below for reference. *

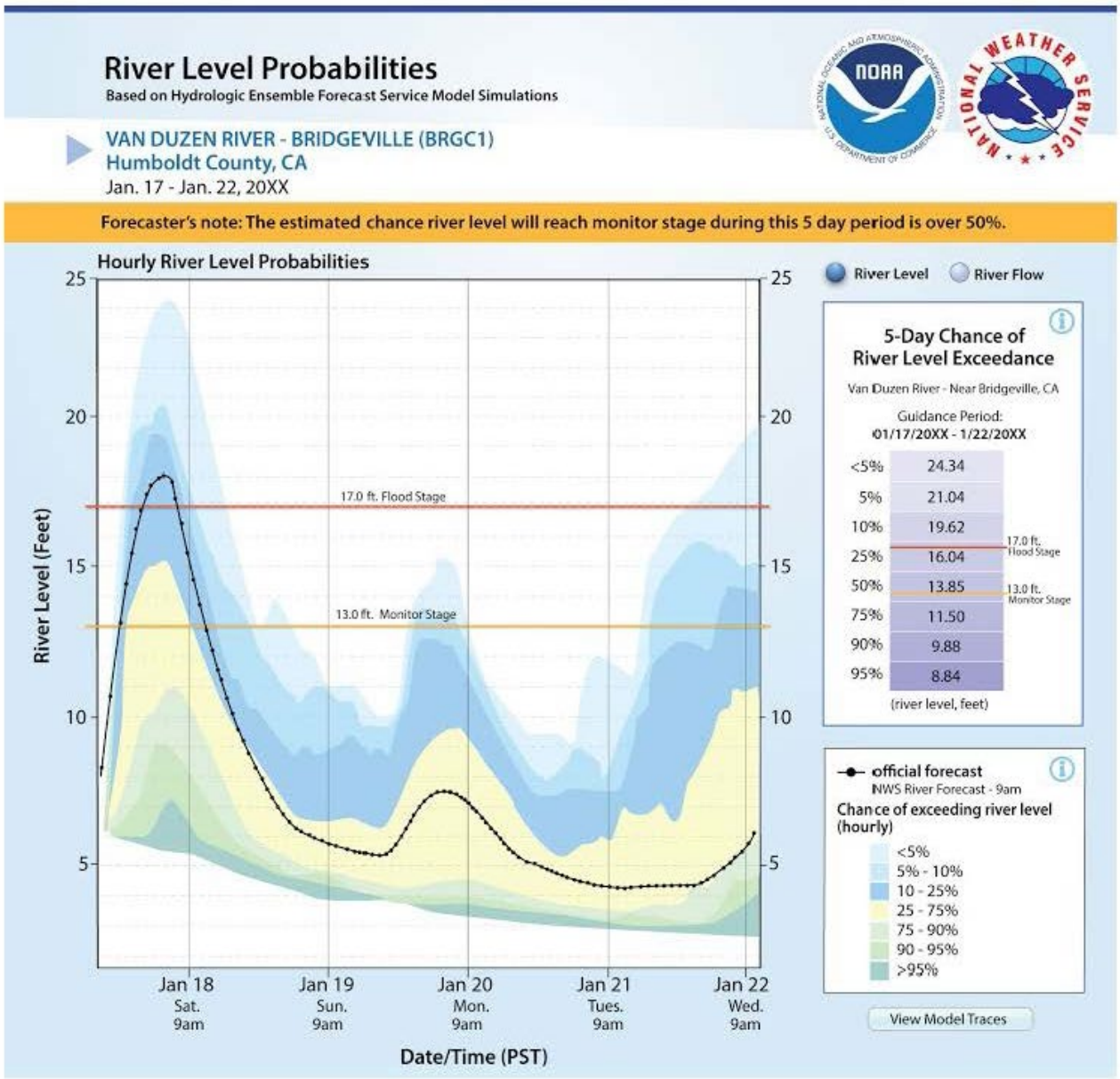
Mark only one oval per row.

	Extremely useful	Very useful	Slightly useful	Not at all useful
Forecast summary				
Observed Precipitation				
Daily QPF				
Observed and Forecast River Levels				
River Level Probabilities				
Interactive graphs				

Thumbnails for Question 6



For Questions 7 and 8



8. 7. What elements of the River Level Probabilities product shown above are most useful in understanding the situation? (check all that apply) *

Check all that apply.

- [ ] Title
- [ ] Legends
- [ ] Colors
- [ ] Percentages
- [ ] Time Period
- [ ] Flood levels (monitor, flood stage)
- [ ] River Level (left axis/side)
- [ ] Range of probable levels (different shades/colors)
- [ ] 5-Day Chance of River Level Exceedance (Box on Right Side)
- [ ] Ability to toggle between river level and peak flow
- [ ] Forecaster's Note

Other: [ ] _____

9. 8. What elements of the River Level Probabilities product are not useful or are confusing to you in understanding the situation? (check all that apply)

Check all that apply.

- [ ] Title
- [ ] Legends
- [ ] Colors
- [ ] Percentages
- [ ] Time period
- [ ] Flood levels (monitor, flood stage)
- [ ] River Level (left axis/side)
- [ ] Range of probable levels (different shades/colors)
- [ ] 5-Day Chance of River Level Exceedance (Box on Right Side)
- [ ] Ability to toggle between river level and peak flow
- [ ] Forecaster's Note

Other: [ ] _____

10. 9. If a probabilistic forecast is different from a deterministic forecast, how does that affect your perception of the forecast given? (check all that apply) *

Check all that apply.

- [ ] I would have less confidence in both forecasts
- [ ] I would have less confidence in the deterministic forecast
- [ ] I would have less confidence in the probabilistic forecast
- [ ] I would not trust future forecasts from this source
- [ ] I would seek out more information to understand why they differed
- [ ] I would ask a forecaster/expert for their opinion
- [ ] I would ignore the forecast

Other: [ ] _____

11. 10. Which social media would you use to find information about the risk of extreme weather/flooding near you? Please check all that apply: *

Check all that apply.

- [ ] Facebook
- [ ] Twitter
- [ ] Weather app

Other: [ ] _____

12. 11. Which digital platform are you most likely to use to access NWS resources? *

Mark only one oval.

- ( ) Smartphone
- ( ) Tablet
- ( ) Computer
- ( ) Other: _____

13. 12. Was anything in the session confusing? *

Mark only one oval.

- Yes
- No

14. 12a. If yes, please explain:

15. 13. What improvements could be made in the format or content? *

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Appendix D.

Round 3 Online Survey

Focus Group Follow-up Survey

Thank you for participating in an earlier focus group for our project testing the understandability and usefulness of National Weather Service (NWS) hydrology products. We have taken your suggestions into consideration and made revisions to the Probability of River Levels product. We modified colors, added percentiles, and clarified wording. Now, we ask you to once again provide us your feedback by answering the questions below. It will help us determine how helpful the revisions are for improving understanding and usability.

As a reminder, this project focused on probabilistic forecast products. The forecasts are assembled from a variety of meteorological models that show a range of possible scenarios of differing location, timing and amounts of precipitation. The ensemble river forecasts show what the river would be for different precipitation scenarios. The NWS would like to understand how these tools can be helpful to individuals who need to be aware of the possibility of flooding where they live.

Please note we are asking demographic and flood experience information again because we need to identify whether there are differing needs for information and opinions about the products, as that will inform our recommendations to the NWS.

* Required

1. What is your age? *

Check all that apply.

- [ ] <20
- [ ] 20-29
- [ ] 30-39
- [ ] 40-49
- [ ] 50-59
- [ ] 60-69
- [ ] 70+

2. What is your gender? *

Mark only one oval.

- ( ) Female
- ( ) Male
- ( ) Prefer not to say
- ( ) Prefer to self describe

3. What is the highest level of education completed? *

Mark only one oval.

- ( ) High school/GED
- ( ) Associate's/2-year Degree
- ( ) Bachelor's/4-year Degree
- ( ) Post graduate work
- ( ) Other: _____

4. We are interested in your experience with extreme weather/flood events. How many times have you been directly affected by flooding (property affected)? Please put a number. *

_____

5. About how many times were you inconvenienced by flooding (had to change plans/travel)? Please put a number. *

_____

6. How many times have family or friends experienced flooding? Please put a number. *

_____

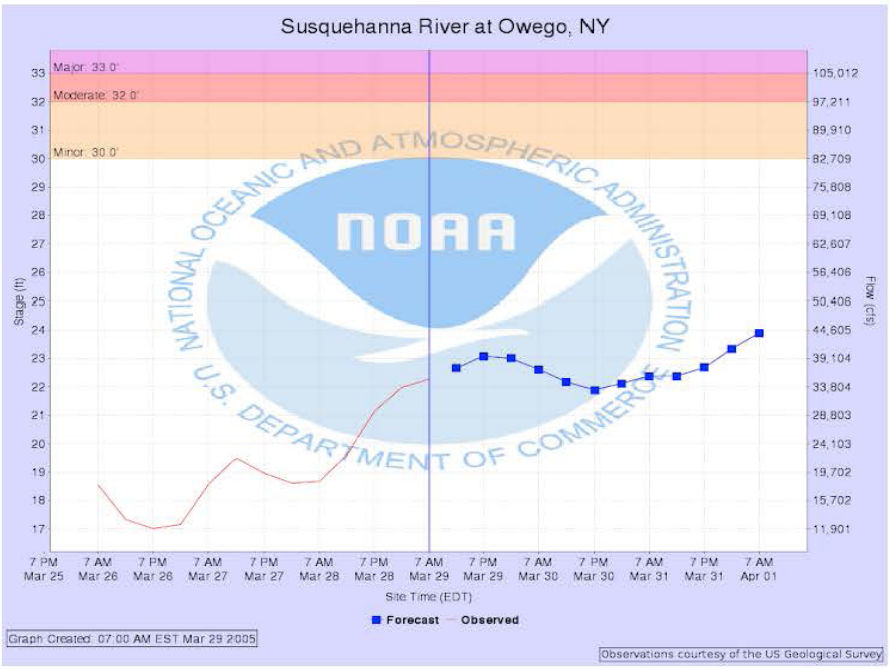
Interest in flood related products

7. Are you interested in forecasts of river levels? *

Mark only one oval.

- ( ) Yes, definitely
- ( ) Somewhat
- ( ) Not really
- ( ) Definitely not
- ( ) Other: _____

Example of Hydrograph (APHS)

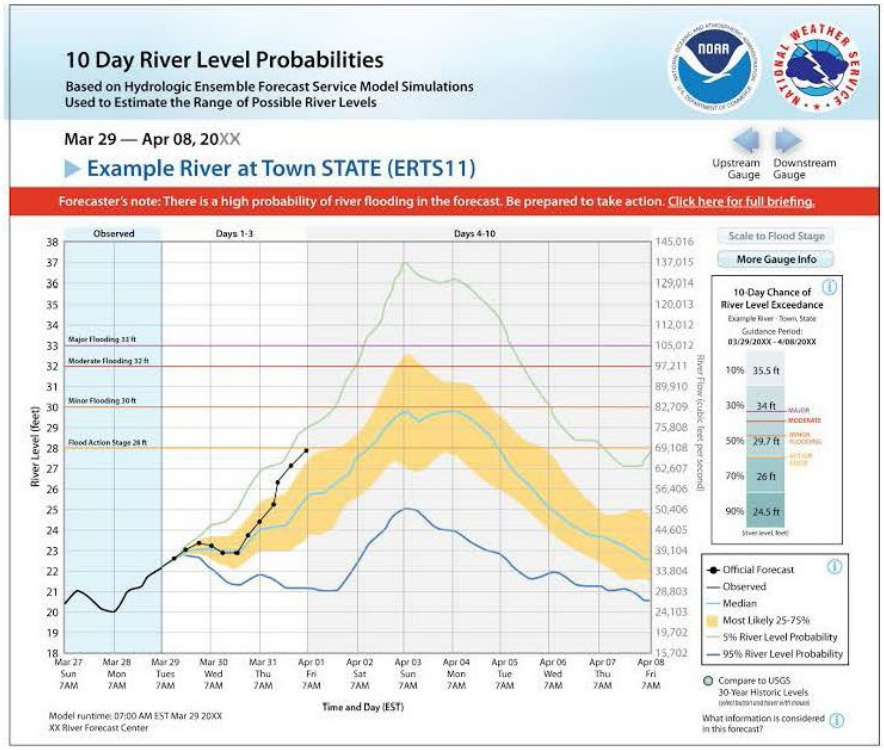


8. Is the Hydrograph (APHS) useful to you? *

Mark only one oval.

	1	2	3	4	5	
Not at all useful	◯	◯	◯	◯	◯	Very useful

Example of Probability of River Level Forecast

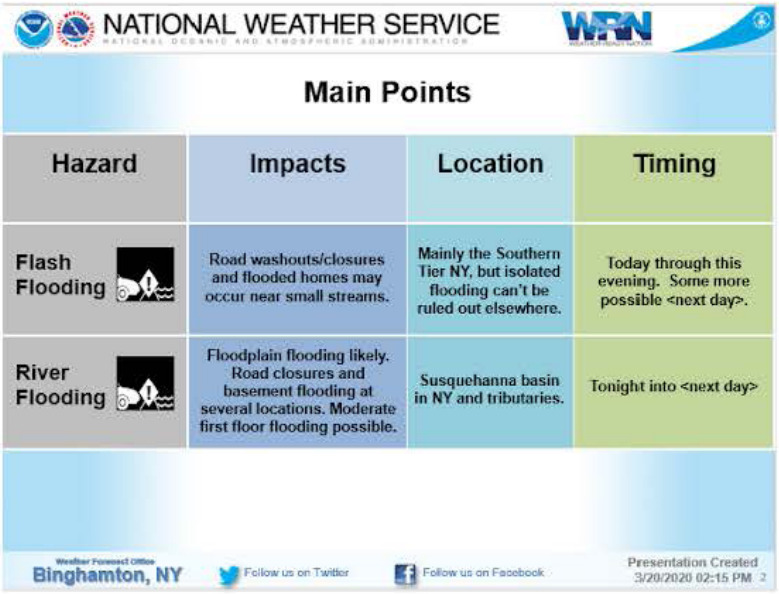


9. Is the Probability of River Level Forecast product useful to you? *

Mark only one oval.

	1	2	3	4	5	
Not at all useful	◯	◯	◯	◯	◯	Very useful

Example of part of a Briefing package.



NATIONAL WEATHER SERVICE

Main Points

Hazard	Impacts	Location	Timing
Flash Flooding	Road washouts/closures and flooded homes may occur near small streams.	Mainly the Southern Tier NY, but isolated flooding can't be ruled out elsewhere.	Today through this evening. Some more possible <next day>.
River Flooding	Floodplain flooding likely. Road closures and basement flooding at several locations. Moderate first floor flooding possible.	Susquehanna basin in NY and tributaries.	Tonight into <next day>

Weather Forecast Office Binghamton, NY Follow us on Twitter Follow us on Facebook Presentation Created 3/20/2020 02:15 PM 2

10. Is the briefing package (multiple products packaged together with text/information from local Weather Forecast Office) useful to you? *

Mark only one oval.

	1	2	3	4	5	
Not at all useful	◯	◯	◯	◯	◯	Very useful

Focus Group participation

11. When did you participate in a focus group *

Mark only one oval.

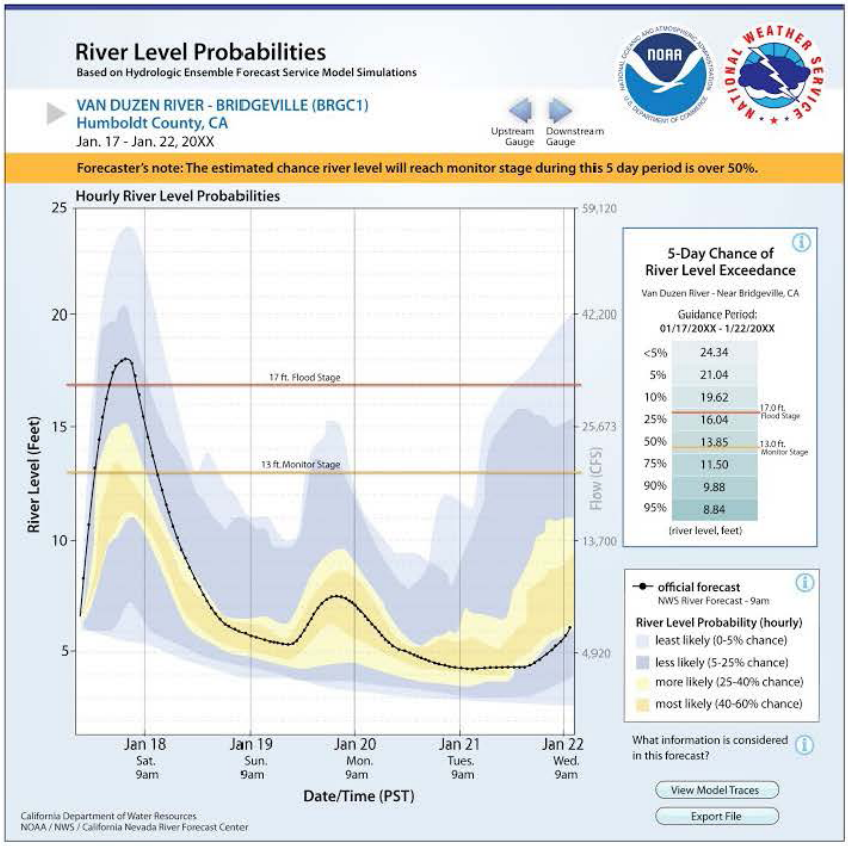
- ◯ Spring 2019
- ◯ Fall 2019
- ◯ Other: _____

12. What focus group location did you participate in? *

Mark only one oval.

- ◯ Eureka, CA *Skip to question 13*
- ◯ Owego, NY *Skip to question 24*
- ◯ Gunnison, CO *Skip to question 38*
- ◯ Durango, CO *Skip to question 49*

Use the product below to answer the following questions.



13. What is this product telling you (check all that apply)? *

Check all that apply.

- [ ] It is most likely (40-60% chance) that river levels will stay below flood stage from Jan 17 to 22
- [ ] There is a small possibility that flood stage could be reached on Jan 22
- [ ] Flooding will occur Jan 17
- [ ] No flooding will happen Jan 17 to Jan 22

Other: [ ] _____

14. After viewing this product how do you view the risk of flooding from Jan 17-22? *

Mark only one oval.

- ( ) Very high
- ( ) Somewhat high
- ( ) Neither high nor low
- ( ) Somewhat low
- ( ) Very low
- ( ) Other: _____

15. Would you take any actions as a result of this product? *

Mark only one oval.

- Yes
- No
- Maybe

16. If yes, what actions would you take as a result of this product (check all that apply).

Check all that apply.

- [ ] Seek out more information
- [ ] Talk to family, friends, and neighbors.
- [ ] Take action to secure outdoor property and reduce property loss from flooding
- [ ] Make sure to have an emergency preparedness kit/stock up on food, water, and batteries
- [ ] Keep an eye on the river

Other: [ ] _____

17. If no, why (check all that apply)?

Check all that apply.

- [ ] I'm not concerned about flooding risk
- [ ] The information in this product doesn't tell me enough
- [ ] I don't believe the forecast
- [ ] I don't know what actions to take

Other: [ ] _____

18. How useful is this product (select one)? *

Mark only one oval.

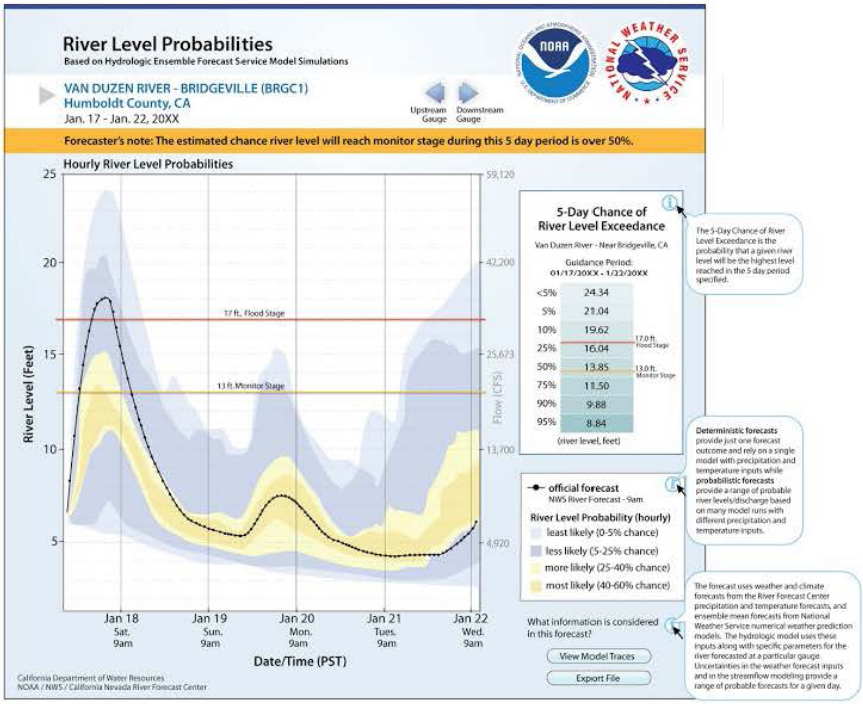
- Very useful
- Somewhat useful
- Neutral (neither useful nor not useful)
- Somewhat not useful
- Not useful

19. How likely are you to use this product in the future? *

Mark only one oval.

- Very likely
- Somewhat likely
- Neutral (neither likely nor unlikely)
- Somewhat unlikely
- Very unlikely

Use the product below to answer the following questions.



20. What elements of this product are most useful in understanding the situation (check all that apply). *

Check all that apply.

- [ ] Title
- [ ] Legends
- [ ] Colors
- [ ] Percentages (0-5%, 5-25%, 25-40%, 40-60%)
- [ ] Likely categories (least, less, more, most)
- [ ] Time period
- [ ] Flood levels (monitor and flood stage)
- [ ] River level (left axis)
- [ ] Flow (right axis)
- [ ] Range of probable levels (different shades/colors)
- [ ] Forecaster's note
- [ ] 5-Day chance of exceedence (box on right side)
- [ ] Option to click upstream and downstream gauge (top arrows)
- [ ] Information pop-ups (i)
- [ ] Option to view model traces
- [ ] Option to export file
- [ ] None

Other: [ ] _____

21. What elements of this product are not useful or confusing to you in understanding the situation (check all that apply). *

Check all that apply.

- [ ] Title
- [ ] Legends
- [ ] Colors
- [ ] Percentages (0-5%, 5-25%, 25-40%, 40-60%)
- [ ] Likely categories (least, less, more, most)
- [ ] Time period
- [ ] Flood levels (monitor and flood stge)
- [ ] River level (left axis)
- [ ] Flow (right axis)
- [ ] Range of probable levels (different shades/colors)
- [ ] Forecaster's note
- [ ] 5-Day chance of exceedence (box on right side)
- [ ] Option to click upstream and downstream gauge (top arrows)
- [ ] Information pop-ups (i)
- [ ] Option to view model traces
- [ ] Option to export file
- [ ] None

Other: [ ] _____

22. What additional information or elements would make this product more useful or understandable to you (if any)? *

_____

_____

_____

_____

_____

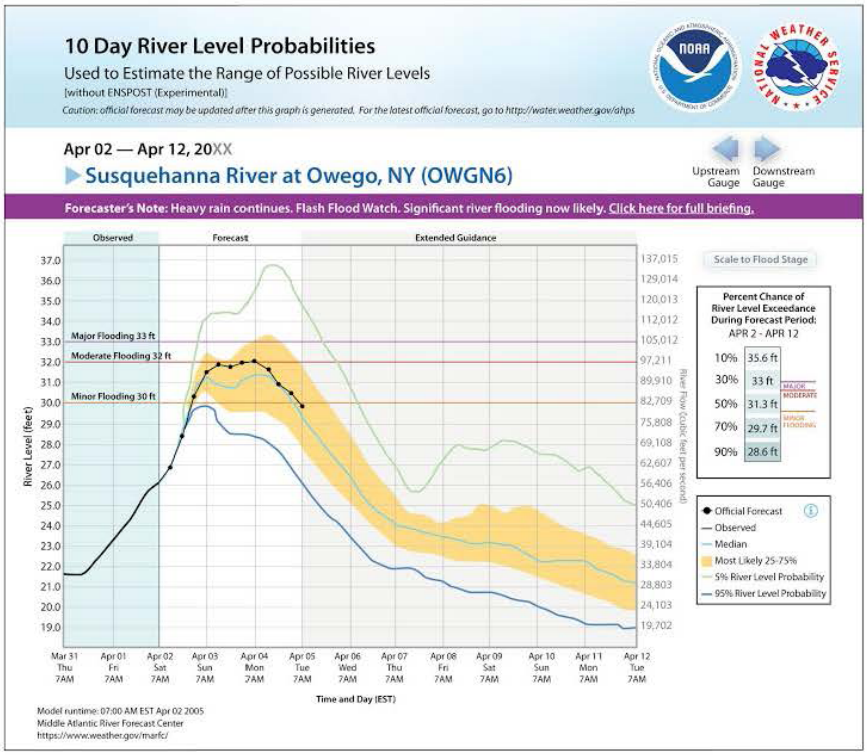
23. The official/deterministic forecast is higher than the probabilistic forecast on Jan 17, how does that affect your perception of the forecast given? (check all that apply) *

Check all that apply.

- [ ] I would have less confidence in both forecasts
- [ ] I would have less confidence in the deterministic forecast
- [ ] I would have less confidence in the probabilistic forecast
- [ ] I would not trust future forecasts from this source
- [ ] I would seek out more information to understand why they differed
- [ ] I would ask a forecaster/expert for their opinion
- [ ] I would ignore the forecast

Other: [ ] _____

Use the product below to answer the following questions.



24. What is this product telling you (check all that apply)? *

Check all that apply.

- [ ] Minor flooding is likely on April 3rd.
- [ ] Major flooding is not at all likely from April 2nd to April 12th
- [ ] There is a chance of minor flooding on April 6th
- [ ] Moderate flooding is likely to occur on April 5th

Other: [ ] _____

25. After viewing this product how do you view the risk of flooding from April 2nd to 12th? *

Mark only one oval.

- ( ) Very high
- ( ) Somewhat high
- ( ) Neither high nor low
- ( ) Somewhat low
- ( ) Very low
- ( ) Other: _____

26. Would you take any actions as a result of this product? *

Mark only one oval.

- Yes
- No
- Maybe

27. If yes, what actions would you take as a result of this product (check all that apply).

Check all that apply.

- [ ] Seek out more information
- [ ] Talk to family, friends, and neighbors.
- [ ] Take action to secure outdoor property and reduce property loss from flooding
- [ ] Make sure to have an emergency preparedness kit/stock up on food, water, and batteries
- [ ] Keep an eye on the river

Other: [ ] _____

28. If no, why (check all that apply)?

Check all that apply.

- [ ] I'm not concerned about flooding risk
- [ ] The information in this product doesn't tell me enough
- [ ] I don't believe the forecast
- [ ] I don't know what actions to take

Other: [ ] _____

29. How useful is this product (select one)? *

Mark only one oval.

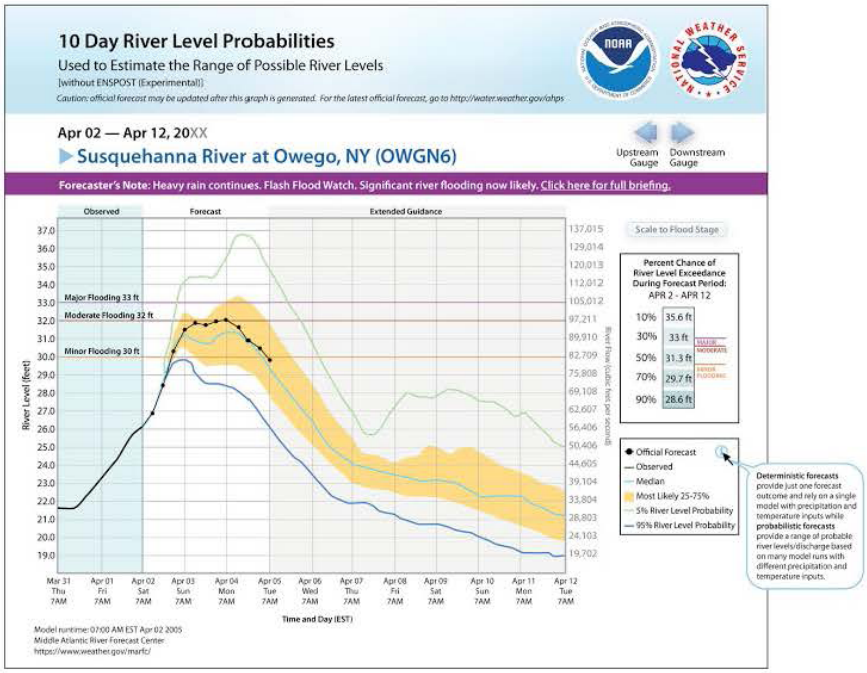
- Very useful
- Somewhat useful
- Neutral (neither useful nor not useful)
- Somewhat not useful
- Not useful

30. How likely are you to use this product in the future? *

Mark only one oval.

- Very likely
- Somewhat likely
- Neutral (neither likely nor unlikely)
- Somewhat unlikely
- Very unlikely

Use the product below to answer the following questions.



31. What elements of this product are most useful in understanding the situation (check all that apply). *

Check all that apply.

- [ ] Title
- [ ] Legends
- [ ] Colors
- [ ] Percentages(25-75%)
- [ ] Time period
- [ ] Flood levels (minor, moderate, and major)
- [ ] River level (left axis)
- [ ] River flow (right axis)
- [ ] Median line
- [ ] 5% and 95% River Level Probability lines
- [ ] Forecaster's note
- [ ] Percent chance of exceedence (box on right side)
- [ ] Option to move upstream or downstream (arrows at the top)
- [ ] Information pop-up box
- [ ] Scale to Flood Stage option (button at the top right)
- [ ] None

Other: [ ] _____

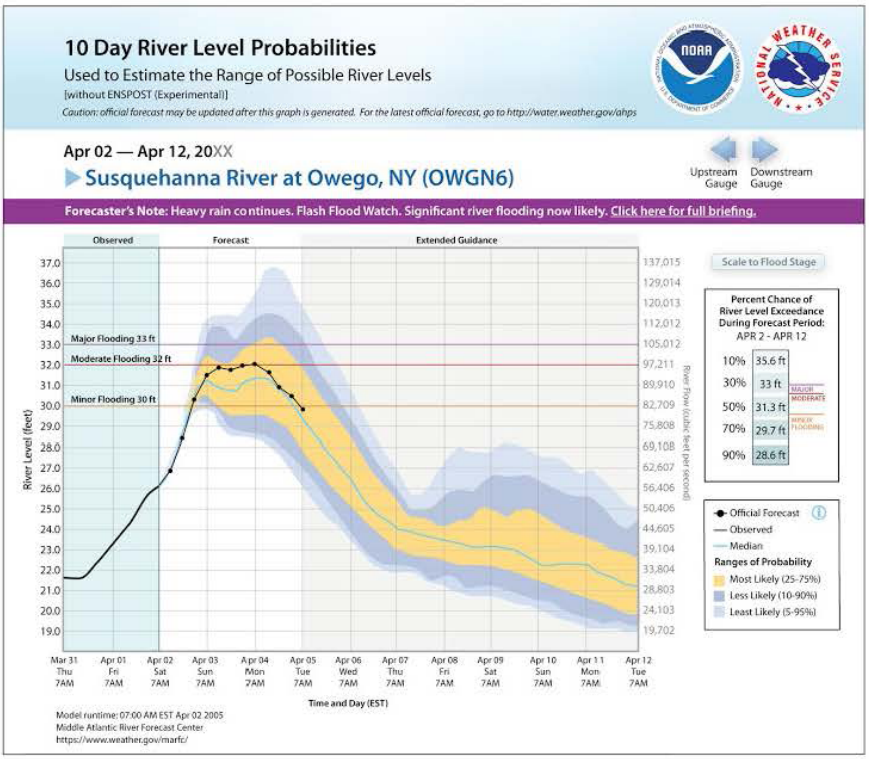
32. What elements of this product are not useful or confusing to you in understanding the situation (check all that apply). *

Check all that apply.

- [ ] Title
- [ ] Legends
- [ ] Colors
- [ ] Percentages (25-75%)
- [ ] Time period
- [ ] Flood levels (minor, moderate, and major)
- [ ] River level (left axis)
- [ ] River flow (right axis)
- [ ] Median line
- [ ] 5% and 95% River Level Probability lines
- [ ] Forecaster's note
- [ ] Percent chance of exceedence (box on right side)
- [ ] Option to move upstream or downstream (arrows at the top)
- [ ] Information pop-up box
- [ ] Scale to flood stage option (button at the top right)
- [ ] None

Other: [ ] _____

Below is another way to represent probabilities - using shaded probabilities. Please respond to the following questions with this graphic in mind.



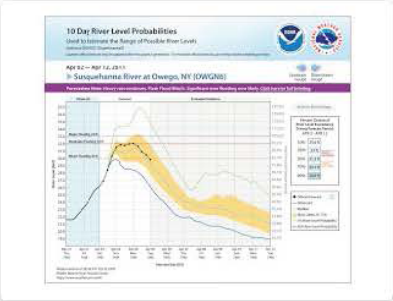
33. Do the shaded ranges of probabilities make the product easier for you to understand? *

Mark only one oval.

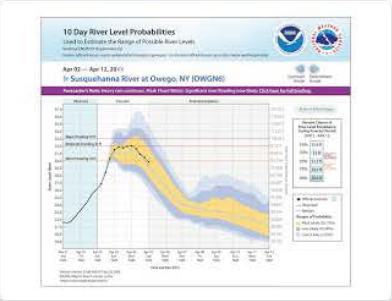
- Yes
- No
- Maybe

34. Which of these products do you prefer? *

Check all that apply.



Option 1



Option 2

35. Why do you prefer this product? *

36. What additional information or elements would make these products more useful or understandable to you? *

37. If a probabilistic forecast is different from a deterministic/official forecast, how does that affect your perception of the forecast given? (check all that apply) *

Check all that apply.

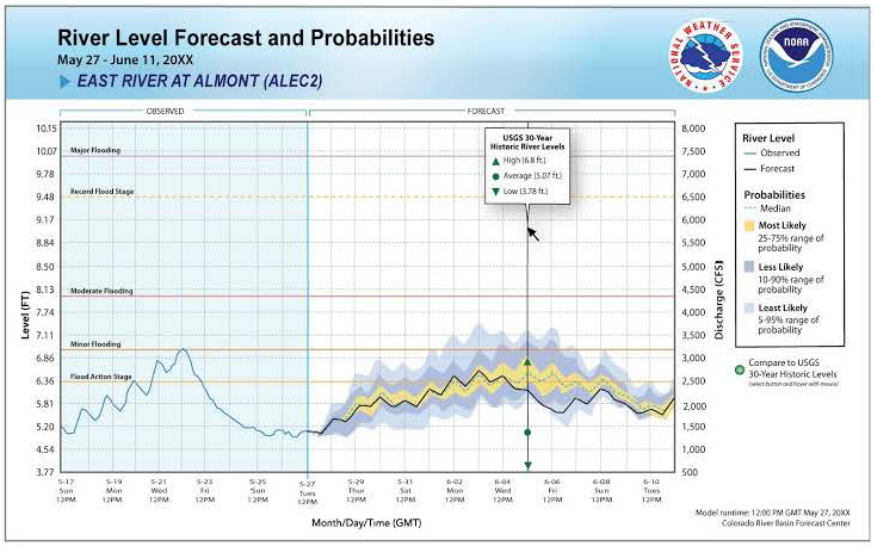
- [ ] I would have less confidence in both forecasts
- [ ] I would have less confidence in the deterministic forecast
- [ ] I would have less confidence in the probabilistic forecast
- [ ] I would not trust future forecasts from this source
- [ ] I would seek out more information to understand why they differed
- [ ] I would ask a forecaster/expert for their opinion
- [ ] I would ignore the forecast

Other: [ ] _____

Skip to question 60

Gunnison, CO

Use the product below to answer the following questions.



38. What is this product telling you (check all that apply)? *

Check all that apply.

- [ ] Minor flooding is likely to occur on June 2nd
- [ ] River levels will be above action stage on June 8th
- [ ] River levels will be above average on June 5th
- [ ] No flooding is likely to occur on June 6th

Other: [ ] _____

39. After viewing this product how do you view the risk of flooding in the time period May 27 to June 11? *

Mark only one oval.

- Very high
- Somewhat high
- Neither high nor low
- Somewhat low
- Very low
- Other: _____

40. Would you take any actions as a result of this product? *

Mark only one oval.

- Yes
- No
- Maybe

41. If yes, what actions would you take as a result of this product (check all that apply).

Check all that apply.

- [ ] Seek out more information
- [ ] Talk to family, friends, and neighbors.
- [ ] Take action to secure outdoor property and reduce property loss from flooding
- [ ] Make sure to have an emergency preparedness kit/stock up on food, water, and batteries
- [ ] Keep an eye on the river

Other: [ ] _____

42. If no, why (check all that apply)?

Check all that apply.

- [ ] I'm not concerned about flooding risk
- [ ] The information in this product doesn't tell me enough
- [ ] I don't believe the forecast
- [ ] I don't know what actions to take

Other: [ ] _____

43. How useful is this product (select one)? *

Mark only one oval.

- Very useful
- Somewhat useful
- Neutral (neither useful nor not useful)
- Somewhat not useful
- Not useful

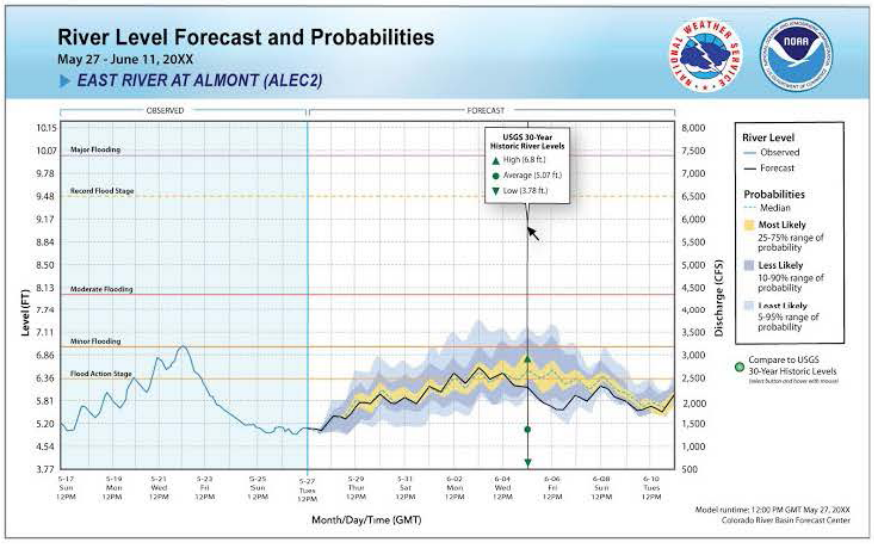
44. How likely are you to use this product in the future? *

Mark only one oval.

- Very likely
- Somewhat likely
- Neutral (neither likely nor unlikely)
- Somewhat unlikely
- Very unlikely

River Level Probabilities

Use the product below to answer the following questions.



45. What elements of this product are most useful in understanding the situation (check all that apply). *

Check all that apply.

- [ ] Title
- [ ] Legend
- [ ] Colors
- [ ] Percentages (5-95%, 10-90%, 25-75%)
- [ ] Likely categories (most, less, least)
- [ ] Time period
- [ ] Flood levels (minor, moderate, and major)
- [ ] River level (left axis)
- [ ] Discharge (right axis)
- [ ] Median line
- [ ] Range of probable levels (different shades/colors)
- [ ] Forecaster's note
- [ ] USGS Historic River Levels Comparison
- [ ] None

Other: [ ] _____

46. What elements of this product are not useful or confusing to you in understanding the situation (check all that apply). *

Check all that apply.

- [ ] Title
- [ ] Legend
- [ ] Colors
- [ ] Percentages (5-95%, 10-90%, 25-75%)
- [ ] Likely categories (most, less, least)
- [ ] Time period
- [ ] Flood levels (minor, moderate, and major)
- [ ] River level (left axis)
- [ ] Discharge (right axis)
- [ ] Median line
- [ ] Range of probable levels (different shades/colors)
- [ ] Forecaster's note
- [ ] USGS Historic River Levels Comparison
- [ ] None

Other: [ ] _____

47. What additional information or elements would make this product more useful or understandable to you? *

_____

_____

_____

48. On June 6th the deterministic forecast (black line) is different from the probabilistic forecast, how does that affect your perception of the forecast given? (check all that apply) *

Check all that apply.

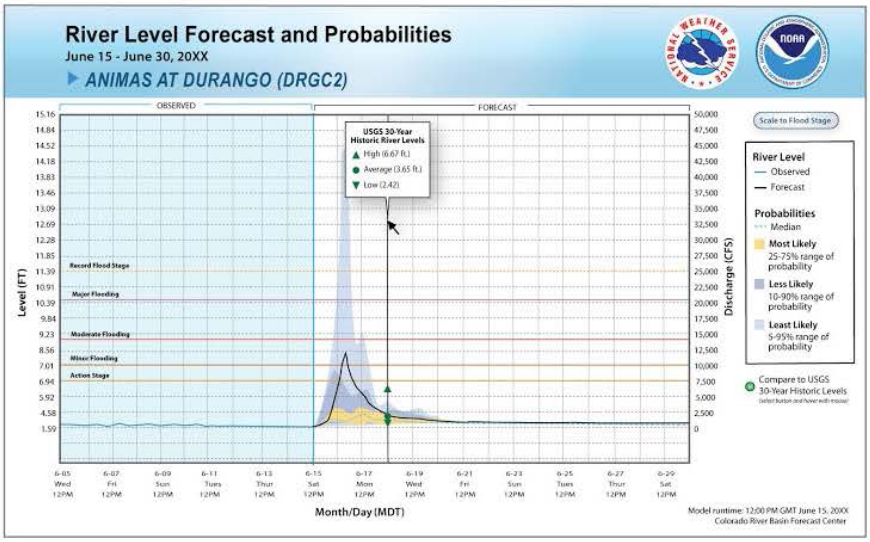
- [ ] I would have less confidence in both forecasts
- [ ] I would have less confidence in the deterministic forecast
- [ ] I would have less confidence in the probabilistic forecast
- [ ] I would not trust future forecasts from this source
- [ ] I would seek out more information to understand why they differed
- [ ] I would ask a forecaster/expert for their opinion
- [ ] I would ignore the forecast

Other: [ ] _____

Skip to question 60

Durango, CO

Use the product below to answer the following questions.



49. What is this product telling you (check all that apply)? *

Check all that apply.

- [ ] No moderate or major flooding is likely to occur June 15-30th
- [ ] Minor flooding is likely on June 16th.
- [ ] Action stage and minor flooding will not be reached June 15-30th
- [ ] River levels will be at average on June 18th

Other: [ ] _____

50. After viewing this product how do you view the risk of flooding in the time period June 15th-30th? *

Mark only one oval.

- Very high
- Somewhat high
- Neither high nor low
- Somewhat low
- Very low
- Other: _____

51. Would you take any actions as a result of this product? *

Mark only one oval.

- Yes
- No
- Maybe

52. If yes, what actions would you take as a result of this product (check all that apply).

Check all that apply.

- [ ] Seek out more information
- [ ] Talk to family, friends, and neighbors.
- [ ] Take action to secure outdoor property and reduce property loss from flooding
- [ ] Make sure to have an emergency preparedness kit/stock up on food, water, and batteries
- [ ] Keep an eye on the river

Other: [ ] _____

53. If no, why (check all that apply)?

Check all that apply.

- [ ] I'm not concerned about flooding risk
- [ ] The information in this product doesn't tell me enough
- [ ] I don't believe the forecast
- [ ] I don't know what actions to take

Other: [ ] _____

54. How useful is this product (select one)? *

Mark only one oval.

- Very useful
- Somewhat useful
- Neutral (neither useful nor not useful)
- Somewhat not useful
- Not useful

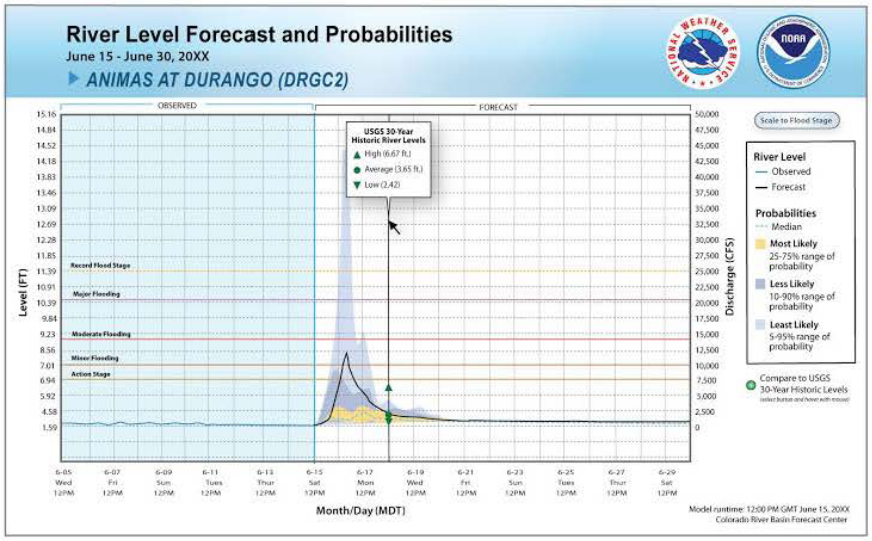
55. How likely are you to use this product in the future? *

Mark only one oval.

- Very likely
- Somewhat likely
- Neutral (neither likely nor unlikely)
- Somewhat unlikely
- Very unlikely

River Level Probabilities

Use the product below to answer the following questions.



56. What elements of this product are most useful in understanding the situation (check all that apply). *

Check all that apply.

- [ ] Title
- [ ] Legends
- [ ] Colors
- [ ] Percentages (5-95%, 10-90%, 25-75%)
- [ ] Likely categories (most, less, least)
- [ ] Time period
- [ ] Flood levels (minor, moderate, and major)
- [ ] River level (left axis)
- [ ] Discharge (right axis)
- [ ] Median line
- [ ] Range of probable levels (different shades/colors)
- [ ] Forecaster's note
- [ ] USGS Historic River Levels Comparison
- [ ] Scale to flood stage option (button at top right)
- [ ] None

Other: [ ] _____

57. What elements of this product are not useful or confusing to you in understanding the situation (check all that apply). *

Check all that apply.

- [ ] Title
- [ ] Legends
- [ ] Colors
- [ ] Percentages (5-95%, 10-90%, 25-75%)
- [ ] Likely categories (most, less, least)
- [ ] Time period
- [ ] Flood levels (minor, moderate, and major)
- [ ] River level (left axis)
- [ ] Discharge (right axis)
- [ ] Median line
- [ ] Range of probable levels (different shades/colors)
- [ ] Forecaster's note
- [ ] USGS Historic River Levels Comparison
- [ ] Scale to flood stage option (button at top right)
- [ ] None

Other: [ ] _____

58. What additional information or elements would make this product more useful or understandable to you? *

_____

_____

59. On June 16th the deterministic forecast (black line) is different from the probabilistic forecast, how does that affect your perception of the forecast given? (check all that apply) *

Check all that apply.

- [ ] I would have less confidence in both forecasts
- [ ] I would have less confidence in the deterministic forecast
- [ ] I would have less confidence in the probabilistic forecast
- [ ] I would not trust future forecasts from this source
- [ ] I would seek out more information to understand why they differed
- [ ] I would ask a forecaster/expert for their opinion
- [ ] I would ignore the forecast

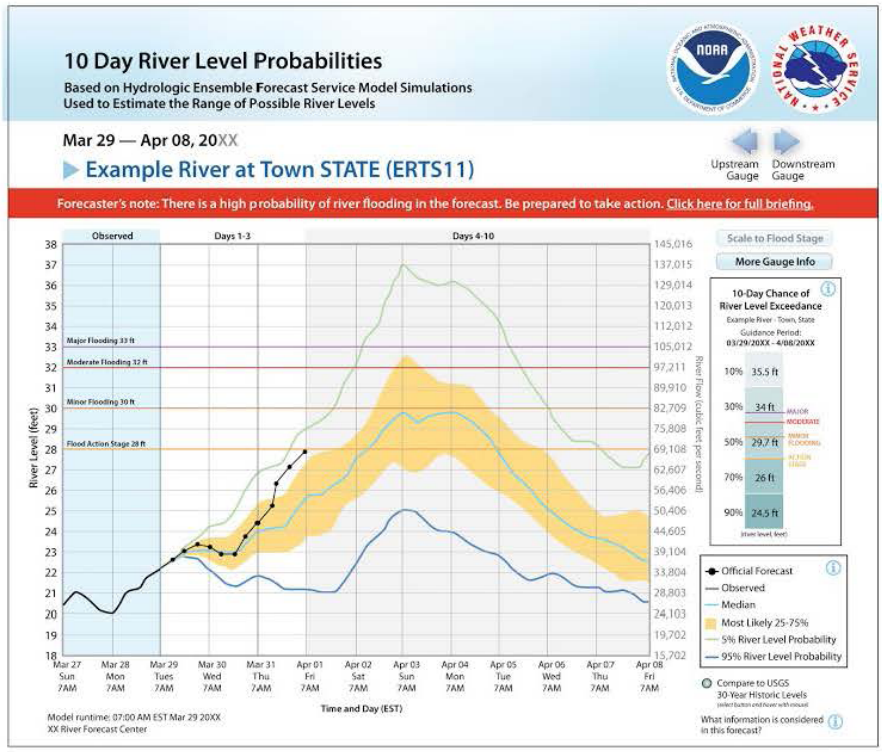
Other: [ ] _____

Skip to question 60

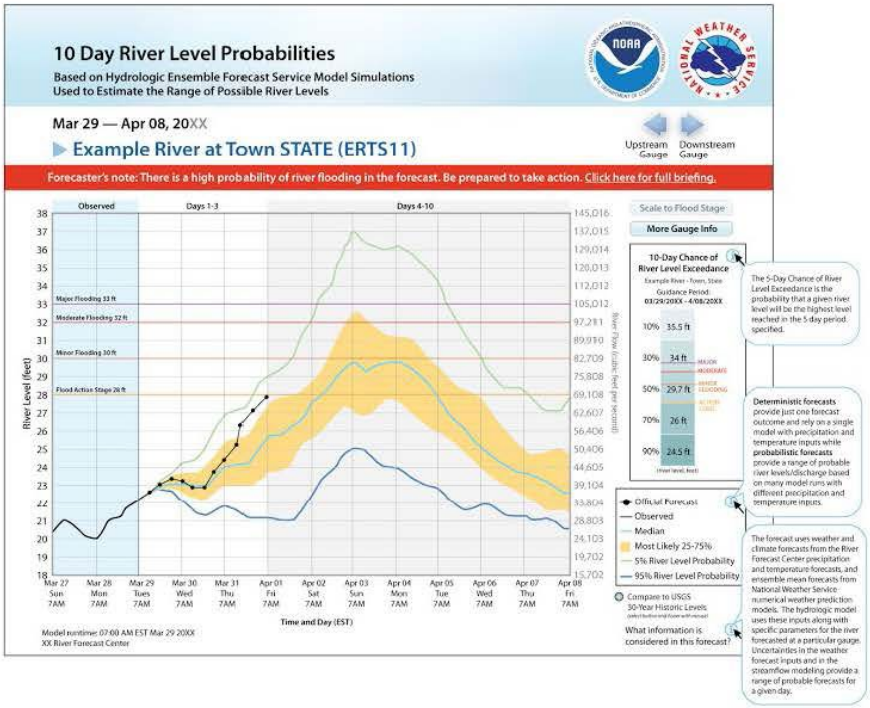
National Product

NOAA is considering developing a national flood level probability product that would have the same features across all forecasting areas. Your input on this possible graphic will help inform that development. Please note that this is an example gauge site of a hypothetical flood situation. The product is shown multiple times with different elements added to reflect the options that would be available on an interactive graph.

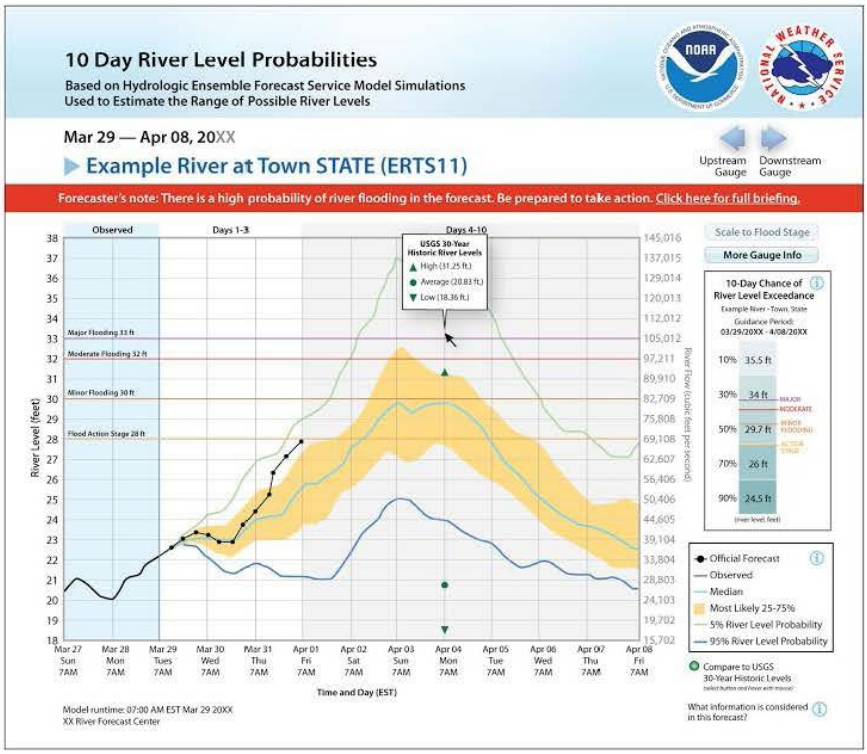
National Product prototype example



National Product example with information (i) boxes expanded



National Product example with USGS Historic River Level Comparison shown



60. What elements of this product are most useful in understanding the situation (check all that apply). *

Check all that apply.

- [ ] Title
- [ ] Legend
- [ ] Colors
- [ ] Percentages (25-75%)
- [ ] Time period
- [ ] Flood levels (minor, moderate, and major)
- [ ] River level (left axis)
- [ ] River Flow (right axis)
- [ ] Median line
- [ ] 5% and 95% River Level Probability Lines
- [ ] Forecaster's note
- [ ] 10 Day Chance of River Level Exceedance (box on the right side)
- [ ] Option to move to upstream and downstream gauges (arrows at the top)
- [ ] USGS Historic River Level Comparison
- [ ] Information boxes (i)
- [ ] Scale to flood stage option (button at top right)
- [ ] None

Other: [ ] _____

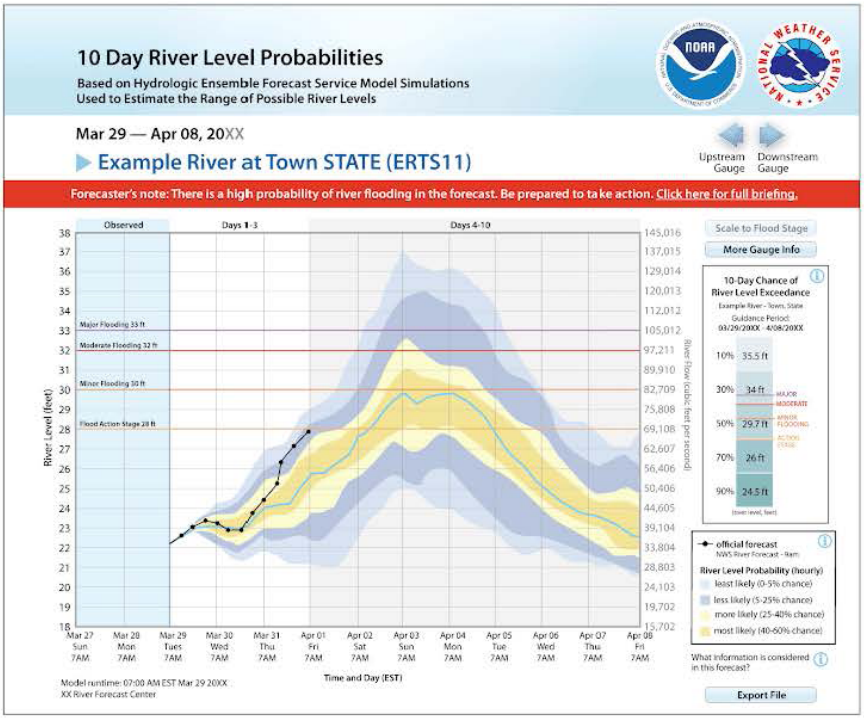
61. What elements of this product are not useful or confusing to you in understanding the situation (check all that apply). *

Check all that apply.

- [ ] Title
- [ ] Legend
- [ ] Colors
- [ ] Percentages (25-75%)
- [ ] Time period
- [ ] Flood levels (minor, moderate, and major)
- [ ] River level (left axis)
- [ ] River Flow (right axis)
- [ ] Median line
- [ ] 5% and 95% River Level Probability Lines
- [ ] Forecaster's note
- [ ] 10 Day Chance of River Level Exceedance (box on the right side)
- [ ] Option to move to upstream and downstream gauges (arrows at the top)
- [ ] USGS Historic River Level Comparison
- [ ] Information boxes (i)
- [ ] Scale to flood stage option (button at top right)
- [ ] None

Other: [ ] _____

Alternate National Product example with Shaded Probabilities



62. Are the likely categories (least, less, more, most)... *

Mark only one oval.

	1	2	3	4	5	
Confusing (I don't understand what they are telling me)	◯	◯	◯	◯	◯	Easy to understand (they help me assess the situation)

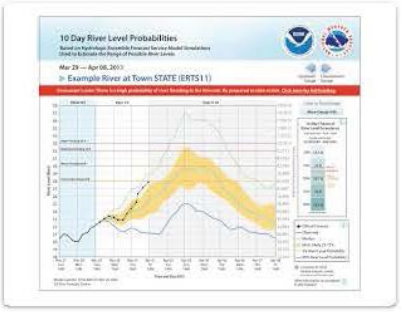
63. Are the percentages (0-5%, 5-10%, 25-40%, 40-60%)... *

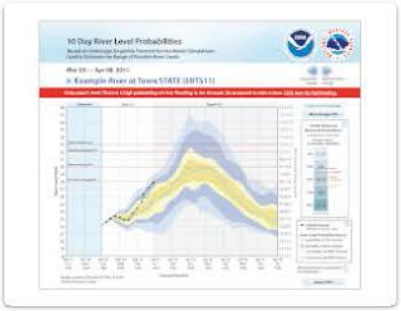
Mark only one oval.

	1	2	3	4	5	
Confusing (I don't understand what they are telling me)	◯	◯	◯	◯	◯	Easy to understand (they help me assess the situation)

64. Which product do you prefer? *

Mark only one oval.





( ) Option 1 ( ) Option 2

65. Why did you select that option? *

_____

_____

_____

_____

_____

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Appendix E.

Demographics and Flood Characteristics of Participants

Table 1. Total number of participants per location and focus group, along with demographic characteristics for both Round 1 and Round 2.

Total	11	11	15	12	10	3	6	5	7	3	11	11	10	4	12	14
	Eureka Pro		Eureka Res		Gunnison Pro		Gunnison Res		Durango Pro		Durango Res		Owego Pro		Owego Res	
Age	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
Under 20	0%	0%	0%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%
20-29	9%	18%	0%	8%	20%	0%	17%	40%	0%	0%	0%	9%	0%	25%	17%	7%
30-39	27%	18%	0%	0%	20%	0%	17%	40%	43%	33%	9%	9%	10%	25%	0%	29%
40-49	18%	45%	7%	8%	30%	67%	0%	20%	14%	0%	36%	36%	0%	25%	0%	21%
50-59	36%	18%	53%	17%	20%	0%	50%	0%	29%	0%	18%	27%	20%	0%	25%	29%
60-69	9%	0%	13%	42%	10%	33%	17%	0%	0%	0%	36%	18%	50%	0%	33%	14%
70-79	0%	0%	27%	17%	0%	0%	0%	0%	14%	67%	0%	0%	20%	25%	17%	0%
Gender																
Male	64%	36%	40%	33%	80%	100%	17%	60%	29%	100%	64%	36%	80%	50%	50%	43%
Female	36%	64%	60%	58%	10%	0%	83%	40%	71%	0%	36%	64%	20%	50%	50%	57%
Nonbin.	0%	0%	0%	8%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Length residence																
under 1	18%	0%	0%	8%	20%	0%	0%	40%	14%	33%	18%	36%	0%	25%	17%	0%
1-2 years	18%	27%	0%	17%	30%	0%	17%	20%	0%	0%	0%	45%	0%	0%	8%	14%
3-5 years	18%	18%	13%	0%	10%	33%	50%	40%	29%	0%	9%	9%	20%	25%	0%	36%
6-8 years	0%	9%	0%	0%	10%	0%	0%	0%	14%	0%	0%	0%	10%	25%	8%	7%
8 or more	45%	45%	87%	75%	30%	67%	33%	0%	43%	67%	73%	9%	70%	25%	67%	43%
Edu.																
High school	9%	0%	20%	8%	0%	0%	0%	20%	29%	0%	9%	27%	10%	0%	25%	36%
Associate	0%	9%	13%	8%	0%	0%	0%	0%	0%	33%	18%	18%	10%	25%	8%	21%
Bachelor	64%	73%	33%	50%	60%	33%	67%	60%	14%	33%	27%	18%	10%	50%	50%	7%
Post graduate	27%	18%	33%	33%	40%	67%	33%	20%	57%	33%	45%	36%	70%	25%	17%	36%

Table 2. Flood related characteristics of participants as reported in the pre-session surveys by focus group and location for Round 1 and Round 2.

	Eureka Pro		Eureka Res		Gunnison Pro		Gunnison Res		Durango Pro		Durango Res		Owego Pro		Owego Res	
Live Floodpl.	**R1**	**R2**	**R1**	**R2**	**R1**	**R2**	**R1**	**R2**	**R1**	**R2**	**R1**	**R2**	**R1**	**R2**	**R1**	**R2**
Yes	0%	18%	53%	25%	30%	0%	0%	80%	29%	67%	18%	9%	10%	75%	25%	57%
No	100%	82%	47%	33%	70%	100%	83%	0%	71%	33%	45%	55%	90%	25%	58%	36%
Unsure	0%	0%	0%	42%	0%	0%	17%	20%	0%	0%	36%	36%	0%	0%	17%	7%
Flood Exp																
Yes	82%	45%	60%	83%	60%	0%	67%	100%	57%	67%	55%	36%	100%	100%	100%	100%
No	18%	55%	40%	17%	40%	100%	33%	0%	43%	33%	45%	64%	0%	0%	0%	0%
When flood																
< 2 years	73%	9%	33%	33%	20%	0%	33%	20%	14%	0%	18%	9%	10%	50%	8%	29%
2-5 years	9%	9%	0%	0%	0%	0%	17%	0%	29%	0%	18%	0%	0%	25%	8%	14%
> 5 years	0%	27%	27%	42%	40%	0%	17%	80%	14%	67%	18%	27%	90%	25%	83%	57%
Respond?																
Yes	55%	18%	33%	25%	30%	0%	0%	0%	43%	67%	18%	0%	60%	75%	58%	43%
No	18%	0%	13%	17%	20%	0%	0%	40%	0%	0%	0%	18%	10%	0%	8%	21%
N/A	27%	82%	53%	58%	50%	100%	100%	60%	57%	33%	82%	82%	30%	25%	33%	36%
Flood risk																
No risk	9%	9%	13%	8%	0%	0%	0%	0%	0%	0%	9%	0%	40%	0%	17%	7%
Little risk	27%	27%	20%	25%	70%	33%	50%	60%	43%	67%	27%	64%	20%	50%	33%	21%
Some risk	55%	55%	27%	42%	10%	67%	50%	40%	14%	33%	45%	27%	0%	25%	17%	29%
Some high	0%	9%	13%	25%	20%	0%	0%	0%	29%	0%	18%	9%	30%	25%	25%	21%
Ex high risk	9%	0%	27%	0%	0%	0%	0%	0%	14%	0%	0%	0%	10%	0%	8%	21%
Prepared?																
Yes	91%	64%	67%	50%	60%	0%	50%	20%	71%	100	55%	9%	80%	75%	83%	79%
No	9%	36%	33%	50%	40%	100%	50%	80%	29%	0%	45%	91%	20%	25%	17%	21%
N/A	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Adv. Notice																
1 day	18%	9%	47%	17%	10%	33%	0%	40%	43%	33%	45%	36%	50%	25%	17%	43%
2 days	55%	18%	27%	33%	30%	33%	17%	20%	29%	0%	36%	27%	20%	25%	42%	50%
3-4 days	9%	36%	7%	33%	10%	0%	33%	40%	0%	33%	18%	27%	0%	25%	33%	7%
5 or more	9%	9%	7%	17%	40%	33%	50%	0%	14%	33%	0%	9%	30%	0%	0%	0%
ASAP	0%	9%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Varied	0%	18%	0%	0%	10%	0%	0%	0%	14%	0%	0%	0%	0%	0%	0%	0%
Unsure	9%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	8%	0%