



January 15, 2014 (2:35 p.m.)

TO: Flood Authority Members
FROM: Scott Boettcher, Staff
SUBJECT: Flood Warning System -- Inundation maps (current status and unfunded needs)

Agenda item #6 of Thursday's Flood Authority meeting concerns the new Flood Warning System inundation maps (current status and unfunded needs). This will be a follow-on discussion from the November Flood Authority meeting where Dave Curtis gave a presentation about flood warning systems in general and then specifically a new approach to inundation maps for the Chehalis Basin system. Thanks and looking forward to the discussion on Thursday. Feel free to call or email if you have any questions (i.e., 360/480-6600, scottb@sbgh-partners.com).

Flood Inundation Maps

(See www.chehalisriverflood.com and click on "Flood Maps")

Inundation Maps Completed To Date:

- ✓ Chehalis River at Centralia (see gage at <http://goo.gl/maps/6kQ87>).
- ✓ Skookumchuck River at Centralia (see gage at <http://goo.gl/maps/KH2P2>).
- ✓ Chehalis River at Doty (see gage at <http://goo.gl/maps/o1RCq>).
- ✓ Skookumchuck River at Bucoda (see gage at <http://goo.gl/maps/JjmSf>).

Inundation Maps Still To Be Completed:

- January 2014 -- Newaukum River near Chehalis (see gage at <http://goo.gl/maps/p5tuE>)
- February 2014 -- Chehalis River at Pe Ell (see gage at <http://goo.gl/maps/jluJ4>)
- February 2014 -- Chehalis River at Grand Mound (see gage at <http://goo.gl/maps/SGafv>)
- February 2014 -- Chehalis River at Porter (see gage at <http://goo.gl/maps/oeWwq>)

Unfunded Needs

The following unfunded needs have been identified by either WEST Consultants, the National Weather Service or both (see Attachments).

1. **Lower Basin Inundation Maps** – Current inundation mapping extends from the Upper Basin at Pe Ell downstream to Porter. The lower sections of the river are impacted by tidal and storm surge influences. The interaction of upstream tidal, upstream storm surge and downstream flood is complex and not presently addressed by current NWS river forecast models. As a result, detailed forecasts of the timing, ultimate depths of flooding, and a description of the areal extent of flooding are not available today. Proposal -- Leverage and extend existing hydraulic models to provide river forecasts for the final reaches of the Chehalis River and Grays Harbor. Cost = \$190,000. Timeframe = 1 year.
2. **Stream Rating Curves** – Several of the gages in the basin essential for generation of accurate inundation maps do not have developed stream rating curves (Chehalis River at Centralia, Skookumchuck River at Centralia, Chehalis River below Thrash Creek, and West Fork Satsop). Stream rating curves show the actual relationships between river flow (e.g. measured in cubic feet per second) and river stages or flood elevations measured in



feet. Stream rating curves are measured over time. Proposal -- A program of stream flow and elevation observations will be conducted to develop the critical stage-flow relationships to support accurate river forecasts. The initial development of these stage-flow relationships is expected to span a three year period to provide time to sample as large a range of river conditions as possible. Cost = \$75,000. Timeframe = 3 years.

3. **Develop Visual Representations of River Forecast Uncertainty** – Inundation maps are based on National Weather Service river forecasts. Forecasts typically carry with them a probability of accuracy. Today's inundation maps now do not carry that probability of accuracy. Proposal – Rework existing inundation maps to visually reflect the level of uncertainty in National Weather Service river forecasts and to conform with standards of practice around articulating forecast probabilities. Cost - \$35,000. Timeframe = 1 year.
4. **Local Host/Sponsor/Champion** – Currently management/administrative and technical support for the Flood Warning System comes through an annual maintenance payment to WEST Consultants. In some respects this is fine and working. In other respects though it may make sense to explore development of a more localized role (e.g., in-Basin, in-State). Management and technical support from WEST now comes from Vancouver, WA (technical) and Sacramento, CA (management/administrative).

Suggested Next Steps

Convene “State of the Gages Meeting” – The Flood Warning System relies on a network of 40+ gages. It has become increasingly clear in setting up the new inundation maps and fine-tuning the Flood Warning System that ownership, operation and maintenance of the gages differ across the Basin. Some gages are owned, operated and maintained solely by one entity (e.g., Flood Authority). Other gages are funded for operation and maintenance through cost-sharing partnerships (e.g., USGS and Chehalis Tribe, USGS and Lewis County, etc.). Many of the gages are threatened with discontinuation due to federal or state budget short-falls [Note: Ecology in fact had to decommission [Black River @Hwy 12](#) and [Wishkah River near Nisson](#) gages effective October 1, 2013 due to lack of funding.] The suggested next step here is to convene meeting with USGS, NWS, Ecology, WEST Consultants, Watershed Science and Engineering, Public Works Staff, to discuss the status of existing gages in the Basin (i.e., location, function, ownership, condition, importance, partners, etc.). The outcome from the meeting would be a shared, comprehensive understanding of gages in the Basin from which further gages dependent efforts could be strategically pursued (e.g., lower basin inundation maps, stream rating curves, etc.)

Additional Background:

- Here is map showing existing Basin gages --
https://www.ezview.wa.gov/site/alias_1492/34856/gages_stations.aspx#Interactive
- Here is tabular listing of existing Basin gages --
[https://www.ezview.wa.gov/Portals/_1492/images/Chehalis%20Basin%20Gages%20&%20Stations%200916013\(1\).pdf](https://www.ezview.wa.gov/Portals/_1492/images/Chehalis%20Basin%20Gages%20&%20Stations%200916013(1).pdf)

Attachments

Extend the Chehalis River Flood Warning System to the Pacific Ocean.

Effective flood forecasts are needed throughout the Chehalis River basin from the uppermost portions of the watershed to the sea. This project will extend the Chehalis River Forecast System to the Pacific Ocean, provide greater certainty in river forecasts, provide tools to quantify river forecast uncertainty for more robust decision-making, and contribute to lower flood insurance premiums in the basin. Techniques and processes developed will have statewide implications. Estimated budget is \$300,000.

Extend River Forecast Models From Porter to the Pacific.

A. Current Condition

- a. Communities such as Montesano, Aberdeen, Hoquiam, and locations around Grays Harbor along the lower 50 miles of the Chehalis River are under served by current Chehalis River forecasts, which stop at Porter. The lower sections of the river are impacted by tidal and storm surge influences that propagate upstream to collide with flood waters surging downstream. This complex interaction of opposing forces are not addressed by the current NWS river forecast models employed on the Chehalis. As a result, detailed forecasts of the timing, ultimate depths of flooding, and a description of the areal extent of flooding are not available today.

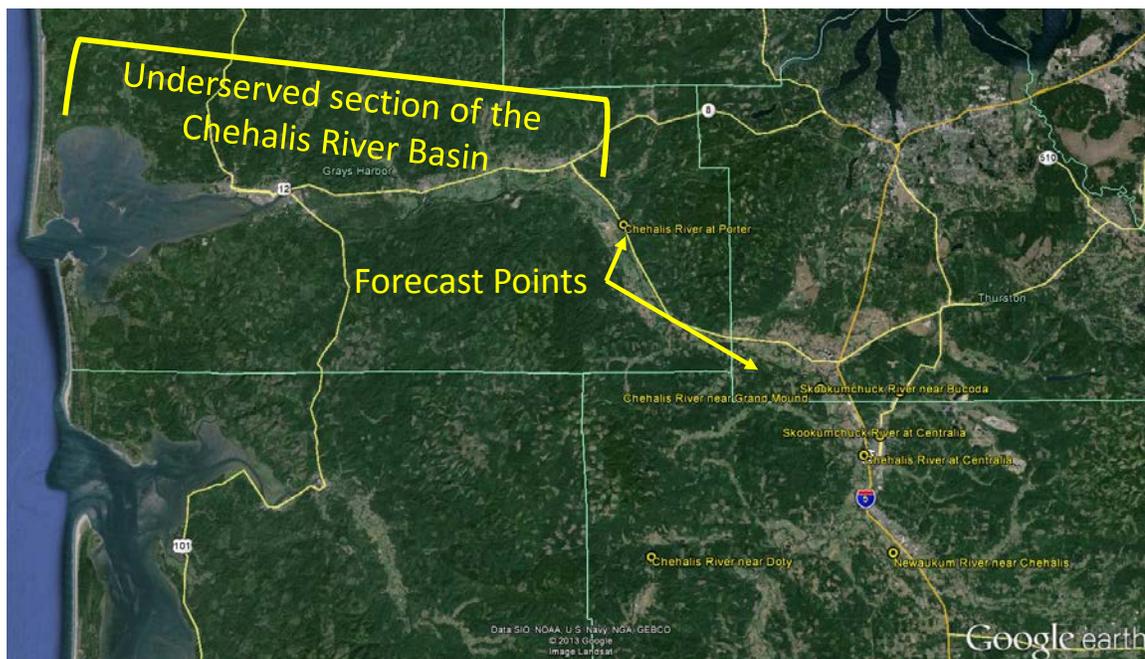


Figure 1: Chehalis River Basin River Forecast Points

B. Proposed action

- a. Fortunately, the technology exists to produce the needed forecasts. Over the past several years, the Chehalis River Basin Flood Authority, the Corps of Engineers, Washington Department of Transportation, and others have funded the development of hydraulic models that include much of the lower Chehalis River. These models can be leveraged and extended to provide river forecasts for the final reaches of the Chehalis River and Grays Harbor.

C. Benefit

- a. The facilitation of new river forecast services to the lower basin will improve the communication of flood risk to the general public with quantified estimates of flood elevations, flood timing, and flood inundation. In addition, inundation maps will enhance flood damage mitigation efforts by local emergency managers and quantified river forecasts will help improve local flood response. These benefits will provide overall river forecast services consistent with existing services provided to the upper portions of the Chehalis River Basin.

D. Cost

- a. \$190,000

E. Schedule

- a. 7/1/2014-6/30/2015 2016?

Develop Stream Gage Rating Curves

A. Current Condition

- a. The two NWS river forecast points (Chehalis River at Centralia and Skookumchuck River at Centralia. See Figures 2 and 3.) do not have observed relationships between river flows (e.g. cubic feet per second) and river stages or elevations measured in feet. NWS river forecasters depend on these relationships to convert forecast estimates of river flows to river elevations for public release of their river forecasts. (Both the public and emergency officials use river elevations for decision-making rather than river flows.)

Currently, stage-flow relationships for these two points are based on theoretical estimates. The lack of observational confirmation of the stage-flow relationship at these points creates uncertainty in the official NWS forecasts affecting the most populous communities in the basin as well as the critical I-5 transportation corridor.

In addition, two stream gages, Chehalis River below Thrash Creek and West Fork Satsop, installed as part of the Chehalis River Basin Flood Warning System, need stage-flow relationships developed to fully contribute to improved river forecasts in the basin.

B. Proposed Action

- a. A program of stream flow and elevation observations will be conducted to develop the critical stage-flow relationships to support river forecasts. The initial development of these stage-flow relationships is expected to span a three year period to provide time to sample as large a range of river conditions as possible.

C. Benefit

- a. The development of observed stage-flow relationships will reduce the uncertainty in NWS River forecasts associated with the Chehalis River at Centralia, and the Skookumchuck River at Centralia. In addition, the reduced uncertainty at these observation points will propagate downstream and reduce uncertainty at downstream forecast points.

D. Cost

- a. \$75,000

E. Schedule

- a. 7/1/2014-6/30/2017



Figure 3: Stream gage – Skookumchuck River at Centralia



Develop Visual Representations of River Forecast Uncertainty

A. Current Condition

- a. The current generation of flood inundation maps (See Figure 4) show expected flood areas corresponding to a specific NWS river forecast. Such a specific estimate of a forecast inundation area can imply a higher degree of precision than is warranted.

Any forecast is uncertain because the forecast is made before some of the anticipated events actually occur. One good example is the use of forecasted rain over the next several days to produce river forecasts. Storms can deviate from their expected course, they can weaken or intensify, and they call slow down or speed up.

Reliance on a specific forecast map without quantifying uncertainties can lead to overconfidence in a specific forecast. This weakens the foundation for robust decision-making by local officials and the public alike.

The NWS is developing methods to account for the inevitable forecast uncertainties to provide users with better decision-making tools. Figure 5 shows an example of possible future inundation maps showing a range of possible inundation areas to reflect forecast uncertainty. Maps like those in Figure 5 can show where flooding is highly likely no matter what happens and areas that might flood if all the right elements of the forecast materialize and actually occur.

B. Proposed Action

- a. New representations of inundation maps will be developed that reflect the level of uncertainty in the NWS river forecasts. The maps will be derived based on NWS forecast products and experience that quantify the uncertain elements of a river forecast.

C. Benefits

- a. Quantification of forecast uncertainty will greatly strengthen robust decision making, enabling for effective damage mitigation planning and response throughout the basin. In addition, improved mapping and river forecast elements will contribute to increased credits under the FEMA Flood Insurance Program Community Rating System (CRS) which can lead to reduced flood insurance rates in the basin.

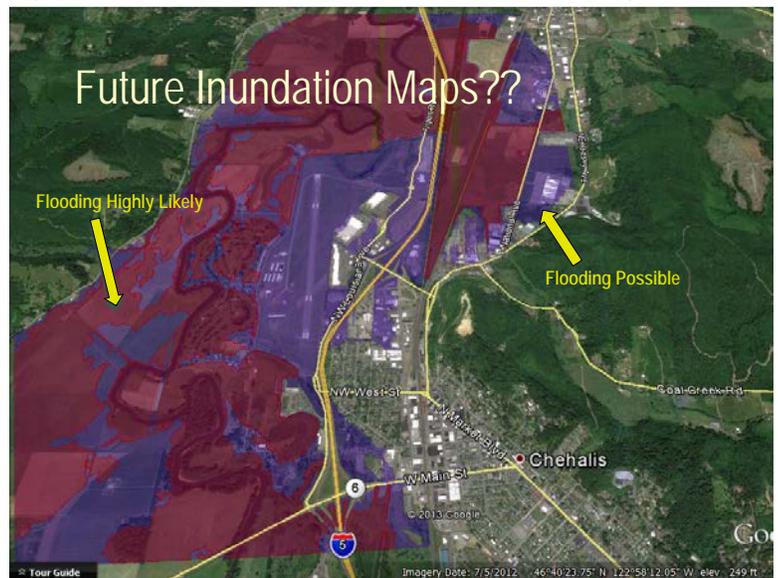
D. Cost

- a. \$35,000

Figure 4: Example of current generation flood inundation map.



Figure 5: Example of possible future inundation maps showing a range of possible inundation areas to reflect forecast uncertainty.





U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE

October 31, 2013

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The National Weather Service (NWS) in Seattle recommends that rating tables be developed for the Chehalis River at Centralia and Skookumchuck River at Centralia stream gages in order to improve the accuracy of forecast of river stage height.

The NWS Northwest River Forecast Center (NWRFC) in Portland, in collaboration with the Weather Forecast Office in Seattle, forecast river flows on the Chehalis River at Centralia and the Skookumchuck River at Centralia. Forecasts are produced for these locations using a hydrological model that accounts for forecast precipitation over each river basin as well as the hydrological components that affect water movement over and through the ground. The model converts the volume of water falling on the ground into the volume of water flowing by the river gage. This forecast flow is then converted to a forecast stage height at a gage based on its rating table - the relationship between the river flow and the stage height. In addition, when a river model is first run, it takes the observed stage height from a gage and uses the rating table to convert that into the river flow to start the model off at the correct flow volume.

Currently, no rating tables based on stream measurements have been developed for the gages at these locations. To compensate for the lack of rating tables at these locations, the NWRFC has synthesized rating tables using river flow data from other locations on each river (both upstream and downstream) as well



as model estimates for the flow at the forecast points themselves. These synthesized rating tables can introduce additional errors to the resulting stage forecasts because they themselves are estimates or approximations of the flow-to-stage relationships. We really don't know for sure what the actual flow is. Having an accurate estimate of the flow of a river is crucial for river forecasting and flood warnings. In addition, the flood inundation mapping available at these sites make the lack of a measured rating an even more important consideration. The inundation areas depicted in the maps derived from the stage height of the river and errors in the forecast stage height can show up much more readily in this graphical form.

The stream gages at these two locations are owned and operated by the NWS and have been in place for many years. However, the NWS is not equipped to fully manage stream gages, including making the flow measurements required to develop rating tables. Currently the NWS must rely on the City of Centralia to annually flush silt and debris from the stilling wells to ensure that the gages work properly. The U.S. Geological Survey is the official stream gaging agency in the federal government, and would be better equipped to manage these observing sites.

In order to ensure the most accurate river forecasts possible, and, in turn, the best flood warnings and forecast flood inundation area maps possible, the NWS recommends that a program be established to produce measured rating tables at these two locations, either by the U.S.G.S. taking over ownership of the gages or by having another qualified organization make and maintain ratings without a change in gage ownership. Producing a calibrated rating table for each of these locations would reduce the error in the resulting river stage forecasts, thus improving the forecasts themselves, as well as flood warnings and inundation mapping.

Sincerely,

A handwritten signature in black ink, appearing to read 'K. Cook', is written over the typed name.

Kirby Cook
Acting Meteorologist-In-Charge