

Memorandum

To: Rob Wilson, County Engineer
From: Larry Karpack & Mark Indrebo
Date: May 26, 2017
Re: Wishkah Road Comprehensive Flood Study

INTRODUCTION

Grays Harbor County (GHC) seeks to identify cost effective measures to reduce flood impacts to Wishkah Road near Aberdeen Washington. The study area extends from approximately mile post (MP) 2.2 to MP 7.6. Wishkah Road parallels the Wishkah River which has historically flooded as many as seven separate locations along the road. The Chehalis River Basin Flood Authority funded the Wishkah Road Comprehensive Flood Study to provide a reach-scale assessment of flooding on Wishkah Road and determine if there were feasible ways to reduce or eliminate flood-related road closures. GHC selected a consultant team led by Watershed Science and Engineering (WSE) to complete the Comprehensive Study. To accomplish this project WSE organized and managed a consultant team comprising the specialists listed in Table 1.

Table 1 – Project team and their specialties.

CONSULTANT	SPECIALTY
Watershed Science & Engineering	Hydrology, Hydraulics & Geomorphology
Grays Harbor Council of Governments	Public Involvement
Pacific Geomatic Services	Bathymetric Survey
GeoTerra	LiDAR and Aerial Imaging
KPFF Consulting Engineers	Civil Design & Cost Estimating
Confluence Environmental	Permitting
Pan Geo	Geotechnical Analysis

The Comprehensive Study included three primary tasks: 1) assessing baseline flood conditions; 2) evaluating the impact of road closures; and 3) identifying measures that could be taken to reduce the impact of flooding. Public involvement was critical to this project, and public meetings were held for each of the three principal tasks.

EXISTING CONDITIONS ASSESSMENT

WSE developed and applied a HEC-RAS 2-dimensional hydraulic model to characterize baseline flood conditions throughout the project area. The model uses topographic, bathymetric, and hydrologic data inputs. Topographic data for this study were collected using airborne LiDAR (Light Detection and Ranging) and aerial imaging techniques. Bathymetric data were gathered via a combination of sonar and standard survey methods. Hydrologic data, including upstream flow inputs and downstream tidal

boundary condition were developed as flows. Flow inputs were developed from a combination of gage data from the Wishkah River, estimates of Wishkah River flow derived from a USGS gage on the Humptulips River, and estimates derived from USGS regression equations for Washington (Sumioka et al, 1998). Tide data were obtained from NOAA gages at Westport and Aberdeen as well as a synthetic long-term tide record that was developed using predicted astronomical tides and meteorologic data including wind and barometric pressure data from Bowerman Airport in Hoquiam. A complete description of the hydraulic model development and key data inputs is included in Appendix A.

An initial stakeholder public meeting for the Comprehensive Study was held on June 29, 2016. At that meeting local landowners were asked to share their experiences with flooding and Wishkah Road closures (see Appendix B-1). This information, along with surveyed high water marks from the January 2015 flood and photos from earlier flood events, were used to calibrate and verify the hydraulic model. The results of the baseline hydraulic modeling were presented to the public at the second stakeholder meeting on October 13, 2016 (Appendix B-2). The modeling was further refined based on feedback from local residents.

Using the refined hydraulic model, simulations were completed for three historical flood events (January 2009, January 2015, and December 2015) and for several design flood events (2-, 10-, and 100-year recurrence intervals). For each flooding location along Wishkah Road the model was used to estimate the frequency, depth, and duration of flooding for each of the simulated events. The length of road inundated during the 100-year event was also determined for each location.

IMPACT OF ROAD CLOSURES

The economic impact of Wishkah Road closures was estimated using a methodology and unit costs derived from a WSDOT assessment of I-5 closures due to Chehalis River flooding (WSDOT 2014). The average annual closure time due to flooding for each site was estimated (see Appendix C for details), and traffic counts provided by the County at several locations within the project area were used to estimate average hourly traffic volume at each location. It was assumed that traffic would detour around the closures using the Wynoochee Valley Road whenever possible. If a detour was not possible (i.e. the road is closed both up- and down-valley from a given location), it was assumed that traffic would be delayed until the primary or detour route was opened. The cost of road closures was calculated by estimating the delay time and extra miles driven as a result of either detouring around the flooding or waiting for floodwaters to recede. This resulted in an average annual cost of flood related closures in the project area.

Economic calculations for the project assumed a 50-year lifespan. Accordingly, the net present value (NPV) of flood-related closure costs was calculated over a 50-year timespan to determine the potential flood damage reduction that eliminating flooding would result in. The 50-year NPV of road closures is \$670,000.

Emergency access during flood events is another critical concern for local residents. Using data from the Grays Harbor County 911 call center, an average calls per hour per residence was estimated for the County, broken down by police and fire department calls. These values were then multiplied by the number of residences impacted by road closures and the average number of hours the road is closed annually. This provides an estimate of the number of calls to 911 that are expected to occur during

times of road closure. Over the 50 year project lifespan, a total of 55 calls to police and 9 calls to fire departments would be expected to occur during times of road closure. It should be noted that this is simply the estimated number of 911 calls during road closures; not all calls to 911 require an emergency response.

FLOOD REDUCTION ALTERNATIVES

WSE held a workshop with KPFF and Confluence to discuss the most economical, but realistic approach to correct flooding issues at each location. Construction, design, permitting, and private property impacts were all considered at a conceptual level. Alternatives considered included raising the road on fill, flood walls or levees, establishing temporary detour routes around flood-prone areas, and relocating portions of the road to higher ground. For each site, the least expensive potential solutions were selected, and a rough order of magnitude cost was developed.

Appendix D includes a summary of the evaluation of alternatives at each site, including a map of the simulated 100-year flood at the site, the length of road flooded, the estimated cost of closures at each site, a description of the conceptual plan for eliminating flooding at the site, and the estimated cost of the alternative. This information was presented to local landowners at the third public meeting which took place on May 3, 2017 (Appendix B-3).

NEXT STEPS

The analyses indicate that the expected 50-year cost of flood related closures on Wishkah Road is \$670,000. The cost to prevent flood-related closures at all locations upstream of Baretich Flats ranges from \$7.9 million to \$18.7 million (Table 2). Given the dramatic difference between the estimated costs and expected benefits of large scale capital improvement projects, the County decided that it was not appropriate to move forward with engineering design of large scale flood reduction projects at this time. Instead, the County will seek other measures to reduce flood related impacts.

Table 2 - Closure costs and costs to correct closures.

Closure Site	Cost of closures*	Cost to correct (low estimate)	Cost to correct (high estimate)
<i>Baretich Road</i>	<i>\$150,000</i>	<i>\$3,300,000</i>	<i>\$5,300,000</i>
<i>MP 2.9</i>		<i>0</i>	<i>\$5,000</i>
<i>Above projects not included in reach-wide total below</i>			
Ellison Dip	\$322,000	\$1,250,000	\$1,800,000
Leutz Road	\$250,000	\$2,500,000	\$2,500,000
Long Swamp	\$500,000	\$2,250,000	\$12,000,000
Wyman Creek	\$163,100	\$1,350,000	\$1,350,000
Miller Hill	\$126,200	\$500,000	\$1,000,000
Total	\$670,000*	\$7,850,000	\$18,650,000
*Note: Since closure times overlap (e.g. the road is closed at Ellison Dip for much of the time it is closed at Long Swamp) the total cost of closures in the project area is less than the sum of the individual site closures.			

Feedback from attendees of the public meetings identified several tasks that could be undertaken to address public concerns and reduce flood related impacts along Wishkah Road. These include:

- 1) Update the FEMA floodplain mapping for the Wishkah River using the modeling and analysis developed for this project.
 - a. Numerous residents at the public meeting (including County staff) noted that the current FEMA maps are highly inaccurate. This is costing people money (as they need to have flood insurance even though they are outside the actual floodplain). It also might lead some people to feel they are not at risk of flooding when they actually are.
 - b. The map in Appendix E shows the FEMA Zone A floodplain and the 100-year floodplain WSE produced. There are numerous areas of difference between the two, primarily in areas with homes.
 - c. Initial analysis indicates 98 homes could be taken out of the FEMA floodplain using the WSE map. Approximately 20 homes would be put into the floodplain.
- 2) Add telemetered stage gage(s) along the Wishkah River
- 3) Flood warning system
 - a. Residents are most concerned about the lack of warning for road closures.
 - b. Could use existing hydraulic modeling together with new and existing gage data and available (NOAA, NWS, others) forecasts to predict road closures.
- 4) Assess flood-prone tributary creeks for potential solutions (culvert replacement, increased channel capacity, sediment removal, etc.)
 - a. Wyman Creek, creek near Leutz Road, others?
 - b. Perform a reconnaissance at each problem site by a hydraulic engineer and a permit specialist to evaluate options and determine a plan of action
- 5) Further explore bypass road options – particularly a forest road that County staff spoke about.
 - a. Would need to determine what level of improvements would be necessary to bring these up to an appropriate level of service and identify any access and/or private property considerations.

Grays Harbor County requested, and the Flood Authority Small Projects Committee approved, reallocating some of the remaining funds from the Wishkah Road Comprehensive Study contract to begin to work on some of the tasks identified above.

CONCLUSION

The Wishkah Road Comprehensive Study sought to identify cost effective flood damage reduction measures that could be undertaken to reduce flood impacts along the Wishkah Road. Hydraulic modeling and analysis was undertaken to characterize baseline flood conditions and provide data on the cost of flood related road closures. A range of potential capital improvement projects were evaluated at a conceptual level but ultimately it was found that the cost of these projects would far exceed the cost of flood related road closures. Instead of pursuing engineering design of capital project Grays Harbor County has decided to evaluate other means for reducing the impact of flooding along the river. These may include remapping the FEMA floodplain, installing water level gaging along the river and

developing an early flood warning system, and evaluating small scale projects that can reduce flood impacts at creek crossings and culverts. These projects will be conducted over the coming months to the extent that funding allows.

Appendix A

Technical Memorandum

To: Rob Wilson, Grays Harbor County

From: Bob Elliot, Larry Karpack & Mark Indrebo

Date: May 22, 2017

Re: Wishkah Road Comprehensive Flood Study: Hydraulic Modeling

OVERVIEW

Grays Harbor County seeks to identify cost effective projects to reduce or eliminate flooding of Wishkah Road between mile post (MP) 2.2 and MP 7.6 along the Wishkah River upstream of the City of Aberdeen. Figure 1 presents a vicinity map of the study reach with MP locations along Wishkah Road labeled as provided by the County. The study includes hydraulic modeling and analysis by Watershed Science and Engineering (WSE), which is the subject of this Technical Memorandum (TM). Results of the hydraulic modeling were intended to identify and evaluate potential flood reduction opportunities with the eventual preparation of conceptual designs for viable alternatives.

BOUNDARY CONDITIONS

Hydraulic modeling of the Wishkah River requires upstream inflow and downstream tidal boundary conditions. Observed streamflow data from a discontinued Washington State Department of Ecology (DOE) gage on the Wishkah River and from a United States Geological Survey (USGS) gage on the nearby Humptulips River were used to characterize flows for the Wishkah River study reach. Because the data record for the Wishkah River gage was only about eight years long, design event peak flow quantiles for this study were estimated using USGS regression equations for Washington (Sumioka et al, 1998). Together, these data provided the inflow boundary conditions for historic and design flow events.

National Oceanic and Atmospheric Administration (NOAA) tide gages at Westport and Aberdeen provide some observed tide data for Grays Harbor but unfortunately neither of these records is long enough to allow estimation of extreme high tide events. Therefore, a long term tide record at the mouth of the Wishkah River was synthesized using predicted astronomical tides and meteorologic data including wind and barometric pressure data from Bowerman Airport in Hoquiam. The following paragraphs describe the hydrologic data development in greater detail.

WISHKAH RIVER FLOW DATA

The Washington DOE operated a flow gage on the Wishkah River near Nisson from April 2005 to September 2013. Although this gage is well upstream of the project reach, and the period of record is relatively short, the data are still the best available source of flow data for the Wishkah River and were thus used to develop inflow estimates for the current modeling. The first step in developing the inflow estimates was to transpose the data from the Nisson gage to the mouth of the river. This was done by scaling the data on the basis of the drainage area times the mean annual precipitation in the basin upstream of the gage site versus the same quantity for the basin to the mouth. The transposed data were then compared with data from the USGS gage on the nearby Humptulips River below Highway 101

and found to be relatively well correlated. Regression analysis for a period of overlapping record (2007 – 2013) established the following correlation:

$$Q_{\text{Wishkah}} = Q_{\text{Humptulips}} \times 0.414 + 42.7 \text{ cfs}$$

Data from the Humptulips record for the period October 2002 through September 2016 were then transposed to the Wishkah River using this equation. The transposed record provided streamflow data for various calibration events and also allowed statistical analysis of mean seasonal flows. Design flows representing the 2-, 10-, 25-, and 100-year recurrence interval events were developed by choosing events from the historical DOE record transposed from Nisson and scaling them to match the design flow quantiles estimated for the mouth using the USGS regional regression equations (Sumioka et al, 1998). Peak flows for the design events are as listed in Table 1. The 10 percent exceedance wintertime (October through April) flow was also computed from the transposed flow data. The wintertime period was selected for analysis as this is the period that is most likely to experience high tides in Grays Harbor. The 10% exceedance event was chosen as this is a relatively conservative estimate for pairing with high tide conditions, such as the 100-year tide, for evaluation of tidally induced flooding. These flow data were used together with tidal data described in the following section as inputs to the hydraulic modeling.

Table 1: Peak flow quantiles for Wishkah River at Mouth

DESIGN EVENT	PEAK DISCHARGE (CFS)
10% Exceedance Winter Flow	1,800
2-year	8,800
10-year	13,700
25-year	16,100
100-year	20,500

TIDAL DATA FOR GRAYS HARBOR AT MOUTH OF WISHKAH RIVER

In addition to the flow data described above, a long term time series of tidal water surface elevations was needed for the hydraulic modeling. Observed tide data are available for a NOAA gage near Aberdeen for parts of 2004 and 2005 and data are available for a NOAA gage near Westport for 2006 through present. However, because neither of these data sets is long enough for reliable stage frequency analysis, and because the Westport data likely do not represent conditions near Aberdeen very well, a longer term time series was created for a location near the mouth of the Wishkah.

The long term time series was created by first computing the astronomical tide for the period October 1974 through September 2016 and then adjusting these data to account for effects of barometric pressure, wind setup, and El Niño-Southern Oscillation (ENSO). The effect of these three factors together is sometimes called the residual. Tide level adjustments were developed for each of these factors using equations or estimates documented in the scientific literature. Data were first computed for the period of observed record at Aberdeen (2004 – 2005) and the predicted residuals were compared to the observed residuals at the NOAA gage. This evaluation showed that the predicted

residuals reasonably captured both the average values and the range of values seen in the observed data. The long term record of tidal residuals was then developed using meteorologic data from Bowerman Airport and these residuals were added to the predicted tides at the mouth of the Wishkah River to produce an hourly record of actual tidal elevations for the period 1974 – 2016. This long term tide record was used for simulations of historical flood events and for the analyses described below.

Frequency analyses were conducted on the constructed tide record and the maximum annual 2-, 10-, 25-, and 100-year tide levels were estimated as shown in Table 2. Tidal stage hydrographs for each of these annual maximum events were created by selecting a typical tide event and scaling it to match the observed peak value in Table 2. Water surface elevations exceeding a specific percentage of time during the flood season were also computed for several different exceedance probabilities. These are also listed in Table 2.

Table 2: Peak Tide Water Surface Elevation Quantiles for Grays Harbor at Mouth of Wishkah River

DESIGN EVENT	PEAK WATER SURFACE ELEVATION (FEET)
100-year	13.2
25-year	12.4
10-year	11.9
2-year	11.0
2% exceedance	9.2
10% exceedance	7.9
20% exceedance	6.9
50% exceedance	4.3
Mean Higher High Water	8.47
Mean Sea Level	3.96

MODEL DEVELOPMENT

TOPOGRAPHY

Development of the hydraulic model required accurate topographic data for the floodplain and river channel. GeoTerra was retained as a subconsultant to gather and classify topographic data using both LiDAR (Light Detection and Ranging) and photogrammetry, resulting in a detailed bare earth ground surface of the floodplain. GeoTerra also delineated features such as buildings, roads, fences, etc. within the data collection area. The topographic data collection effort was completed in June 2016.

Pacific Geomatic Services (PGS) was retained as a subconsultant to collect in-water (bathymetric) survey data extending from Johnston Street at the Aberdeen City limit, approximately river mile (RM) 2.1, to the Turner Bridge on Wishkah Road near Aberdeen Gardens at RM 12.7 (Figure 1). PGS collected bathymetric data throughout the river and interpolated a continuous surface of the river bottom. The resulting bed surface was then combined with the GeoTerra LiDAR surface to create a continuous

topographic/bathymetric surface. The combined surface was imported into the hydraulic modeling software and used to develop the computational domain of the model. Figure 2 (four sheets) presents a color-shaded representation of the final topographic surface along with the final 2D computational grid (discussed below). The bathymetric data collection and surface development was completed in July 2016.

MODEL EXTENT

The hydraulic model was developed using the latest version of the HEC-RAS software by the U.S. Army Corps of Engineers, version 5.0.3. A two-dimensional (2D) computational area was defined extending from Johnston Street to the Turner Bridge on Wishkah Road (RM 2.1 to 12.7), including both the river channel and the entire floodplain. The 2D area was composed of a grid of computational cells nominally sized 10 feet by 10 feet. Break lines were added in key locations to more accurately represent the base topographic surface and to force cell edges along topographic features and divides (such as roadways) which control breakout flow. Such break lines were included along the channel invert of the river, its left and right banks, along the Wishkah Road edge of roadway and centerline, and other road, ridge, and drainage lines. The complete extent of the 2D area domain is shown in Figure 3.

The 2D area includes the lower 1.2 miles of Wyman Creek, which passes under Wishkah Road about 0.8 miles upstream of its confluence with Wishkah River. This road crossing, referred to by Grays Harbor County as the Monarch Creek Bridge (see Figure 1), is one of the repetitive flooding areas of specific interest in this study. It should be noted that bathymetric data were not collected for Wyman (Monarch) Creek. A break line was added to the channel alignment, as estimated from the LiDAR data, to define the drainage as best as possible. However, the model does not represent the actual channel bed and would not be well-suited for evaluating flood events on Wyman Creek. The modeling and results of this study are focused on flooding that originates from the Wishkah River, i.e. backflow or backwater extending up Wyman Creek from its mouth.

The model was extended downstream of Johnston Road to Grays Harbor using a separate HEC-RAS model developed by WSE under the North Shore Levee project for the City of Aberdeen. This consisted of a 1D branch with cross-sections and lateral structures along the channel banks and levees connecting into separate overbank 2D areas. This connects the model to Grays Harbor where tidal boundary conditions are specified, and allows simulation of the tidal flow exchange up the Wishkah River into the 2D comprehensive study reach.

ROUGHNESS

Roughness zones within the Wishkah 2D area were initially established using the USGS National Land Cover Database (NLCD), which defines boundaries of varying land cover and vegetation type and assigns a Manning's roughness coefficient for each. The coarse nature of the NLCD coverage does not define the river channel very accurately, so the channel zone was re-delineated using aerial photographs and topographic data. Manning's coefficients (n-values) were adjusted from the NLCD values based upon engineering judgement supported by aerial and on-site observations, and further adjusted during the model calibration process as discussed below (and summarized in Table 3). Manning's n-values within the downstream 1D reach and connecting 2D areas therein were not changed from those assigned in the North Shore Levee project.

CALIBRATION

Three recent flood events were simulated to calibrate the hydraulic model. These were the January 5, 2015 flood, the December 9, 2015 flood and the January 7, 2009 flood. Inflow and tidal boundary conditions for all three events were based upon the historical record developed as described under the Boundary Conditions section. Slight adjustments were made to the tide data for these particular events based on a comparison between the computed tidal residuals in the long term record and the residual data for these specific events at Westport.

Measured high water mark data were provided by Grays Harbor County for the January 5, 2015 event. Manning's roughness coefficients (n-values) were adjusted, within reasonable limits, to result in a calibrated model that closely replicated the surveyed water surface elevations of the high water marks. Table 3 summarizes the final Manning's n-values used in the model for the Wishkah 2D area after calibration. Table 4 includes a comparison of the simulated versus observed water surface elevations from the calibration event. The high water marks used for comparison are identified by their MP location along Wishkah Road and are shown on Figure 1. At most locations, the model results are within about 0.3 feet (3.6 inches) of the measured high water mark. The only exception is Long Swamp where the model result is 0.56 feet higher than the surveyed value, which is conservative. Further model adjustment to reduce this difference would have compromised the adjacent comparisons at Ellison Dip and Wyman Creek.

Additional historical events simulated include December 9, 2015, a slightly smaller event on the Wishkah in terms of flow but with a higher tide, and January 7, 2009 which was a considerably larger event on the Wishkah coincident with a very high tide. The intent of these two additional flood simulations was to compare model results to observations (either measured or anecdotal) to validate the model's accuracy. WSE has been unable to obtain reliable observations from either event, but received various flood photos taken presumably during the 2009 flood. The timing of these photos as compared to the flood peak is uncertain, but the estimated extent and depth of flooding nevertheless compares reasonably well with the simulated results.

Table 3: Final 2D Model Roughness Coefficients

LAND COVER AREA CATEGORY	MANNING'S ROUGHNESS (N-VALUE)
Barren land rock/sand/clay	0.04
Cultivated crops	0.06
Deciduous forest	0.10
Developed, high intensity	0.10
Developed, low intensity	0.06
Developed, medium intensity	0.08
Developed, open space	0.06
Emergent herbaceous wetlands	0.10
Evergreen forest	0.12
Grassland/herbaceous	0.06
Mixed forest	0.10
Pasture/hay	0.06
River channel below Ellison	0.045
River channel above Ellison	0.04
Shrub/scrub	0.12
Woody wetlands	0.10

Table 4: Summary of Existing Conditions Simulation Results

		Location along Wishkah Road																																			
		Baretich Road (M.P. 2.3)				Frosty Way (M.P. 2.5)				Hoffman Road (M.P. 2.6)				Near 3170 Wishkah Road (M.P. 2.9)				Ellison Dip (M.P. 3.8)				Near 11 Leutz Road (M.P. 4.1)				Long Swamp (M.P. 4.6 - 5.3)				Wyman Creek (M.P. 5.8)				Miller Hill (M.P. 7.5)			
		Min Gnd ¹ (feet)	Max WL (feet)	Depth (feet)	Duration (hrs)	Min Gnd ² (feet)	Max WL (feet)	Depth (feet)	Duration (hrs)	Min Gnd ² (feet)	Max WL (feet)	Depth (feet)	Duration (hrs)	Min Gnd ¹ (feet)	Max WL (feet)	Depth (feet)	Duration (hrs)	Min Gnd ¹ (feet)	Max WL (feet)	Depth (feet)	Duration (hrs)	Min Gnd ² (feet)	Max WL (feet)	Depth (feet)	Duration (hrs)	Min Gnd ¹ (feet)	Max WL (feet)	Depth (feet)	Duration (hrs)	Min Gnd ³ (feet)	Max WL (feet)	Depth (feet)	Duration (hrs)				
Condition																																					
Calibration Events																																					
January 7, 2009		10.50	13.27	2.77	25.25	11.10	13.45	2.35	30.75	10.90	14.02	3.12	36.00	11.12	14.33	3.21	35.75	10.76	15.08	4.32	42.50	10.40	15.35	4.95	46.50	11.66	16.59	4.93	46.00	15.63	17.26	1.63	57.00	19.90	21.74	1.84	31.25
January 5, 2015 (simulated)		10.50	10.33	-0.17	0.00	11.10	10.35	-0.75	0.00	10.90	11.14	0.24	3.00	11.12	11.51	0.39	4.50	10.76	12.54	1.78	16.50	10.40	12.95	2.55	18.75	11.66	14.36	2.70	20.50	15.63	15.59	-0.04	0.00	19.90	19.80	-0.10	0.00
January 5, 2015 (observed)			10.35				10.66				11.13				11.50				12.84							13.80				15.83							
January 5, 2015 (difference)			-0.02				-0.31				0.01				0.01				-0.30							0.56				-0.24							
December 9, 2015		10.50	11.59	1.09	8.25	11.10	11.59	0.49	5.50	10.90	11.91	1.01	13.50	11.12	12.14	1.02	14.50	10.76	12.88	2.12	32.00	10.40	13.14	2.74	47.25	11.66	14.28	2.62	52.50	15.63	15.59	-0.04	0.00	19.90	19.75	-0.15	0.00
Candidate 100-year events																																					
100-year tide, 10% exceedance winter flow		10.50	12.84	2.34	11.25	11.10	12.81	1.71	10.50	10.90	12.68	1.78	12.25	11.12	12.60	1.48	9.75	10.76	12.55	1.79	14.25	10.40	12.55	2.15	20.25	11.66	12.61	0.95	9.50	15.63	15.42	-0.21	0.00	19.90	14.14	-5.76	0.00
10% exceedence tide, 10-year flow		10.50	11.23	0.73	11.75	11.10	11.70	0.60	12.50	10.90	12.54	1.64	20.50	11.12	12.89	1.77	21.25	10.76	13.83	3.07	32.25	10.40	14.15	3.75	39.50	11.66	15.42	3.76	36.00	15.63	16.18	0.55	10.25	19.90	20.80	0.90	9.00
25% exceedence tide, 25-year flow		10.50	11.52	1.02	11.25	11.10	12.06	0.96	14.25	10.90	13.00	2.10	20.75	11.12	13.40	2.28	22.00	10.76	14.41	3.65	33.00	10.40	14.74	4.34	38.50	11.66	16.10	4.44	42.50	15.63	16.85	1.22	16.75	19.90	21.52	1.62	14.50
MHHW tide, 100-year flow		10.50	14.05	3.55	n/a ⁴	11.10	14.21	3.11	n/a ⁴	10.90	14.84	3.94	n/a ⁴	11.12	15.19	4.07	n/a ⁴	10.76	16.03	5.27	n/a ⁴	10.40	16.32	5.92	n/a ⁴	11.66	17.62	5.96	n/a ⁴	15.63	18.27	2.64	n/a ⁴	19.90	22.79	2.89	n/a ⁴
MSL tide, 100-year flow		10.50	12.69	2.19	14.75	11.10	13.12	2.02	20.00	10.90	14.08	3.18	26.00	11.12	14.52	3.40	27.50	10.76	15.55	4.79	37.00	10.40	15.88	5.48	43.00	11.66	17.33	5.67	49.00	15.63	18.05	2.42	40.50	19.90	22.75	2.85	22.25
Candidate 10-year events																																					
10-year tide, 10% exceedance winter flow		10.50	12.06	1.56	8.25	11.10	12.05	0.95	6.50	10.90	11.95	1.05	7.75	11.12	11.91	0.79	6.00	10.76	11.90	1.14	8.50	10.40	11.91	1.51	11.00	11.66	11.95	0.29	5.00	15.63	15.42	-0.21	0.00	19.90	13.70	-6.20	0.00
MHHW tide, 10-year flow		10.50	11.62	1.12	n/a ⁴	11.10	11.96	0.86	n/a ⁴	10.90	12.76	1.86	n/a ⁴	11.12	13.11	1.99	n/a ⁴	10.76	13.98	3.22	n/a ⁴	10.40	14.28	3.88	n/a ⁴	11.66	15.51	3.85	n/a ⁴	15.63	16.24	0.61	n/a ⁴	19.90	20.81	0.91	n/a ⁴
MSL tide, 10-year flow		10.50	9.19	-1.31	0.00	11.10	10.28	-0.82	0.00	10.90	11.17	0.27	5.00	11.12	11.70	0.58	8.00	10.76	13.02	2.26	18.25	10.40	13.47	3.07	23.75	11.66	15.04	3.38	29.25	15.63	15.94	0.31	9.50	19.90	20.77	0.87	8.75
Candidate 2-year events																																					
2-year tide, 10% exceedance winter flow		10.50	11.49	0.99	5.75	11.10	11.47	0.37	3.25	10.90	11.44	0.54	5.00	11.12	11.44	0.32	3.50	10.76	11.46	0.70	5.75	10.40	11.47	1.07	7.25	11.66	11.50	-0.16	0.00	15.63	15.42	-0.21	0.00	19.90	13.29	-6.61	0.00
MHHW tide, 2-year flow		10.50	9.97	-0.53	0.00	11.10	10.06	-1.04	0.00	10.90	10.85	-0.05	0.00	11.12	11.09	-0.03	0.00	10.76	11.86	1.10	n/a ⁴	10.40	12.21	1.81	n/a ⁴	11.66	13.47	1.81	n/a ⁴	15.63	15.57	-0.06	0.00	19.90	19.09	-0.81	0.00
MSL tide, 2-year flow		10.50	6.78	-3.72	0.00	11.10	6.93	-4.17	0.00	10.90	8.15	-2.75	0.00	11.12	8.51	-2.61	0.00	10.76	9.80	-0.96	0.00	10.40	10.39	-0.01	0.00	11.66	12.47	0.81	9.25	15.63	15.56	-0.07	0.00	19.90	19.03	-0.87	0.00
Notes:																																					
¹ Surveyed by Grays Harbor County (feet NAVD)																																					
² From LiDAR data, along fog line (feet NAVD)																																					
³ From LiDAR data, along centerline (feet NAVD)																																					
⁴ The high flow event combined with MHHW provides a reasonably conservative estimate for tidally influenced flood depths, but can result in unreasonably long flood durations.																																					

SIMULATION RESULTS

Because flooding along Wishkah Road can be due to high river flow, high tides, or a combination of both, assigning a unique exceedance probability or recurrence interval (e.g. a 100-year event) throughout the study reach is complicated. There are multiple combinations of inflow discharge and downstream tidal conditions that may define a 100-year or any other design event, and these will vary depending upon location along the Wishkah River. In order to establish existing conditions corresponding to a 100-year, 10-year, and 2-year event, multiple simulations were required for each.

One possible scenario consists of the 100-, 10-, and 2-year flows on the Wishkah River combined with a nominal or average tide condition that does not independently induce flooding, such as mean sea level (MSL). However, given the duration of high flows during flood events on the Wishkah River, it is possible that the tide at the time of the peak of the flood might coincide with a higher than average tide condition which could further increase flooding. A conservative assumption for flood depths would be to assume constant Mean Higher High Water (MHHW) throughout the event and thus ensure that the higher tide was simulated coincident with the peak flow.

The complementary scenario to large inflows is a condition with high downstream tides coincident with a moderate flow. To account for these types of events, the 100-, 10-, and 2-year high tides were assumed to occur together with the 10% exceedance winter flow, estimated as described previously.

Each of the above conditions was simulated with the HEC-RAS model. Furthermore, there are many other possible flow and tidal conditions that would also result in a statistical 100-, 10-, or 2-year flood event. For example, a 25-year flow combined with a fixed 25 percent chance exceedance tide would have a combined probability of 1 in 100, i.e. 100-year event, as would a 10-year flow combined with a 10 percent exceedance tide. These two additional intermediate combinations were also simulated, resulting in five candidates that could represent the 100-year event (see Table 4). Note that the 100-year inflow was simulated with both MSL and MHHW tides as the former provides a more reasonable estimate of flood duration while the latter provides a more conservative estimate of peak flood levels. For the 10-year and 2-year design events only the simulations of the flow and tide extremes described above were made as the 100-year results indicated the intermediate scenarios would not control at any location.

Existing conditions results of each candidate simulation for the three recurrence-interval floods are summarized in Table 4. Results are presented for the following study areas, at low lying locations on Wishkah Road that frequently flood:

Study Area #1 – Baretich Flats (MP 2.3-2.6)

Study Area #2 – Ellison Dip (MP 3.8)

Study Area #3 – Long Swamp (MP 5.0)

Study Area #4 – Wyman Creek (MP 5.8)

Study Area #5 – Miller Hill (MP 7.5)

Baretich Flats study area consists of three discrete locations in Table 4, based upon the high water marks measured by the County following the January 5, 2015 event: Baretich Road, Frosty Way, and Hoffman Road. Included is a fourth high water mark location just upstream of Baretich Flats, near 3170 Wishkah

Road. Also included in the table is an additional flood location which was not identified in WSE's scope of work near 11 Leutz Road (near its intersection with Wishkah Road at M.P. 4.1). Note that the Wyman Creek study area was identified as the Monarch Creek Bridge by the County, as mentioned previously. The fifth study area was misidentified as Vienna Tracts in the scope of work, but has been renamed "Miller Hill" based on feedback from local residents. This site is also apparently the approximate location where the school bus turns around on its route along Wishkah Road.

Examining the results of each candidate 100-year event reveals that the 100-year flow combined with MHHW tide results in the worst-case flood depths, while the 100-year flow combined with MSL tide results in the worst-case flood durations at all reported locations (see Table 4). Wishkah Road would remain under water for between 15 and 49 hours during the 100-year flow MSL event, depending on location. The maximum depths on Wishkah Road with the controlling 100-year flow MHHW event generally range between 2.5 feet and 6 feet. More detailed results from this event were processed for each of the study areas. Figure 3 presents the maximum existing condition water surface elevations throughout the model domain for the 100-year flow with MHHW. Figures 4 to 8 plot the simulated maximum flood depths in the individual study areas, while Figures 9 to 13 plot the simulated velocities. Individual homes and structures are shown in each plot to enable depth or velocity results to be determined at specific locations of interest.

SUMMARY AND CONCLUSION

WSE has developed and calibrated a HEC-RAS 2D model of the Wishkah River along Wishkah Road, extending upstream from the City of Aberdeen 10.6 miles to the Turner Bridge. The purpose of the modeling was to help identify and evaluate cost effective projects to reduce or eliminate flooding along Wishkah Road, specifically at five study areas prone to repetitive flooding.

Existing condition simulations were completed for candidate 100-year, 10-year, and 2-year flood conditions, considering various combinations of inflow and tidal boundary conditions. Results are documented herein, including a tabular summary of flood elevations, maximum flood depths on Wishkah Road and estimated flood durations. The greatest flood durations and depths occur during the 100-year flow event, with Wishkah Road remaining under water for as long as two days and maximum depths exceeding 5 feet in some locations. Also included are plots of flood depths that can be used to identify flood risk at individual private properties.

REFERENCES

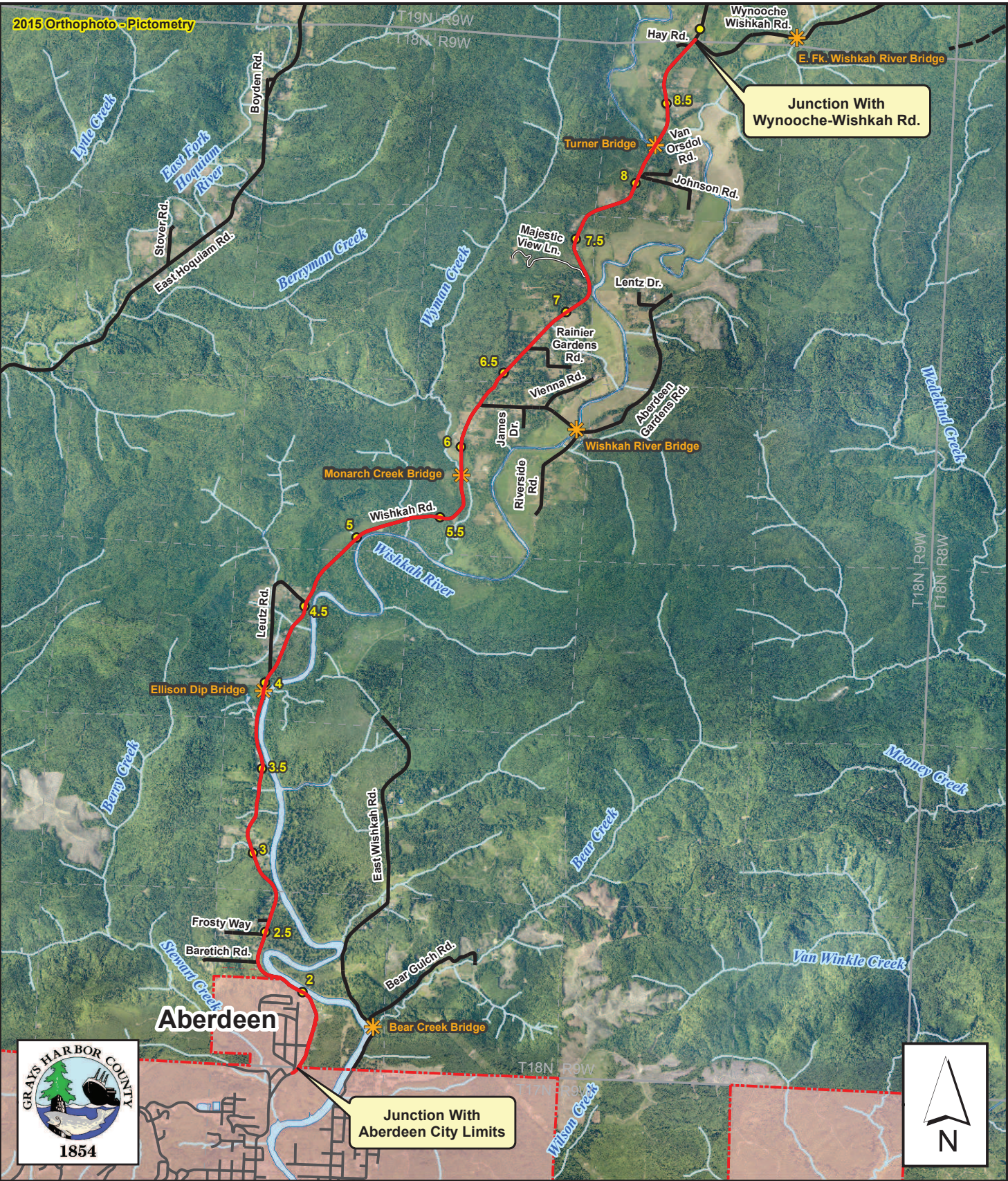
- Grays Harbor County, 2016. Wishkah Road profiles and 1-5-2015 flood High Water Mark survey.
- Sumioka, S.S., D.L. Kresch, and K.D. Kasnick, 1998. *Magnitude and Frequency of Floods in Washington*. Water-Resources Investigations Report 97-4277, U.S. Geological Survey, Tacoma, WA.
- U.S. Army Corps of Engineers (Corps), 2016. *HEC-RAS River Analysis System, 2D Modeling User's Manual, Version 5.0*. CPD-68. U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA. April.
- U.S. Geological Survey (USGS), 2011. *National Land Cover Database (NLCD)*. Multi-Resolution Land Characteristics Consortium (MRLC), Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD.

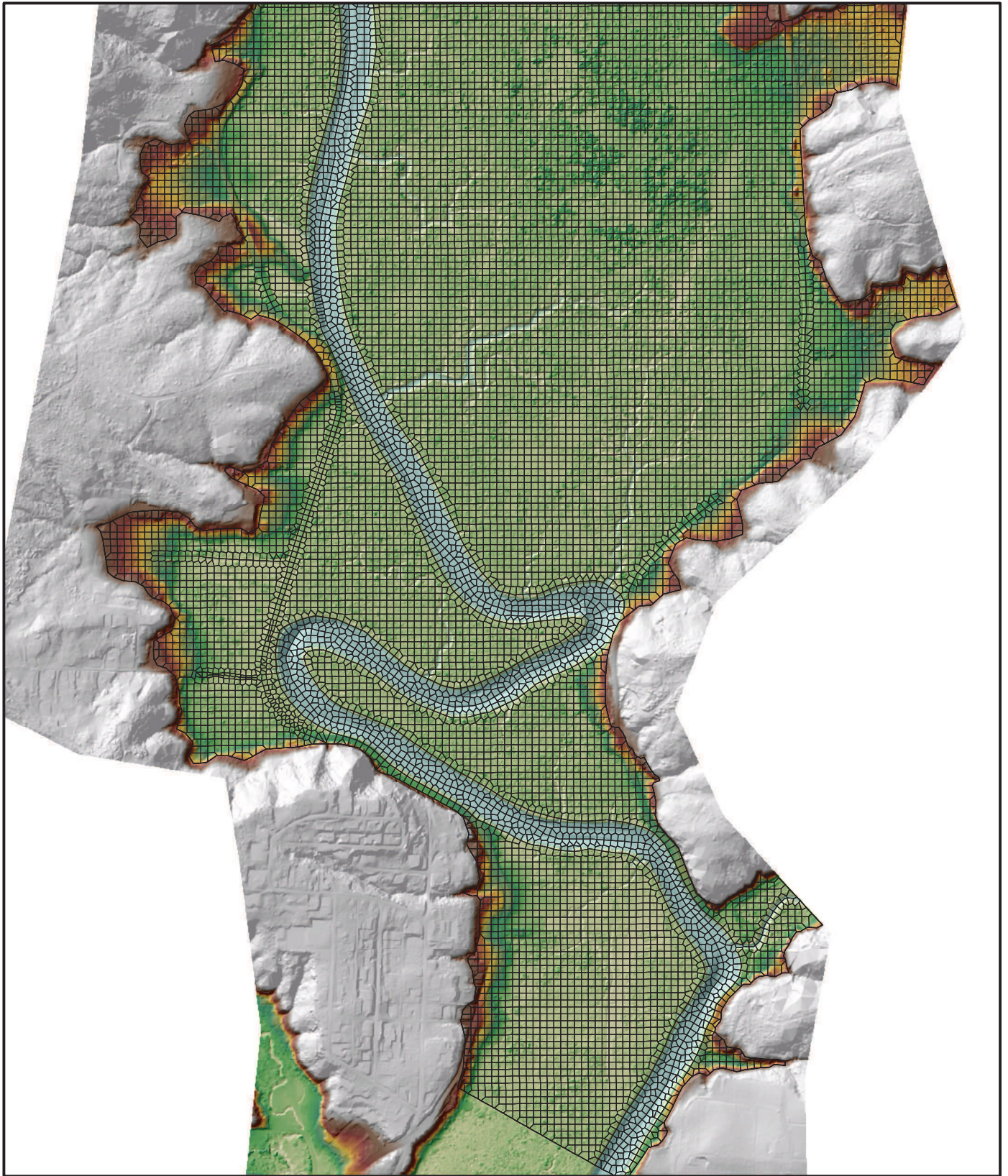
Vicinity Map - Wishkah Road

Aberdeen City Limits to Wynoochee-Wishkah Road

1 inch = 4,000 feet

Disclaimer:
This spatial data is intended for reference purposes only. Any use other than that intended shall be at the sole responsibility of the user. The information appearing on this document was obtained from a variety of sources, as typically identified hereon. The user acknowledges that inconsistencies, errors and omissions may be contained within the data used to prepare this product, and such data may originate from other sources than Grays Harbor County.
By use of this document, the user further indemnifies and holds harmless Grays Harbor County for any adverse consequences resulting from the use of this product.
Any questions regarding the information presented hereon or data used to prepare this product should be directed to the contact organization, Grays Harbor County Department of Central Services - GIS Program or other local, state, federal agency, as listed hereon.





Grays Harbor County, WA



**Wishkah Road Comprehensive
Flood Study
Topographic Surface with
2D Model Mesh**

0 700 1,400
Feet



Scale: 1:12,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet

16 Nov 2016



Figure 2a



Grays Harbor County, WA



**Wishkah Road Comprehensive
Flood Study
Topographic Surface with
2D Model Mesh**

0 700 1,400
Feet

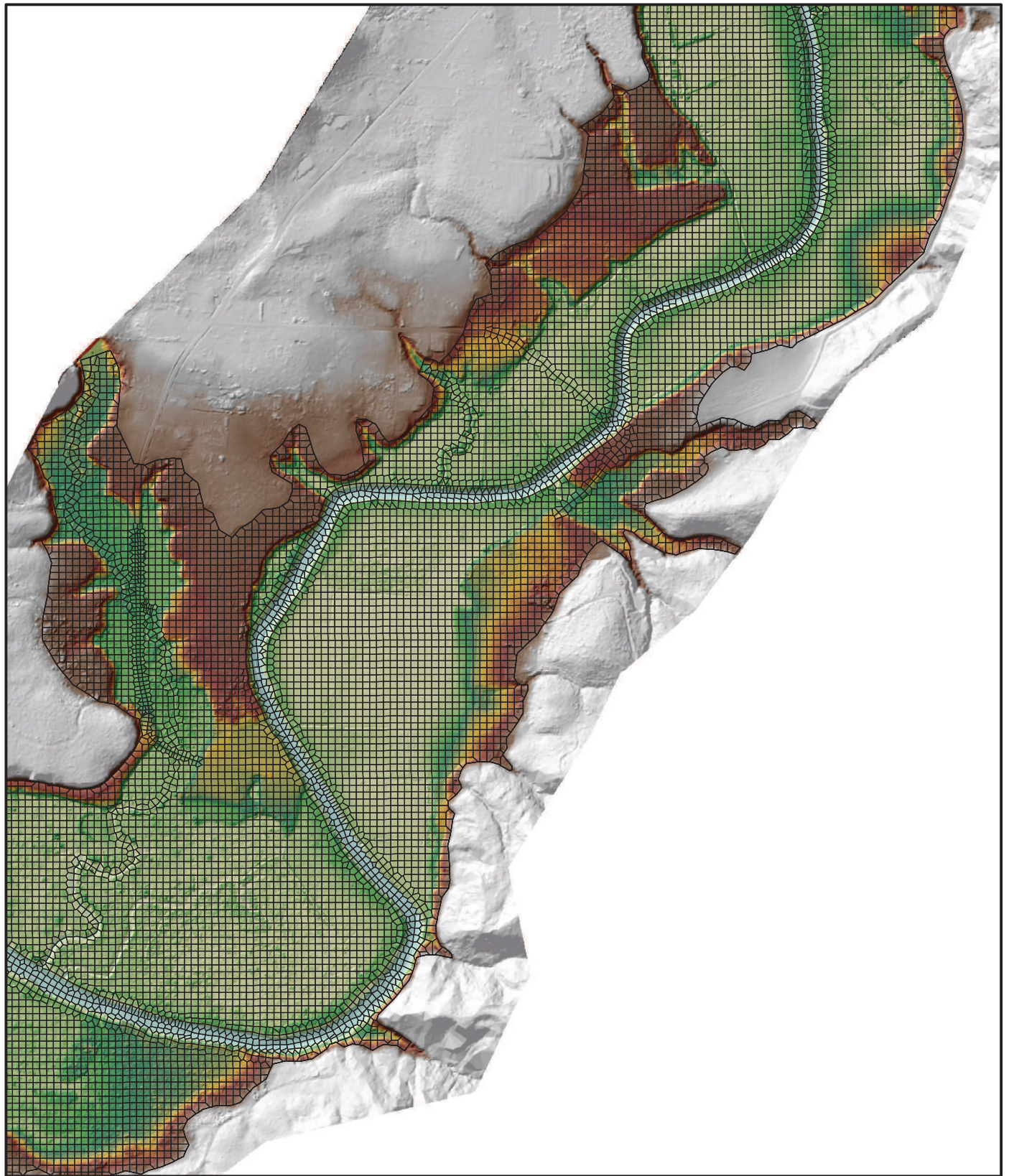


Scale: 1:12,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet

16 Nov 2016



Figure 2b



Grays Harbor County, WA



**Wishkah Road Comprehensive
Flood Study
Topographic Surface with
2D Model Mesh**

0 700 1,400 Feet

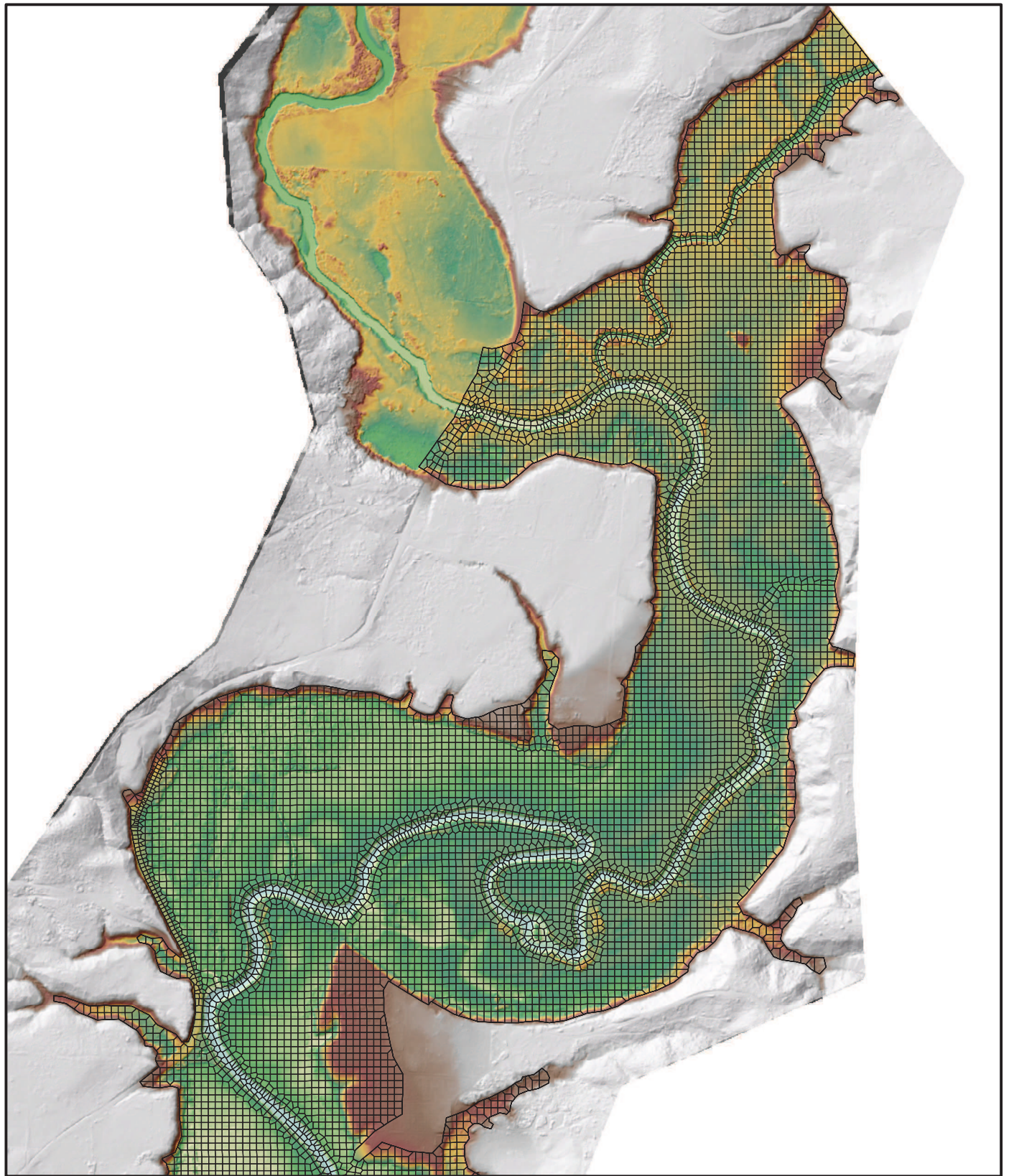


Scale: 1:12,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet

16 Nov 2016



Figure 2c



Grays Harbor County, WA



**Wishkah Road Comprehensive
Flood Study
Topographic Surface with
2D Model Mesh**

0 700 1,400 Feet



Scale: 1:12,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet

16 Nov 2016



Figure 2d

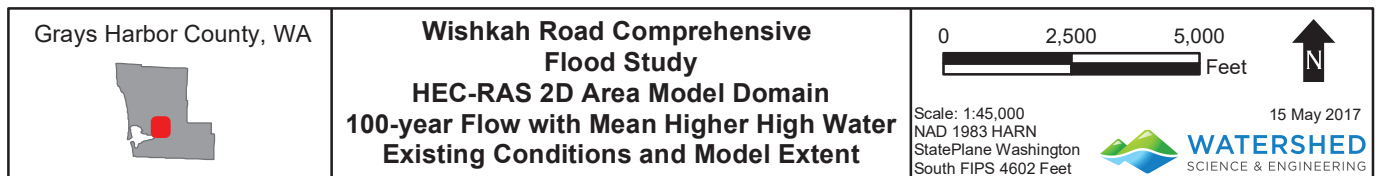
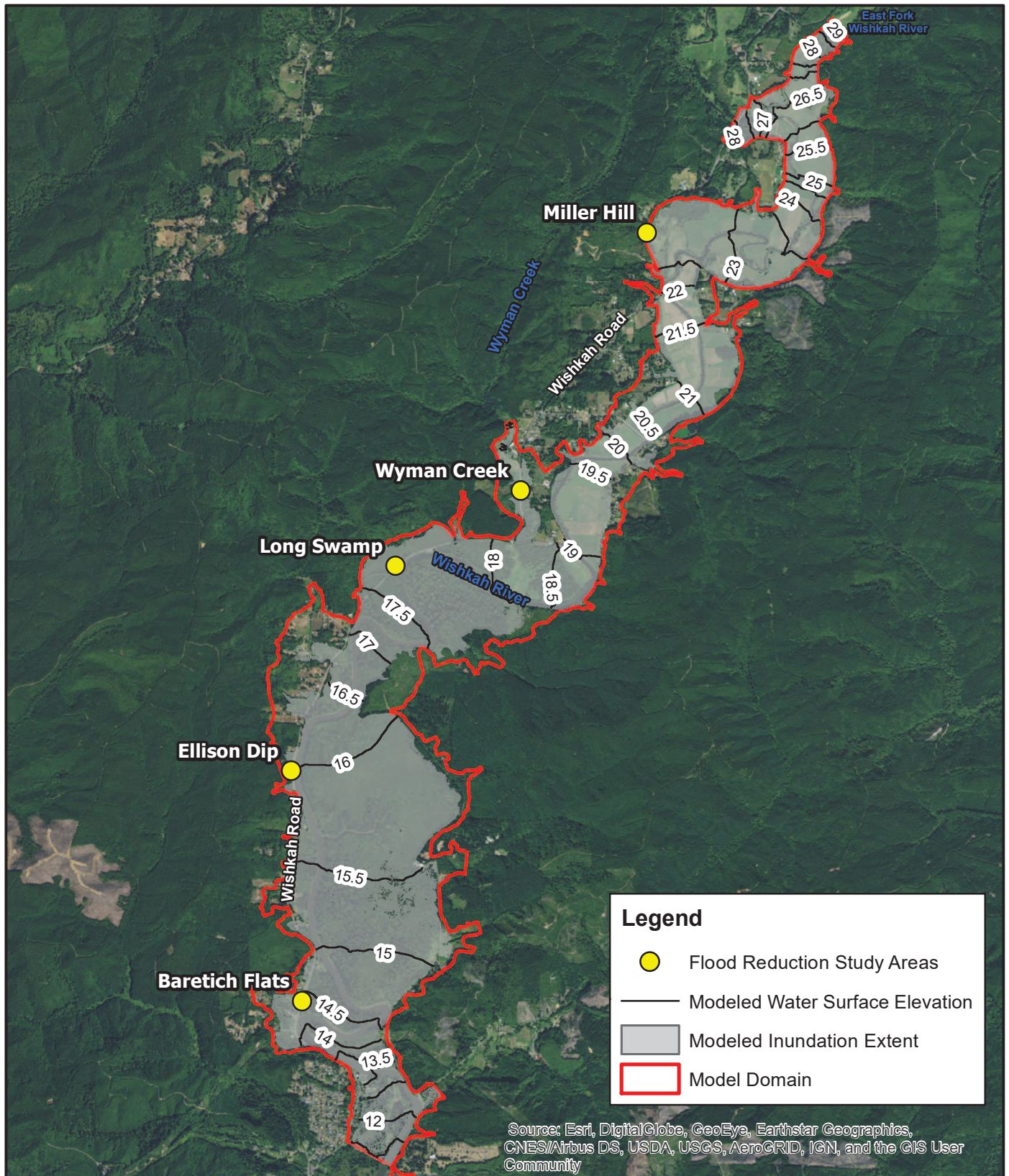
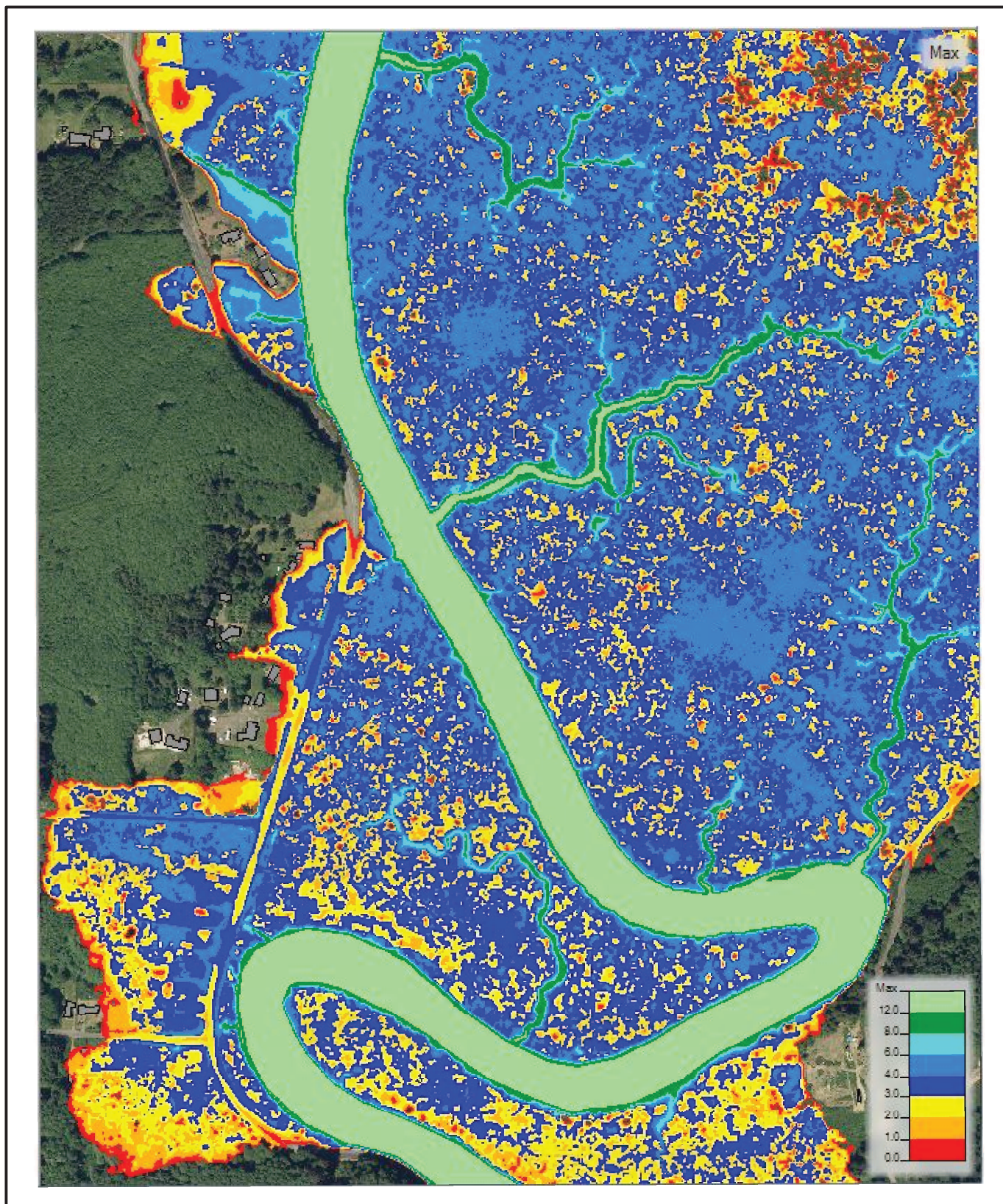


Figure 3






<p>Grays Harbor County, WA</p> 	<p>Wishkah Road Comprehensive Flood Study 100-year Flow with Mean Higher High Water Maximum Depth Baretich Flats to End of CHE Model</p>	<p>0 310 620  Feet</p> <p>Scale: 1:6,500 NAD 1983 HARN StatePlane Washington South FIPS 4602 Feet</p> <p>17 May 2017</p>  <p>WATERSHED SCIENCE & ENGINEERING</p>
--	---	--

Figure 4

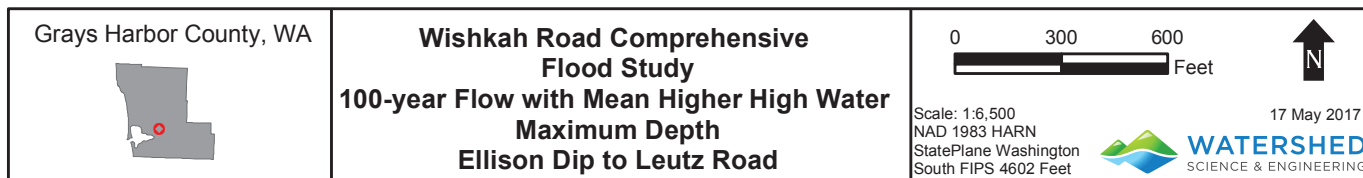
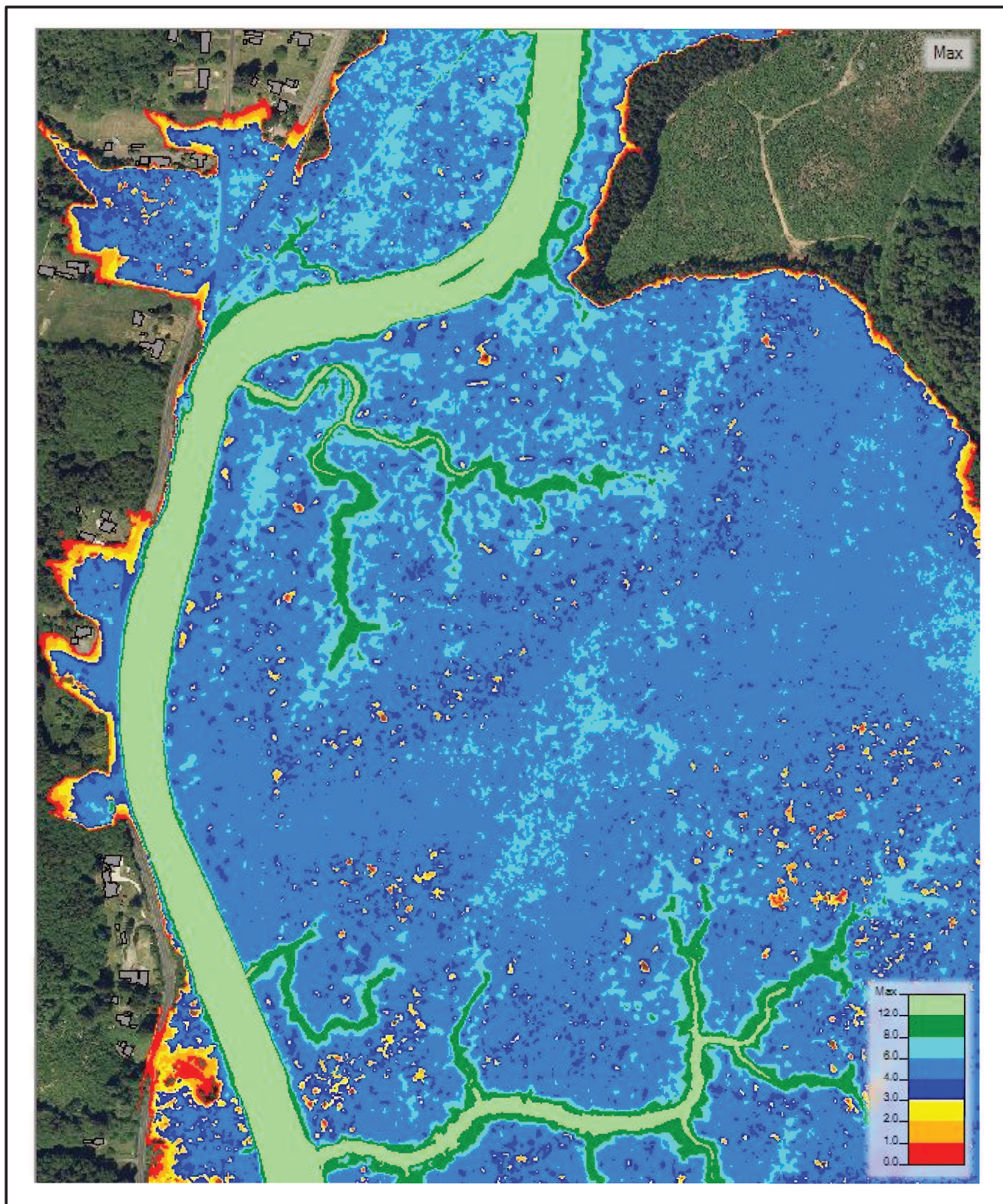
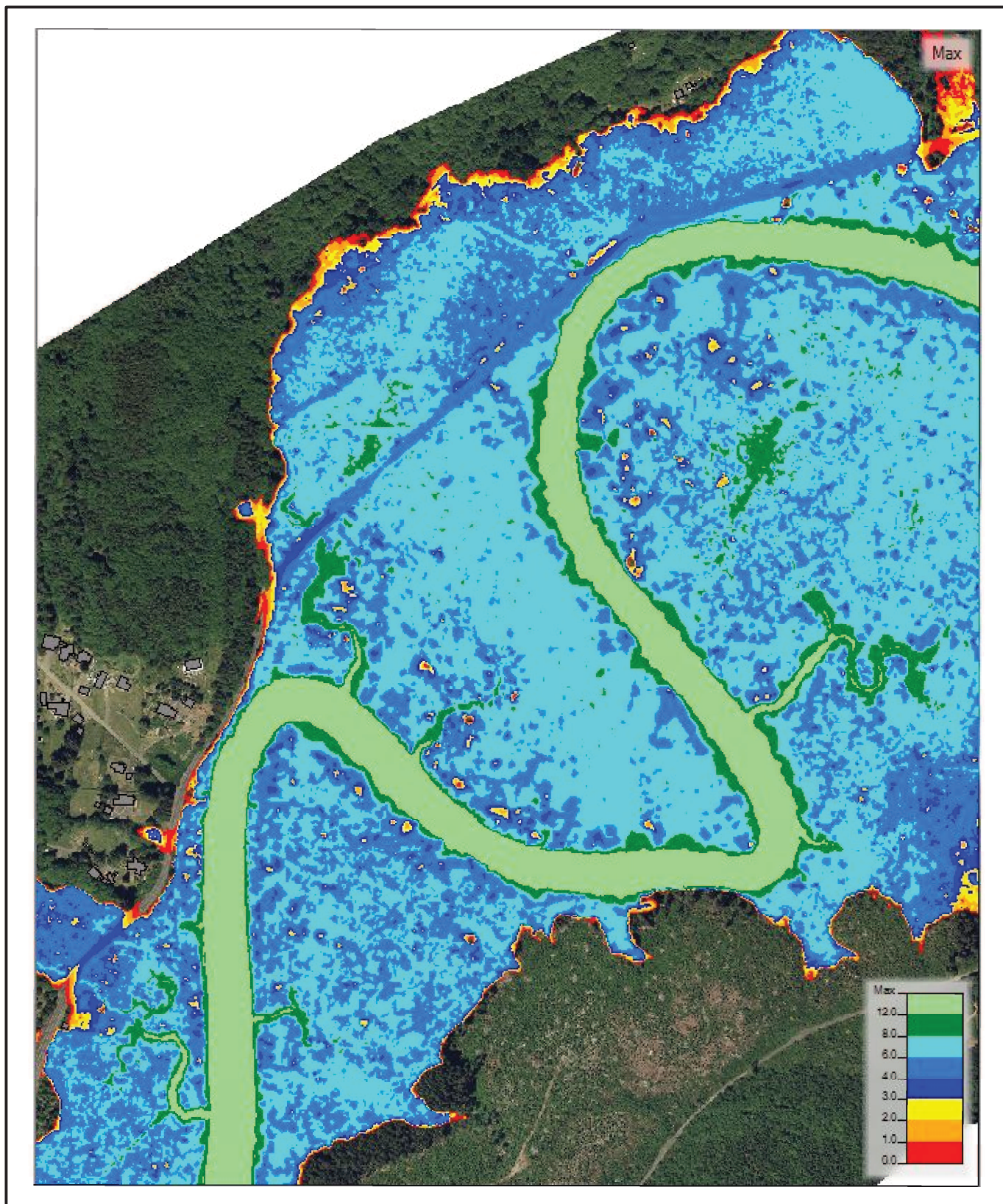


Figure 5







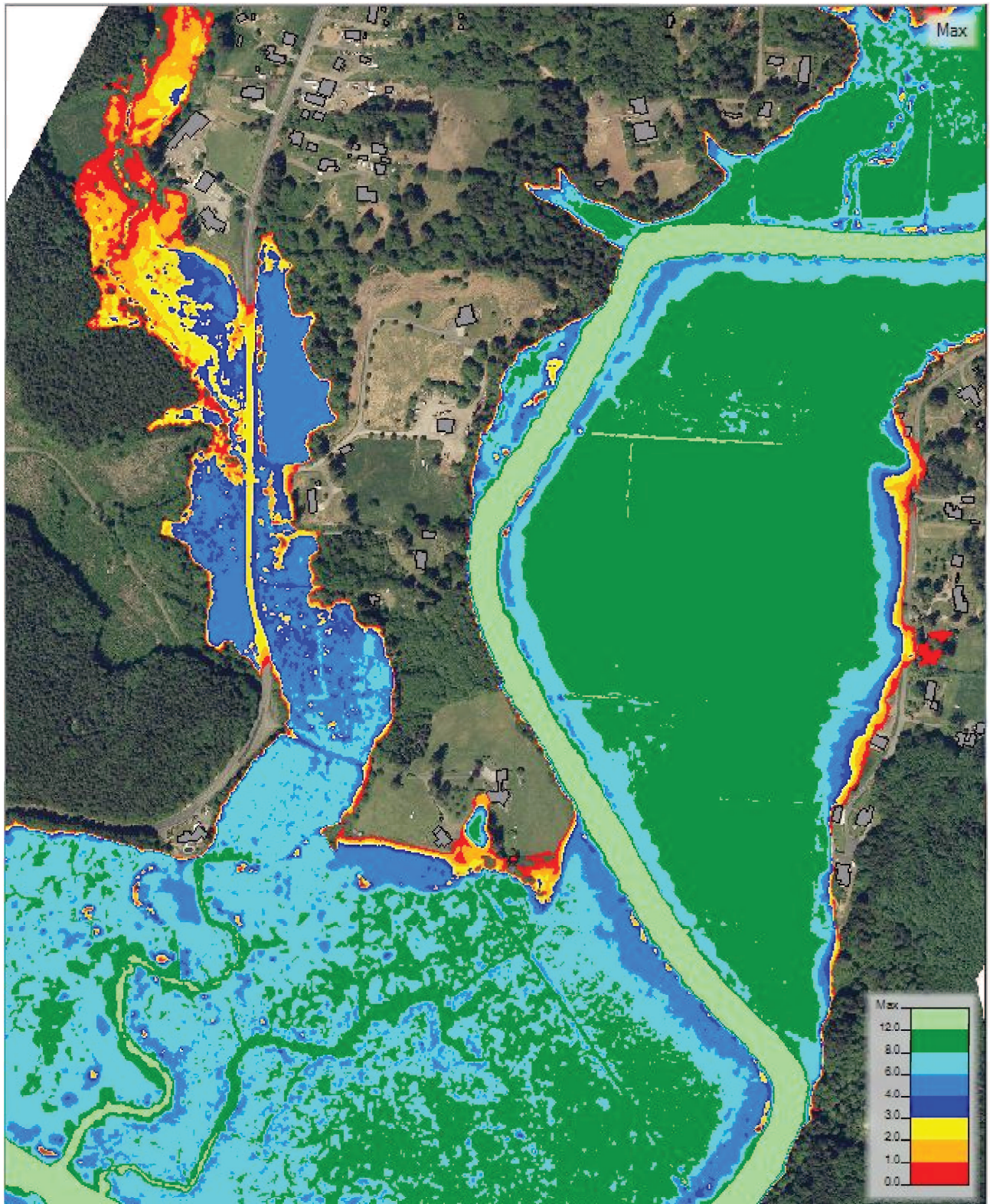
<p>Grays Harbor County, WA</p> 	<p align="center">Wishkah Road Comprehensive Flood Study 100-year Flow with Mean Higher High Water Maximum Depth Leutz Road to Long Swamp</p>	<div style="display: flex; align-items: center;"> <div style="flex: 1;"> <p>0 300 600</p>  <p>Feet</p> </div> <div style="flex: 0.5; text-align: center;">  <p>N</p> </div> </div> <div style="display: flex; justify-content: space-between; font-size: small;"> <div> <p>Scale: 1:6,500 NAD 1983 HARN StatePlane Washington South FIPS 4602 Feet</p> </div> <div align="right"> <p>17 May 2017</p>  <p>WATERSHED SCIENCE & ENGINEERING</p> </div> </div>
--	--	---

Figure 6



Grays Harbor County, WA



**Wishkah Road Comprehensive
Flood Study
100-year Flow with Mean Higher High Water
Maximum Depth
Wyman (Monarch) Creek**

0 300 600
Feet

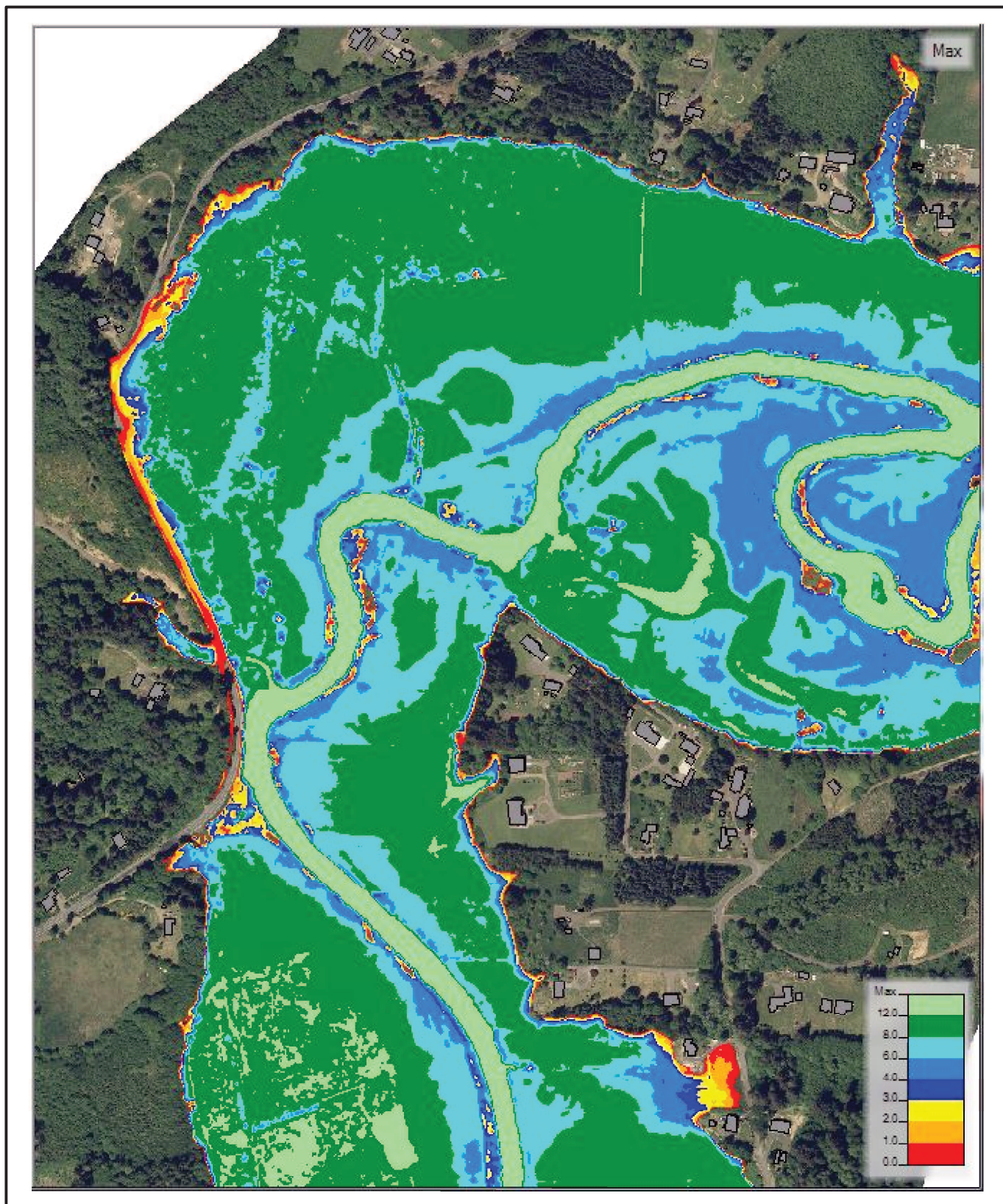


Scale: 1:6,500
NAD 1983 HARN
StatePlane Washington
South FIPS 4602 Feet

17 May 2017



Figure 7






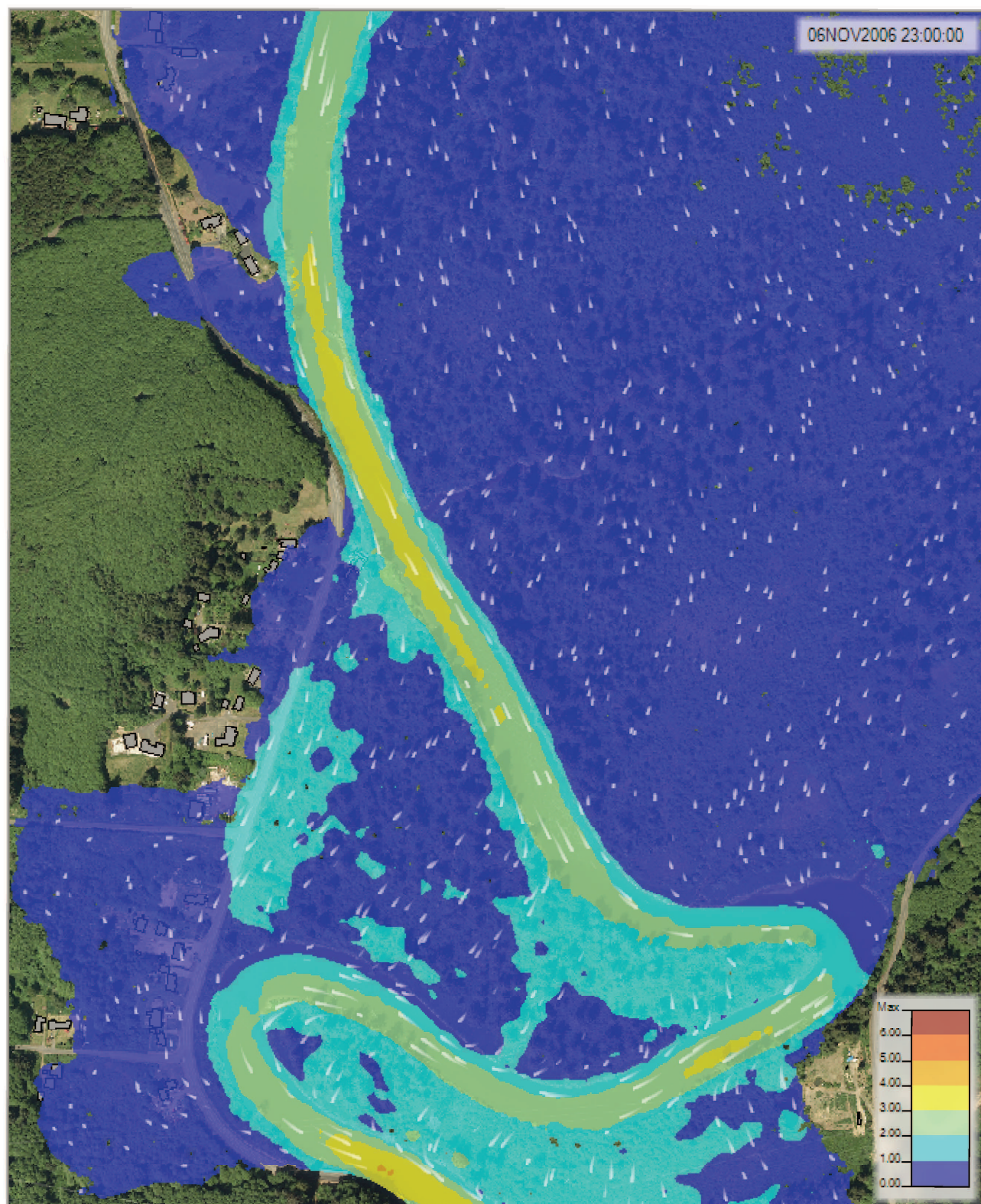
<p>Grays Harbor County, WA</p> 	<p>Wishkah Road Comprehensive Flood Study 100-year Flow with Mean Higher High Water Maximum Depth Miller Hill</p>	<p>0 300 600  Feet</p> <p>Scale: 1:6,500 NAD 1983 HARN StatePlane Washington South FIPS 4602 Feet</p> <p>17 May 2017</p> 
--	--	---

Figure 8



Grays Harbor County, WA



**Wishkah Road Comprehensive
Flood Study**
100-year Flow with Mean Higher High Water
Maximum Velocity
Baretich Flats to End of CHE Model

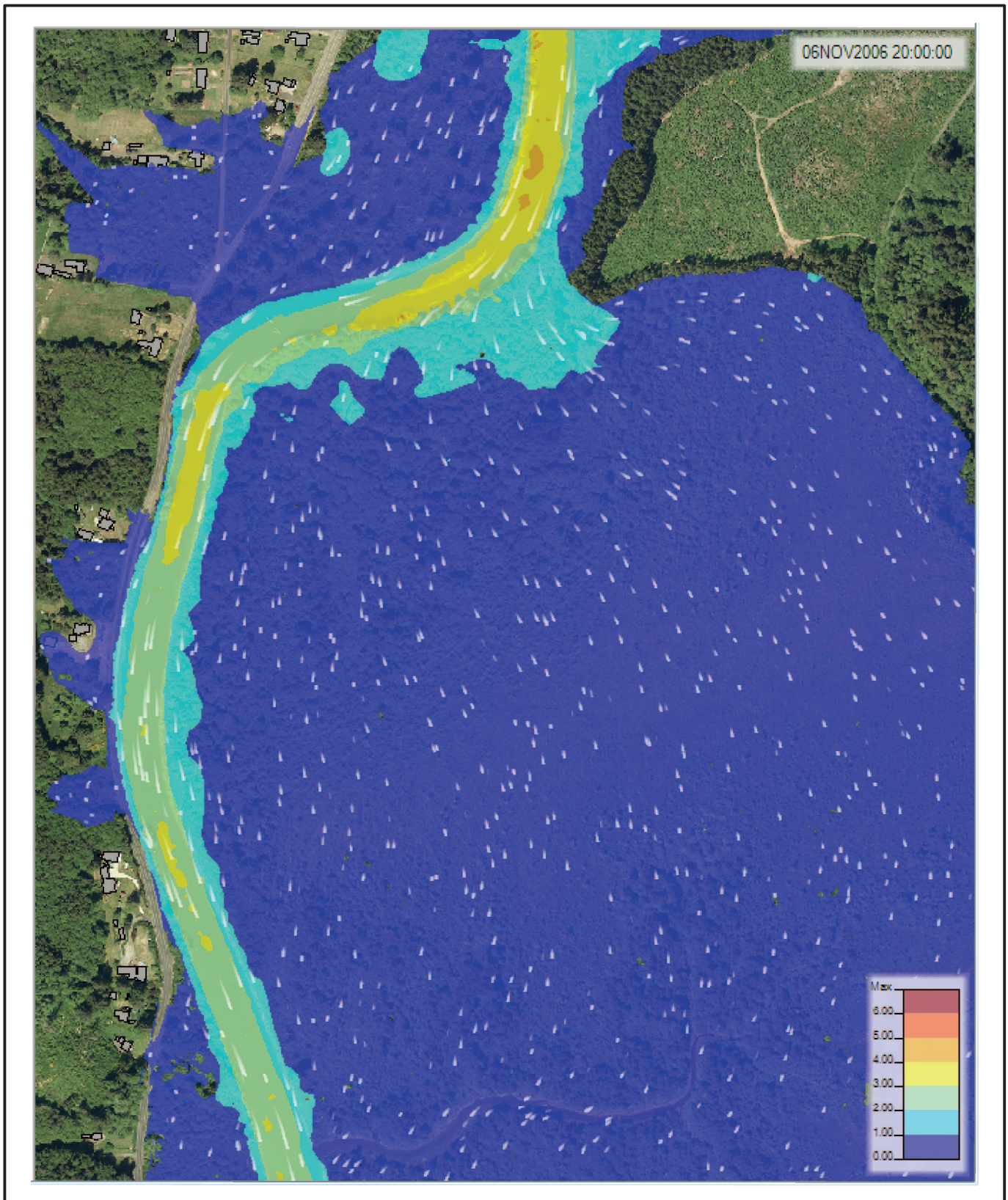
0 300 600
Feet



Scale: 1:6,500
NAD 1983 HARN
StatePlane Washington
South FIPS 4602 Feet

17 May 2017
WATERSHED
SCIENCE & ENGINEERING

Figure 9







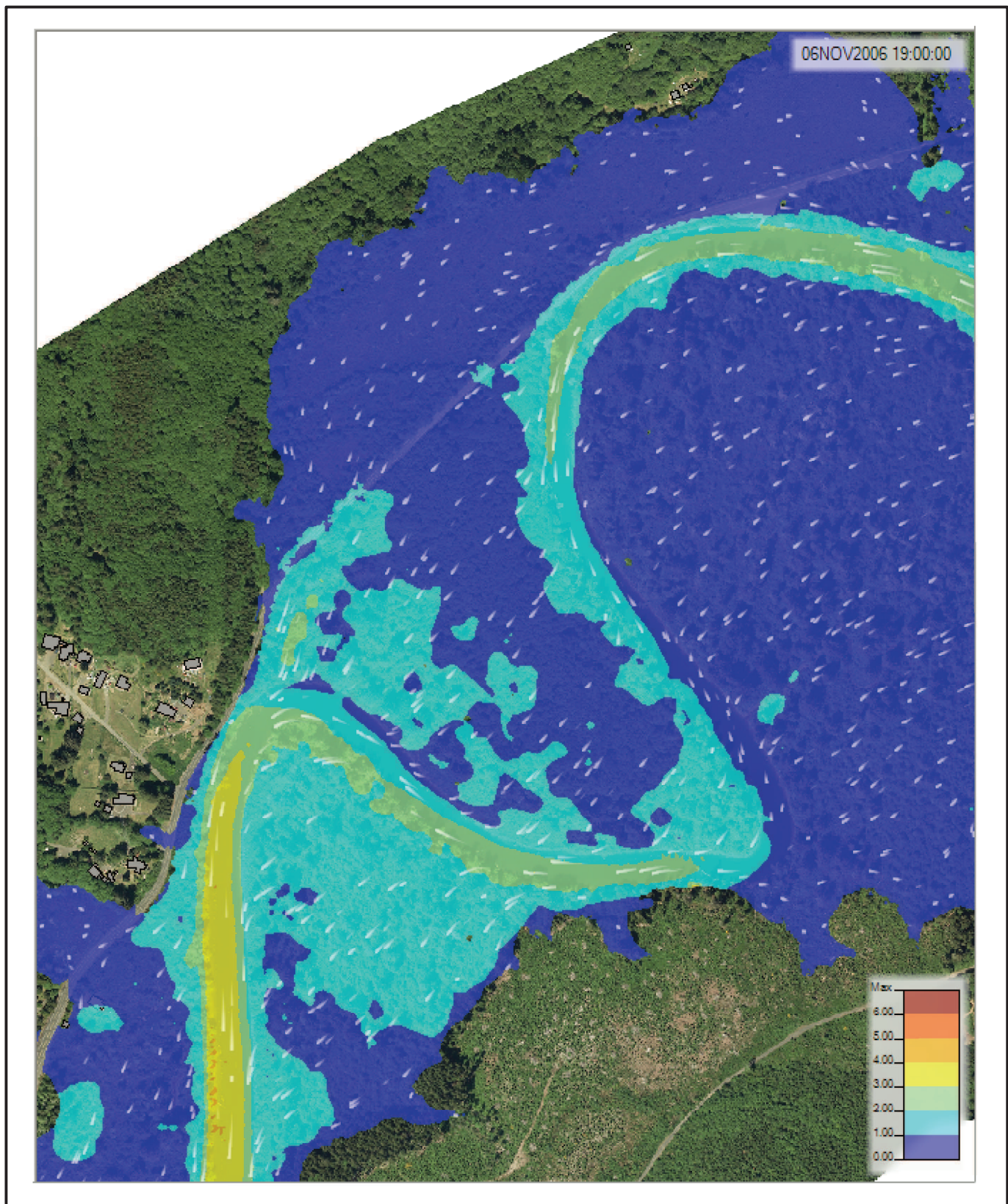
<p>Grays Harbor County, WA</p> 	<p>Wishkah Road Comprehensive Flood Study</p> <p>100-year Flow with Mean Higher High Water</p> <p>Maximum Velocity</p> <p>Ellison Dip to Leutz Road</p>	<div style="display: flex; align-items: center;"> <div style="flex: 1;"> <p>0 300 600</p>  <p>Feet</p> </div> <div style="flex: 0.5; text-align: center;">  <p>N</p> </div> </div> <div style="display: flex; justify-content: space-between; font-size: small;"> <div> <p>Scale: 1:6,500 NAD 1983 HARN StatePlane Washington South FIPS 4602 Feet</p> </div> <div style="text-align: right;"> <p>17 May 2017</p>  <p>WATERSHED SCIENCE & ENGINEERING</p> </div> </div>
--	---	---

Figure 10







<p>Grays Harbor County, WA</p> 	<p align="center">Wishkah Road Comprehensive Flood Study</p> <p align="center">100-year Flow with Mean Higher High Water</p> <p align="center">Maximum Velocity</p> <p align="center">Leutz Road to Long Swamp</p>	<div style="display: flex; align-items: center;"> <div style="flex: 1;"> <p>0 300 600</p>  <p>Feet</p> </div> <div style="flex: 0.5; text-align: center;">  <p>N</p> </div> </div> <div style="display: flex; justify-content: space-between; font-size: small;"> <div> <p>Scale: 1:6,500 NAD 1983 HARN StatePlane Washington South FIPS 4602 Feet</p> </div> <div align="right"> <p>17 May 2017</p>  <p>WATERSHED SCIENCE & ENGINEERING</p> </div> </div>
--	--	--

Figure 11

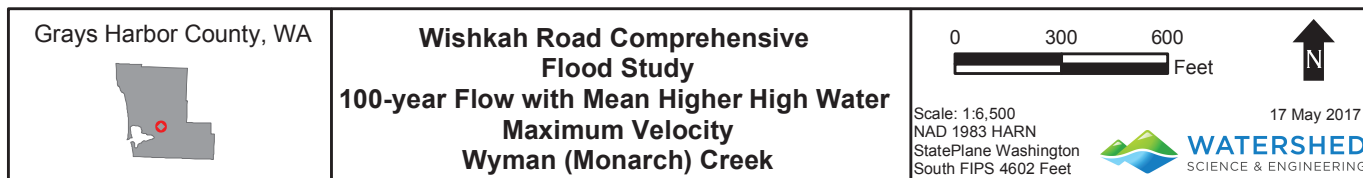
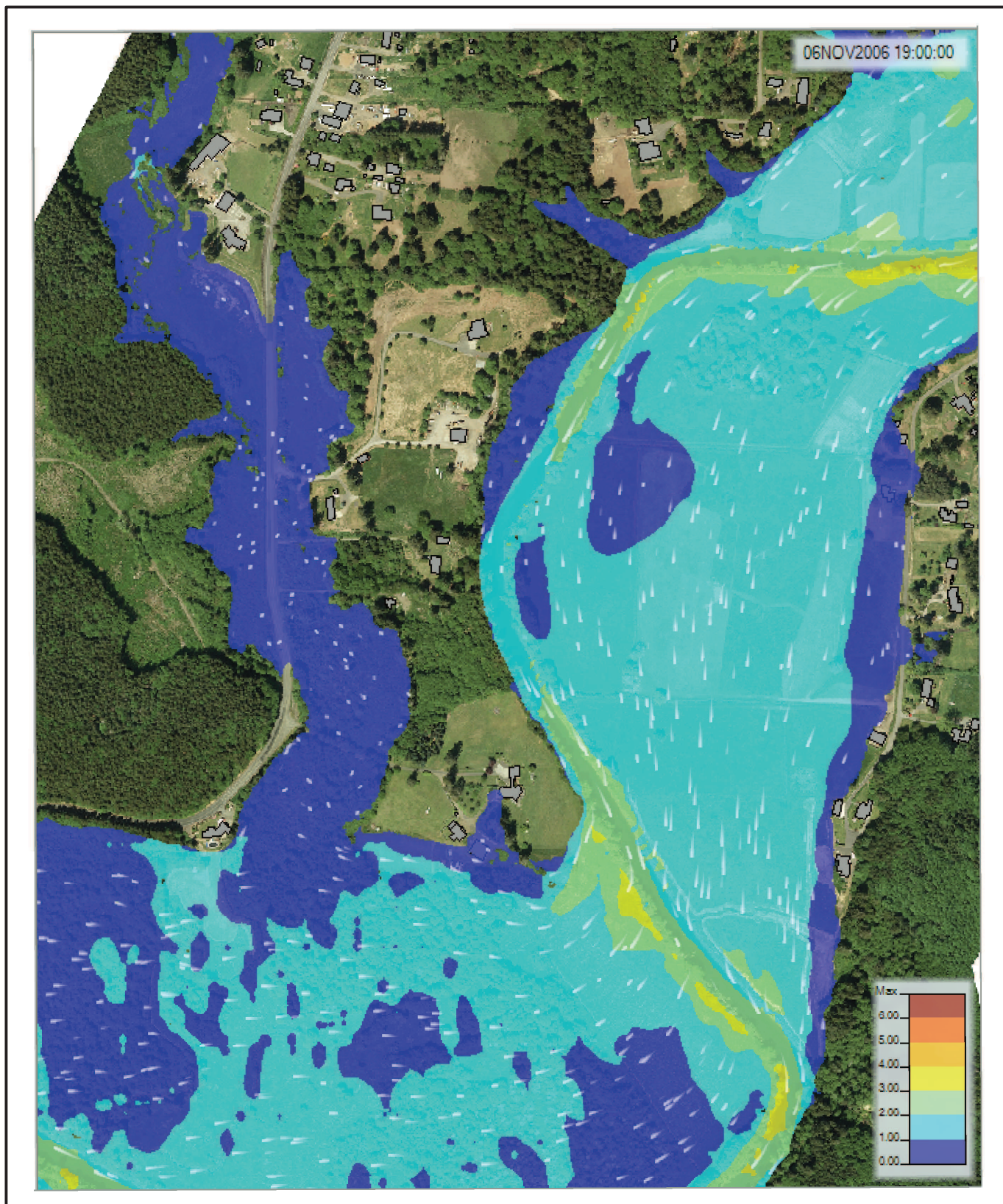
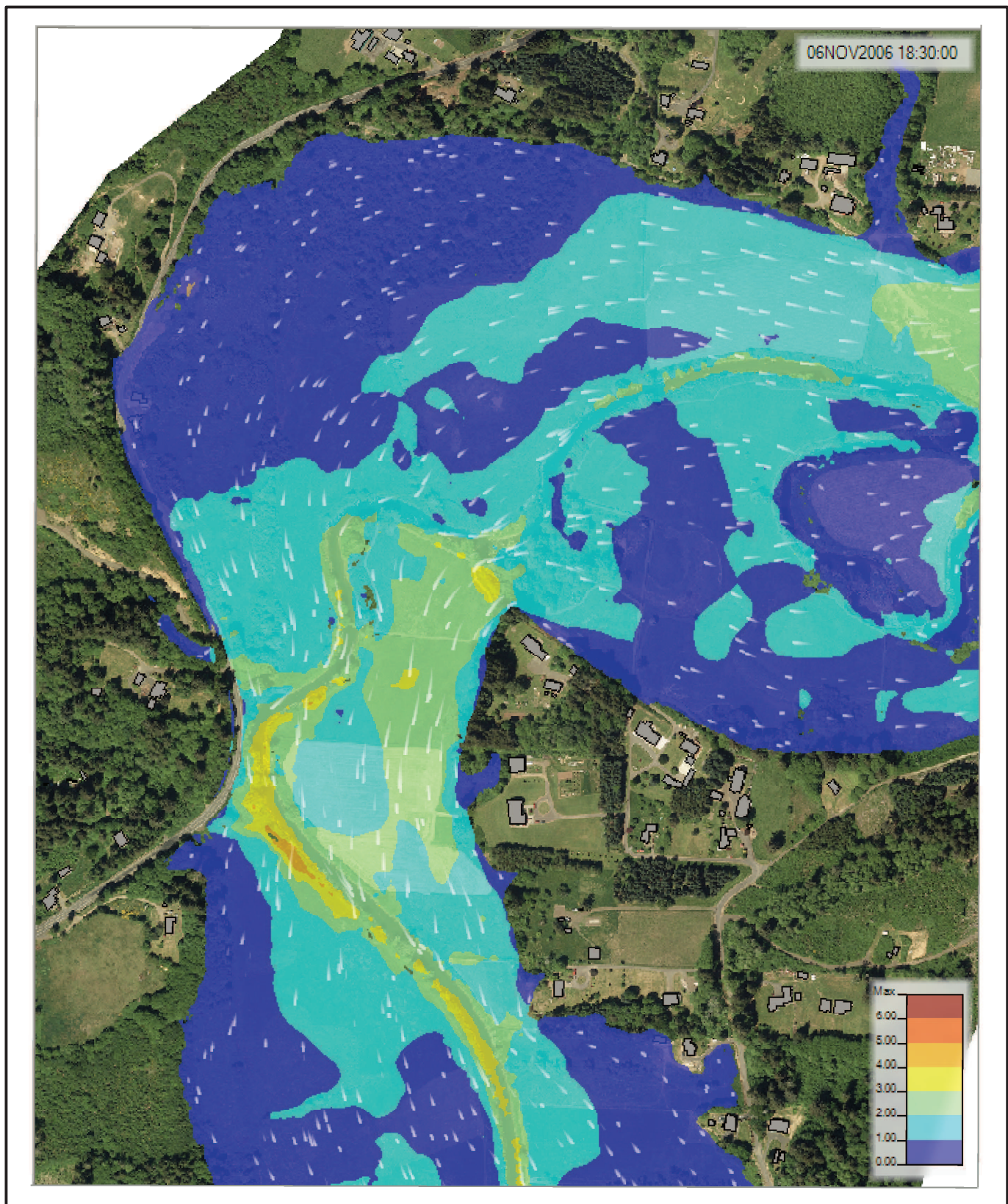


Figure 12



Grays Harbor County, WA



**Wishkah Road Comprehensive
Flood Study
100-year Flow with Mean Higher High Water
Maximum Velocity
Miller Hill**

0 300 600
Feet

Scale: 1:6,500
NAD 1983 HARN
StatePlane Washington
South FIPS 4602 Feet



17 May 2017



Figure 13

Appendix B1



**Wishkah Road Comprehensive Flood Study
Kick-Off Meeting/Open House
June 29, 2016, 6:00-8:00pm**

MEETING LOCATION:

The meeting was held at the Port of Grays Harbor Commission Room at 111 S. Wooding Street, Aberdeen, WA 98520.

ATTENDANCE

- Commissioner Frank Gordon
- Mike Zawislak
- Steve Gadwa
- Jane Lauzon
- Al Smith
- Tom Mayr
- John Wright
- Becky Dombrowsky
- Peggy Fouts
- Doug and Nancy Tikka
- Kyle Fritz from Cascade Natural Gas
- Nancy Perron
- Frank Kersh
- Perry Narreo
- Sebastian Rodriguez
- Marilyn Peters

Note – actual head count showed 18 attendees; two did not sign in.

Staff:

- Larry Karpack, Watershed Science & Engineering: Hydrologist/Engineer
- Mark Indrebo, Watershed Science & Engineering: Geologist/Geomorphologist
- Rob Wilson, Grays Harbor County: Assistant County Engineer
- Vicki Cummings, GHCOG: Executive Director
- Zana Dennis, GHCOG: Office Coordinator

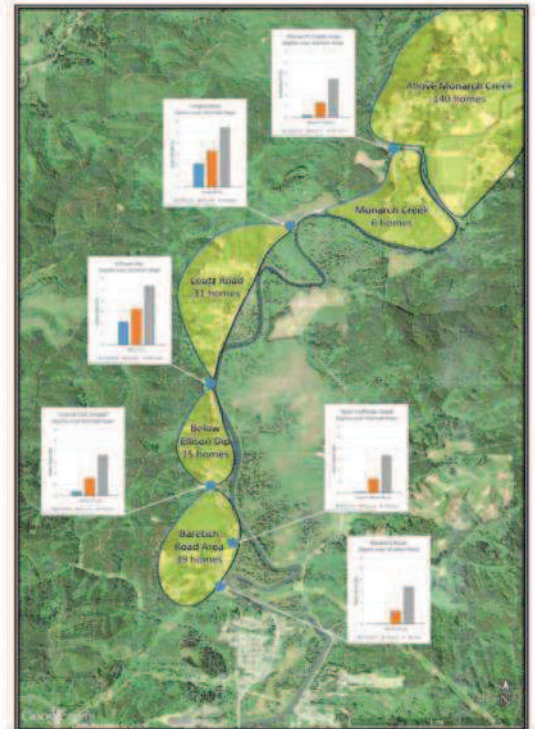
AGENDA

1. Welcome/Introductions
2. What is the Wishkah Road Comprehensive Flood Study?
3. How did the project originate?
4. Why do I need to be involved?
5. How can I participate?
6. Group discussion
7. Meeting wrap up/What's next?

385, pre-approved invitations (example below) were sent out on Friday June 3, 2016 to residents in the affected area as identified by WSE.



Anyone who resides in the Wishkah Road area is invited to participate. Your knowledge of area flooding is key to developing a successful project. Please join Grays Harbor County and the project team to learn more about the Wishkah Road Project and your role in its success.



Wishkah Road Flood Study Kick-Off Meeting: June 29, 2016, 6:00-8:00pm
Port of Grays Harbor, 111 S. Wooding, Aberdeen

Project website – <https://www.ezview.wa.gov/?alias=1937&pageid=36729>

PRESENTATION (PowerPoint)

➤ Project Team

- Watershed Science & Engineering - Project Management, Hydrology, Hydraulics & Geomorphology
- Grays Harbor Council of Governments - Public Involvement
- KPFF Consulting Engineers - Civil Design & Cost Estimating
- Confluence Environmental Company - Permitting
- Pacific Geomatic Services - Bathymetric Survey
- GeoTerra Mapping Group - LiDAR & Aerial Imaging
- PanGEO – Geotechnical Analysis

➤ Description:

Purpose of the project is to study the frequency, duration and extent of flooding on the Wishkah Road between M.P. 2.2 and M.P. 7.6 and identify cost effective flood hazard reduction alternatives for areas of frequent flooding, including, but not limited to, the following:

- Study Area #1 -- Baretich Flats (M.P. 2.2).
- Study Area #2 -- Ellison Dip (M.P. 3.8).
- Study Area #3 -- Long Swamp (M.P. 5.0).
- Study Area #4 -- Monarch Creek (M.P. 5.8).
- Study Area #5 -- Vienna Tracts (M.P. 7.6).

➤ The project will:

Part 1:

- Review and evaluate relevant previous studies, reports, and information.
- Implement a community awareness and engagement strategy that will include community meetings at critical junctures of the project, publically accessible website containing critical information documents, advertisement of key decisions and the schedule for such, etc.
- Determine baseline conditions flood elevation, depth, duration and frequency for various low points along Wishkah Road within the comprehensive study area.
- Identify, describe, and provide a preliminary evaluation of potential projects to reduce or eliminate Wishkah Road flood closures within the study area.

Part 2:

- Evaluate feasibility and adverse impacts/effects for the identified project alternatives.
- Provide detailed hydraulic modeling for project alternatives that appears to be feasible to estimate the benefits of each.
- Identify permits and regulatory requirements for each feasible alternative within the comprehensive study area.
- Identify property and easements needed for each feasible alternative within the comprehensive study area.
- Prepare preliminary plan, design and construction cost estimates for each feasible project within the comprehensive study area.
- Provide benefit/cost analysis for each feasible alternative within the comprehensive study area.

- Recommend for final design a project or set of projects to address flooding throughout the comprehensive study area.
 - Provide scope, schedule, and sequencing for final design and permits for the recommended project(s).
- Flood Hazard Reduction Benefits:
Project will benefit residents of Grays Harbor County, particularly those who reside or travel north of Aberdeen on the Wishkah Road, by exploring options to improve the passability of Wishkah Road.
- Project Process, Part 1; Assess Existing Conditions:
- Flooding History
 - Road Closures
 - Topographic (LiDAR)
 - Bathymetry (Channel Survey)
 - Hydrologic Modeling
 - River Flow
 - Tidal Influences
 - Hydraulic Modeling of Existing Conditions
 - Develop Alternatives
- Project Process, Part 2; Alternatives Analysis:
- Screen for Feasibility
 - Preliminary Designs
 - Additional Analysis
 - Hydraulic
 - Geotech
 - Others
 - Benefit/Cost Analysis
 - Preferred Alternative
 - Scope & Schedule for Final Design & Permitting
- Part 1 Timeline
Physical Data Gathering
- May-June 2016
- Historical Data
- June-September 2016
- Existing Conditions Assessment
- July-September 2016
- Alternatives Discussion Meeting
- October 2016
- Part 2 Timeline
Preliminary Designs & Permitting Strategies
- November 2016
- Additional Analyses
- March 2017
- Preferred Alternative
- April 2017

- Why do you need to be involved?
 - Your experience matters-We want to hear your story.
 - Share experiences & ideas.
 - Now is the time to speak up.
 - Share knowledge and refine study findings.
 - Contribute to recommendations.
- How do I participate?
 - Public Meetings
Next meeting in October 2016
 - EZ View website
www.ezview.wa.gov
Scroll down to Grays Harbor County –
Wishkah Road Comprehensive Flood Study Project
 - Call or E-mail WSE
206-521-3000 or mark@watershedse.com
 - Call or E-mail GHCOG
360-537-4386 or vcummings@ghcog.org
- Group Breakout
 - Where do you see most frequent flooding? Pictures?
 - How frequently does flooding effect you? Dates?
 - How significant is flooding to your every-day life?
 - What are your primary concerns with respect to flooding?
 - What do you think the County should consider?
 - What do you think would be a reasonable cost?
- Next Steps
 - Finalize survey (bathymetry & LiDAR)
 - Incorporate your input
 - Existing Conditions Analysis
 - Alternative Development
- Next Meeting
Alternatives Discussion
 - October, 2016

VERBAL COMMENTS

- At 2.2 to 2.7 for 47 years. When the road floods, the school bus stops at 2.2 & bus either drops kids & they wade thru to parent's high vehicles or kids are taken back to school.
- I live @ about 4.5 between the 2 ends of Leutz Rd on Wishkah Rd. In flooding I am isolated by 2.2 & additional mileposts to Long Swamp, which is impassable. Also impassable @ intersection of Leutz & Wishkah. Water is increasing each year. Leutz Rd. is flooding more each year. The Frequency of the flooding is twice daily w/ tides @ high tides and storms. Probably 16x a year parts of the road are impassable. In 2008 the flooding isolated my home for 6 full days before we could get to or from town. Many times the County Crew is too busy to put up

Road Closed signs due to so much County-wide impact. Nancy Perron 3419 Wishkah Rd. 533-0691.

- Live on the hill top by Baretich Road. Have lived in the area since 1983 and there have only been two occasions when I couldn't get out & get to town. Flood wall is not a good use of the money, raising the road would be effective and cheaper. Concerned that the flood wall project was based on safety so there is no cost/benefit ratio.
- Cascade Gas Company has problems as the flooding gets in the regulators and is the main feed for Aberdeen and Hoquiam. Plus they are not able to access leaks during floods, which is a huge hazard and cost lives/damage/infrastructure if it caused an explosion.
- Raised house to stop damage to house. Floods still damage cars and property.
- Floods are based on high tides and rainwater runoff.
- Flood events seem to be influenced by high rain or high tide events.
- Frustrated that the previous project when they put in a flood wall by Chehalis Basin was engineered and then the funding was moved to Mary's River, etc.
- Roads are sinking in many spots.
- Raising the roads may be the cheapest/easiest solution.
- Hand dug trenches from the 30's that were put in to disperse the flood waters are now filled with debris so the flooding is worse.
- Need to fix the culvert with the tide gate. The floods come in from behind.
- When it floods you can get to Baretich Rd when you can't get to Ellison or Long Swamp.
- There are several beaver dams in the area that are contributing to or causing the high water problem.
- Localized flooding is happening more frequently. It's because of all the beaver dams. The county needs to take of the beaver dams.
- Wishkah Road is an identified tsunami route. Fixing flooding on this route should be a high priority.

MAP COMMENTS

Please see attached MAP PDF.

WRITTEN COMMENTS

Becky Dombrowsky - 3011 Wishkah Road, Aberdeen

I just want someone to know the worst it got it went over my hip boots on the road in front of my house.

Note from Vicki Cummings – verbal comment associated with this: We raised the house six feet. The county said, just raise it to road height. My husband said no and raised it higher.

Marilyn Peters - 85 Leutz Road, Aberdeen

Floods every year can't get out both sides.

SUBMISSIONS

1 page of color photographs from Jane Lauzon at 64 Leutz Rd. Aberdeen.

ADJOURNMENT

The open house closed at approximately 8:00 the remaining attendees leaving by 8:13 p.m.

Legend

- Project Extents
- Major Streams
- Public Roads

Floods here now, never used to. High rain flood.

Floods here now
River usually
in rain flood

Luetz Rd.
Ellison 1990
3x trapped due to flood
No services/fire aid
Beavers are damming culverts.

Luetz Rd.
Ellison 1990
3x trapped due to flood
No services/fire aid
Beavers are damming culverts.

Flood water
Hills
Flooding
Beaver dams
Floods now frequent now

Flood water and racing 4x4's floats bridge & offsets.
3636 Wishkah Rd. for 40 yrs. Floods are more frequent
now and beaver dams are a factor.

Tidal Flood

Tidal Flood

Water in house 6.8"

Water in house
6.8"

Cascade moving
station to
other side of
River red dot

Cascade Natural Gas is moving
station to other side of river.
See red dot on map.

Grays Harbor County, WA

WISHKAH ROAD COMPREHENSIVE FLOOD STUDY PROJECT AREA

0 1,700 3,400 Feet



Legend

- Project Extents
- Major Streams
- Public Roads

Beaver Dams causing flooding.
Creek flooding 4 times per year.
Wyman Creek.

Beaver Dams
causing flooding
Creek flooding
4 times per
year

Perron Residence

Beaver Dams
causing flooding
Creek flooding
4 times per
year

Hay Swamp
Area
Road Risen
3ft

Hay Swamp Area
Road Risen 3ft.

Old Mink Farm
Luetz Rd.
Marilyn Peterson

Dec 2009
Highest water level.

Dec 2009
highest water level

3015 Wishkah flooded 4 times
Damage to vehicles.

3015 Wishkah
flooded 4 times
Damage to vehicles.

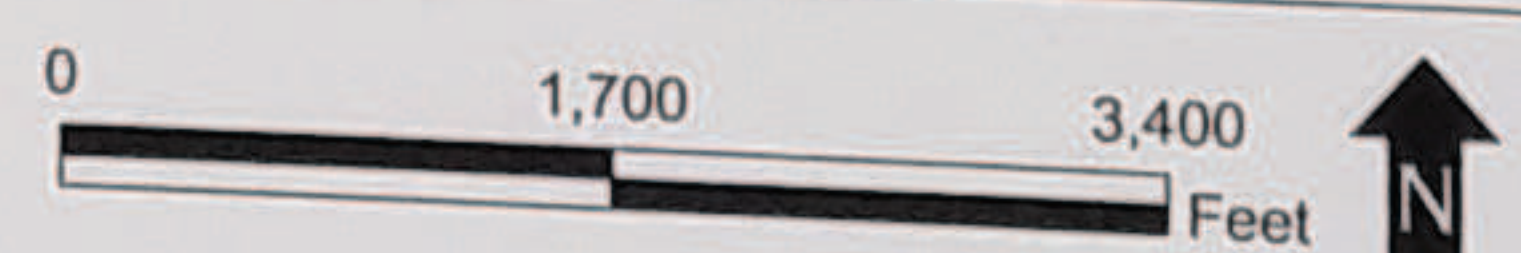
3015 Wishkah
flooded 4 times
Damage to vehicles.

Barefich & Wishkah Culvert
needs replaced / bridge?

Raised house due to floods.
Floods still come up to porch
and cause vehicle damage.

Grays Harbor County, WA

WISHKAH ROAD COMPREHENSIVE FLOOD STUDY PROJECT AREA



Wishkah Road Comprehensive

Flood Study

June 29, 2016 Open House

Comments

Name Becky Dombrowsky

Address 3011 Wishkah Rd

I just want someone to know
the worst it got it went
over my hip boots on the road
in front of my house

(Raised house 6 ft) (Council said to
Road height - He said No.)
husband (Vic. comment)

Wishkah Road Comprehensive

Flood Study

June 29, 2016 Open House

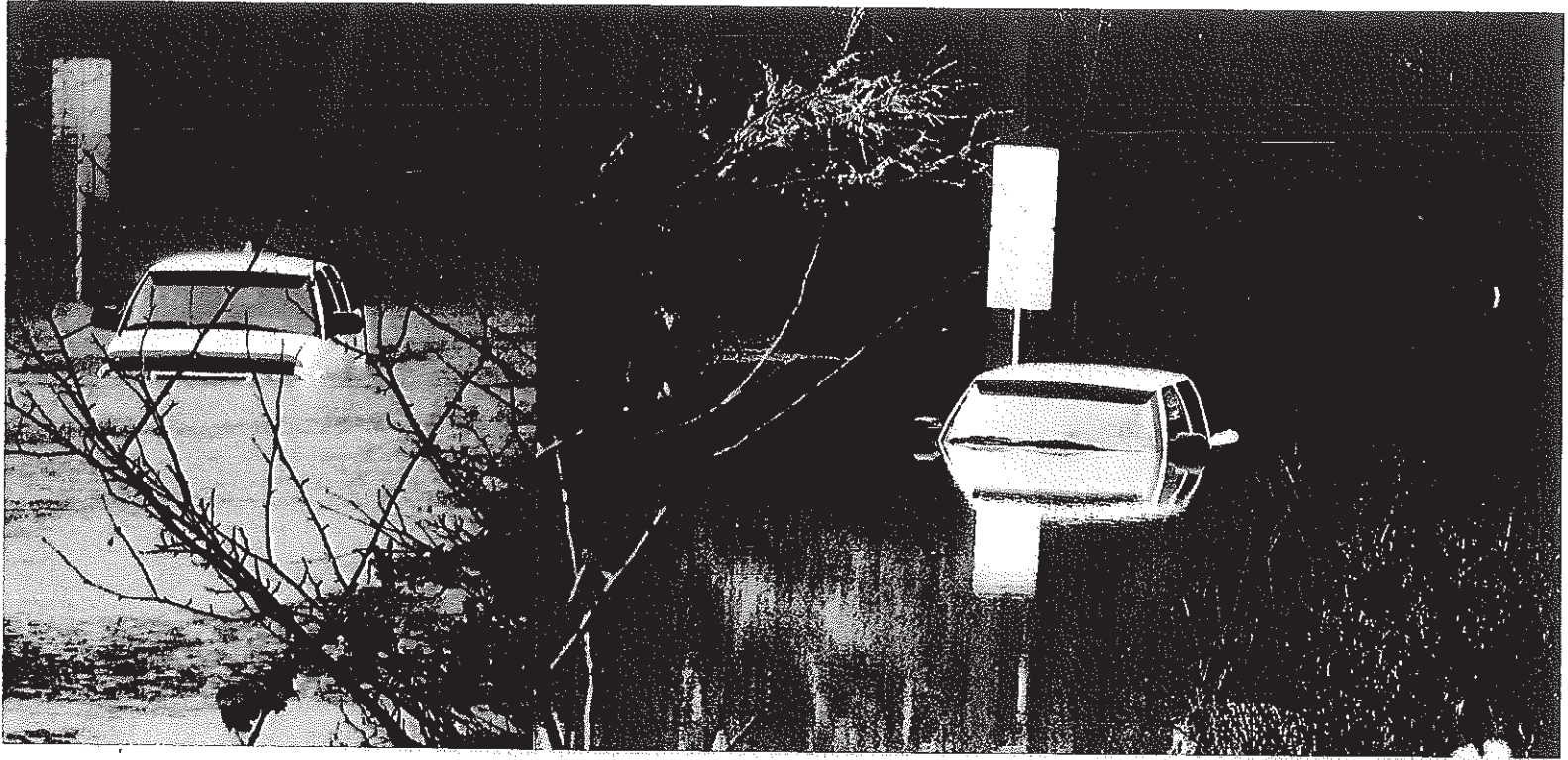
Comments

Name Marilyn Peters

Address 185 Leutz Rd. Ab.

98620

Floods every year
can't get out both
sides



THE DAILY WORLD

THURSDAY, NOVEMBER 24, 2009

YOUR SHOT



RAYMOND SMITH

A mailbox is nearly submerged on Wishkah Road on Wednesday after a stormy night on Tuesday. If you have a photo that helps show what life is like here on the Twin Harbors and you want to share it with the rest of the community, e-mail a high resolution version to photo@thedailyworld.com. Include your daytime phone number, the name of the photographer, a description of what's happening in the photo, when and where it was taken and the names of the people who are prominent in the shot.

1/7/09

Appendix B2



**Wishkah Road Comprehensive Flood Study
Open House
October 13, 2016, 6:00-8:00pm**

MEETING LOCATION:

The meeting was held at the Port of Grays Harbor Commission Room at 111 S. Wooding Street, Aberdeen, WA 98520.

ATTENDANCE (signed in)

- Commissioner Frank Gordon
- Mike Zawislak
- Jane Lauzon
- Tom Wright
- Becky Dombrowsky
- Nancy Perron
- Frank Kersh
- Don Lentz
- Brandon Answorth

Note – actual head count showed 14 non-project team attendees.

Staff:

Watershed Science and Engineering

- Larry Karpack, M.S., P.E., Hydrologist and Hydraulic Engineer
- Bob Elliot, M.S., P.E., Senior Hydraulic Modeling Specialist
- Mark Indrebo, M.S., L.G., Senior Geomorphologist

- Rob Wilson, Grays Harbor County: Assistant County Engineer
- Vicki Cummings, Grays Harbor Council of Governments: Executive Director

AGENDA

1. Welcome/Introductions
2. Kick-off meeting review
3. What activity has taken place since the kick-off meeting?
4. How can I help?
5. Meeting wrap up/What's next?

INVITATION

308, pre-approved invitations (example below) were sent out on Monday September 26, 2016 to residents in the affected area as identified by WSE.



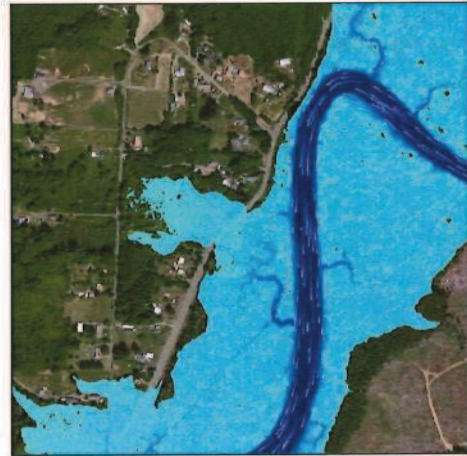
Wishkah Road Comprehensive Flood Study

Grays Harbor County has been funded by the Chehalis River Basin Flood Authority to identify cost-effective options to reduce or eliminate flooding along Wishkah Road between mile post (M.P.) 2.2 and M.P. 7.6.

Please join us to discuss work to date on the project, including:

- 1) Data gathered
 - a. LiDAR and bathymetric survey
 - b. Flood frequency analysis, including river flow and tide
- 2) Hydraulic model of existing conditions
- 3) Potential alternatives to consider

Anyone who resides in the Wishkah Road area is invited to participate. Your knowledge of area flooding is key to developing a successful project. Please join Grays Harbor County and the project team to learn more about the Wishkah Road Project and your role in its success.



Open House - Project Update & Alternates Discussion: **October 13, 2016, 6:00-8:00pm**
Port of Grays Harbor, 111 S. Wooding, Aberdeen

Project website – <https://www.ezview.wa.gov/?alias=1937&pageid=36729>

The Open House began at 6:07pm.

1. Welcome and Introductions

Vicki Cummings welcomed the audience and discussed safety and building layout. She introduced Larry Karpach who introduced members of the Watershed Science and Engineering team.

2. Kick-off meeting review

3. What activity has taken place since the kick-off meeting?

Both of the above items were addressed in the associated PowerPoint presentation.

PRESENTATION (PowerPoint) - Project Updates and Alternatives Discussion

➤ Study Purpose and Project Process Review

- Assess existing conditions
- Verify model
- Define flood reduction alternatives

➤ Alternatives Analysis

- Screen for Feasibility
- Preliminary Designs
- Additional Analysis
- Hydraulic Modeling
- Geotechnical
- Other Considerations
- Benefit/Cost Analysis
- Preferred Alternative
- Scope & Schedule for Final Design & Permitting

➤ Hydrology

- Calibration events
 - January 9, 2015
 - December 8, 2015
- River flow and tide combinations
 - 10-year flow; 10-year tide
 - 2-year flow; 100-year tide
 - 100-year flow; 2-year tide
 - 2-year tide; low flow
 - Low tide; 2-year flow

➤ Model Extent and Project Area

Depicted calibration events, candidate 200-year events, candidate 100-year events, candidate 20-year events and candidate 2-year events at:

- Baretich Road
- Frosty Way
- Hoffman Road
- End of CHE Model
- Ellison Dip
- Long Swamp
- Monarch Creek
- Vienna Tracts

Water depth and water surface elevation for Vienna Tracts, Monarch Creek, Long Swamp, Ellison Dip and Baretich Road were also discussed. WSE displayed the model output interactively with the audience exploring different areas and flooding events as the discussion progressed.

➤ Tidal Data

Event-Elevation-Duration Data for Simulated Tide Record at Aberdeen

- Wishkah River Flow Quantiles
- Aberdeen Tide Quantiles (actual not predicted tides)

➤ Alternatives

- Raise Road
 - Fill

- Pilings

➤ Alternatives (continued)

- Improve culverts/bridges
- Levee
- Floodwall
- Relocate road
- Non-traditional
 - Helicopter pad(s)
 - Hovercraft/Amphibious Vehicle
- ?? Other

Larry Karpack explained that each site may have different set of alternatives.

4. How can I help?

After an in-depth presentation and explanation of depicted calibration events and tidal data, the project team asked participants for their feedback on the information. Larry Karpack carefully explained the difference between flow and tidal events. He asked the audience if they felt the data presented was what they actually experienced during flood events.

Members of the audience suggested the frequency of the tidal events were not accurate. They commented that the flooding was happening more frequently than represented. It was suggested that gages should be installed at various locations where landowners could mark/date high water marks.

VERBAL COMMENTS:

- Take care of flooding issues at Long Swamp, Baretich Flats and Ellison Dip and that will take care of the flooding issues on Wishkah Road.
- Miller Hill is the area referred to as the bus turn around.
- Several audience members confirmed that the December 2015 flood event caused 1 to 1 ½ feet of water over the roadway.
- Tom Wright shared pictures of the December 2015 event with the project team.
- In the Aberdeen Gardens area the water was 4 ft. deeper in the 2015 event than in the 2007 event.
- During the December 2015 flood the water was 4 to 5ft. over the road in the Long Swamp area not 2ft.
- Is this study going to influence the project on Baretich Road? Larry Karpack answered that some of the data and information from this process is being used to assist with the design of the project at Baretich Road.
- Audience members questioned the data showing that flood waters at Ellison were deeper than at Baretich flats.
- Why is this being studied again and more money is being spent? Larry Karpack answered the other project (Wishkah Road Flood Levee Project) is a site specific project and didn't take into account all of the other flood locations along Wishkah Road.

- There used to be two culverts at Baretich Road and now there is only one. There must be about 60 log trucks a day using Wishkah Road. That's a lot of weight on the road.

5. **Meeting Wrap Up/What's Next?**

- **Preliminary Designs & Permitting Strategies**
November -December 2016
- **Additional Analyses**
January –April 2017
- **Preferred Alternative**
May 2017
- **Next Steps**
 - Select alternatives that warrant preliminary designs
 - Identify and carry out necessary analyses to assess alternatives
- **Next Meeting**
 - Present Results & Choose Preferred Alternative
 - April, 2016

For more information:

- EZ View website
www.ezview.wa.gov
Scroll down to Grays Harbor County –
Wishkah Road Comprehensive Flood Study Project
- Call or E-mail WSE
206-521-3000 or mark@watershedse.com
- Call or E-mail GHCOG
360-537-4386 or vcummings@ghcog.org

WRITTEN COMMENTS

None

ADJOURNMENT

The open house closed at approximately 7:50 the remaining attendees leaving by 8:05 p.m.

Appendix B3



Wishkah Road Comprehensive Flood Study Open House May 3, 2017, 6:00-8:00pm

MEETING LOCATION:

The meeting was held at Robert Gray Elementary School, 1516 N. B Street, Aberdeen WA, 98520.

ATTENDANCE (signed in)

- Al Smith
- Perry Norres
- Dustin Johnson
- Brenda Johnson
- Roy Coady
- Brandon Ainsworth
- Loren & Gayle Wade
- Michael Zawislak Sr.
- Frank Gordon
- Rep. Brian Blake
- Ed & Anna Patuck
- Dan Wood
- Jane Lauzon
- Debra Olson-Rios
- Becky Olson-Queen
- Mike Lentz
- Vicki Lentz
- Keith & Peggy Fouts
- Mark Stensager
- Rep. Steve Tharinger
- Jeanette Johnson
- Carey Baltzell
- Marilyn Peters
- Aaron Hendricks
- DeeAnne Shaw
- Nancy Perron
- Brandon Carman

Note – actual head count showed 39 non-project team attendees.

Project Team:

Grays Harbor County

- Vickie Raines, Grays Harbor County Commissioner
- Rob Wilson, Grays Harbor County: County Engineer

Watershed Science and Engineering

- Larry Karpack, M.S., P.E., Hydrologist and Hydraulic Engineer
- Mark Indrebo, M.S., L.G., Senior Geomorphologist

Grays Harbor Council of Governments

- Vicki Cummings, Executive Director

AGENDA

1. Welcome/Introductions
2. Project Update
3. Open Discussion
4. Meeting wrap up/What's next?

INVITATION

298, pre-approved invitations (example below) were sent out on April 11, 2017 to residents in the affected area as identified by WS&E.



Wishkah Road Comprehensive Flood Study

Grays Harbor County has been funded by the Chehalis River Basin Flood Authority to identify cost-effective options to reduce or eliminate flooding along Wishkah Road between mile post (M.P.) 2.2 and M.P. 7.6.

Please join Grays Harbor County and the project team to discuss work to date on the project, including:

1. Road closures and impacts
2. Alternatives considered
3. Benefit/Cost of potential actions

If you are affected by flooding along Wishkah Road we welcome your participation at this meeting to discuss the flooding issues and look at potential solutions.



Photo courtesy of Keith and Peggy Fouts, 2009

Open House - Project Alternatives Benefit/Cost Discussion:

**May 3, 2017, 6:00-8:00pm
Robert Gray Elementary
1516 N B Street**

Project website – <https://www.ezview.wa.gov/?alias=1937&pageid=36729>

The Open House began at 6:10pm.

1. Welcome and Introductions

Commissioner Vickie Raines welcomed the attendees and discussed building safety and housekeeping. She introduced Representative Brian Blake and Representative Steve Tharinger and thanked them for coming, then introduced the project team.

2. Project Update

Larry Karpack gave a brief review of items discussed at the previous Open Houses on June 29, 2016 and October 13, 2016. He discussed information that was collected at various points along the Wishkah River and addressed how that information was used to verify the hydraulic modeling. He reminded attendees that the focus of this study project was to characterize existing flooding conditions, gain an understanding of the magnitude and duration of flooding, and identify any cost effective measures that could be taken to address the flooding.

PRESENTATION (PowerPoint) - Project Update Impacts, Benefits, and Feasibility

Study Purpose

- Funded by Chehalis River Basin Flood Authority
- Reach Scale Assessment MP 2.2 to MP 7.6
- Reduce or Eliminate Flooding
- Cost Effective
- Separate from Floodwall project

Project Process: Part 1 -Recap

- Assess Existing Conditions
 - Hydraulic Modeling of Existing Conditions
 - *Topographic (LiDAR) Data*
 - *Bathymetry (Channel Survey)*
 - *Hydrologic Analysis*
 - Verify Model

Calibration

Models calibrated to three recent flood events; January 5, 2015, December 9, 2015, and January 7, 2009.

Project Process: Part 2

- Assess Flood Impacts
 - Closure Frequency & Duration
 - Closure Costs
- Identify Conceptual Alternatives & Costs
- Screen for Feasibility
 - Benefit & Costs
- Next Steps

Road Flooding Information

- Length & depth of flooding
- Guides project alternatives

Flood Simulation Statistics

- Frequency, depth and duration of flooding
- Broken down by event
- Used to extrapolate average annual closure time

Average Annual Closure Time

- Calculated annual closure time expected for each event we modeled
- Used worst-case for each recurrence interval calculation
- Used calculus (integral) to add up total closure time for modeled events plus all the events in between

Cost of Closures

- Calculated for 50 years
- Used same unit cost as recent Chehalis River flooding studies
- Average annual closure time
- Hourly traffic volume
 - Cars vs trucks
- Trapped vs detoured
 - Trapped –time lost until road opens
 - Detoured –extra time and mileage
- Closure cost = Cost of time and mileage

Project Alternatives

- Workshop
 - WSE –Hydrology, Hydraulics, Geomorphology
 - KPFF Consulting Engineers –Civil Design
 - Confluence Environmental –Permitting & Mitigation

Alternatives

- Conceptual level
- Potential project features varied by site
- Sought least cost alternatives where possible including:
 - Raise road
 - Standard fill
 - Mechanically stabilized earth (MSE)
 - Floodwall
 - Improve culverts & bridges
 - Relocate road or emergency bypass route
- Permitting & mitigation costs considered

Cost to Correct

- ROM –Rough Order of Magnitude
- Some had considerable range

Benefits and Costs

Closure Site	Cost of closures*	Cost to correct (low estimate)	Cost to correct (high estimate)
<i>Baretich Road</i>	<i>\$150,000</i>	<i>\$3,300,000</i>	<i>\$5,300,000</i>
<i>MP 2.9</i>		<i>0</i>	<i>\$5,000</i>
<i>Above projects not included in reach-wide total below</i>			
Ellison Dip	\$322,000	\$1,250,000	\$1,800,000
Leutz Road	\$250,000	\$2,500,000	\$2,500,000
Long Swamp	\$500,000	\$2,250,000	\$12,000,000
Wyman Creek	\$163,100	\$1,350,000	\$1,350,000
Miller Hill	\$126,200	\$500,000	\$1,000,000
Total	\$670,000*	\$7,850,000	\$18,650,000
<p><i>*Note: Since closure times overlap (e.g. the road is closed at Ellison Dip for much of the time it is closed at Long Swamp) the total cost of closures in the project area is less than the sum of the individual site closures.</i></p>			

Summary sheets were not provided for Baretich Road or MP 2.9. The Baretich Road Flood Wall project is under way under a separate contract, and flooding near MP 2.9 is very minor and can likely be corrected with standard road maintenance activities.

Other Impacts

➤ Emergency Response

- Estimated average calls to 911 per residence per hour
 - *911 and census data*
 - *Police and Fire separately*
 - *Included all calls, not just those that generated a response*
- Counted Residences –in project area and upstream
- Multiplied calls per hour times hours road is closed
- Summed potentially disrupted calls over 50 years life of project
 - Police –55 calls affected over 50 years –out of 46,000 total calls
 - Fire –9 calls affected over 50 years –out of 7,300 total calls

{End PowerPoint Presentation}

A document summarizing the flood areas and the potential project descriptions was distributed. This included the following sites:

- Study Area #1 – Ellison Dip (M.P. 3.8)
- Study Area #2 – Near Leutz Road (M.P. 4.0 & 4.4)
- Study Area #3 – Long Swamp (M.P. 4.6 – 5.3)
- Study Area #4 – Wyman Creek (M.P. 5.8)
- Study Area #5 – Miller Hill (M.P. 7.5)

These site summary descriptions included flooding data for the 100-year, 10-year, and 2-year flood events, and provided information pertinent to each location including:

- Road flooding information
- Cost of road closures
- Estimated cost to correct
- Flood observations
- Flood simulation statistics, and
- Potential project alternatives including description and range of costs.

At each of these locations the study team assessed flood impacts such as the frequency and duration of road closures and the associated cost, identified conceptual alternatives and costs, and screened the alternatives for feasibility. This process revealed that the Estimated Total Cost for all events at all locations over the 50-year lifecycle amounted to \$670,000. The low end estimated cost for potential corrective measures at all locations upstream of Baretich Road over the 50-year lifecycle was estimated at \$7,850,000. The estimated high end cost was \$18,650,000.

3. Open Discussion

During the open discussion period several of the attendees voiced their concerns about impacts the potential project alternatives could have on their individual properties if implemented. Specifically, any alternative they felt would “push” the flood waters onto their property. Larry pointed out that no project alternatives were currently being proposed since the cost of projects was so high relative to the potential flood reduction benefit.

It was asked if the North Shore Dike was taken into consideration in the evaluation of the proposed projects. Larry explained that since no projects were being designed as part of this study there was nothing to evaluate in terms of cumulative impacts. Audience members were concerned the dike would force the water upriver and make the flooding in their area worse. Larry explained how the presence of the dike would generally not have the effect of pushing water upriver and that potential impacts of the North Shore levee would be evaluated in that project (which is entirely separate from this study).

There was discussion about datum elevations referring to FEMA, NAVD, City of Aberdeen data and LiDAR data all being different.

Someone asked if WSE looked at the flood areas from an earthquake/evacuation route point of view. Larry noted once again that since no projects were being designed at this time there was no evaluation of the effect of earthquakes on the flooding sites. It was noted that the Baretich Road project is moving forward; they are driving sheet pile to form a flood wall. Representative Tharinger noted that the sheet pile would help to stabilize that segment of the road during a quake.

In closing Larry told attendees the objective of this project was to characterize flooding problems and evaluate feasible solutions. Since no economically viable alternatives were found, there was no detailed design or evaluation of large scale capital projects.

Commissioner Raines addressed the audience saying that based on the 50-year lifecycle cost it doesn't make sense to put millions of dollars into funding potential fixes. The flooding is not from the Chehalis River so funds through the Chehalis River Basin Flood Authority won't be available. The North Shore Dike will help with flooding and with insurance rates in the City of Aberdeen. Commissioner Raines noted that the County would look into other measures that could be taken to reduce flood impacts to residents along the Wishkah Road.

4. Meeting Wrap Up/What's Next?

Commissioner Raines thanked Larry and Mark for their due diligence and pulling all of the information together in an understandable way so decisions could be made. She asked those in attendance if there was anything that should be brought up that hasn't already been discussed; anything that everyone should be aware of.

Public comments included:

- FEMA mapping for the Wishkah River is very inaccurate.
 - Larry responded that FEMA approximate studies, like the Wishkah River upstream of Aberdeen, are often highly inaccurate. FEMA attempts to go back and fix these studies but has not been able to update all of these studies in a timely manner.
- We need a flood gauge on the Wishkah.
 - Rob responded that the County recently installed a gage near Baretich Road but the data are not telemetered so it can only be read manually
 - Commissioner Raines responded the Flood Authority has a website that has a gauge system for the entire basin so you can see the water levels coming in. Be sure to check that site.
 - Commissioner Raines also said that the County could evaluate getting additional water level gaging on the Wishkah River
- We need better information on when the river will flood.
 - Commissioner Raines said that the Flood Authority has information on flood and rainfall forecasts on their website.
 - Larry indicated that it might be possible to use the modeling from this study to develop a flood warning system for the Wishkah
- Access for emergency responders was the primary reason for looking at improvements to Wishkah Road.
 - Commissioner Raines indicated that she was aware of the project history, and reiterated that County funding is limited and needs to be spent responsibly
 - Rob indicated there other potential projects in the County could have more benefit to public safety.
- Representative Tharinger suggested that potential future lawsuits over fish passage at culverts could provide an impetus for road improvements.

- One resident asked “Near Baretich Road where does the water go if it can’t go through the culverts under Wishkah Road? The water comes up but can’t go over the road and is trapped there. “
 - Rob noted that the specific reason for this project was to seek ways to keep the Wishkah Road open for emergency vehicle access. The current project was not intended to eliminate flooding of private property.
- A resident noted that there is a gravel road that goes from near Baretich Road to near the Turner Bridge that can be used during an emergency.

Commissioner Raines closed the open house by inviting anyone with concerns or comments to contact her directly saying, “The County will come out and look at the issue and discuss it with the landowner”.

WRITTEN COMMENTS

None

ADJOURNMENT

The open house closed at approximately 7:35 with the remaining attendees leaving by 8:00 p.m.

For more information:

- EZ View website
www.ezview.wa.gov
Scroll down to Grays Harbor County –
Wishkah Road Comprehensive Flood Study Project
- Call or E-mail WSE
206-521-3000 or mark@watershedse.com
- Call or E-mail GHCOG
360-537-4386 or vcummings@ghcog.org

Appendix C

Memorandum

To: File

From: Mark Indrebo, Watershed Science & Engineering

Date: May 26, 2017

Re: Potential benefit of Wishkah Road improvements

As part of the Wishkah Road Comprehensive Flood Study, WSE is tasked with assessing flood reduction alternatives for their benefit/cost ratio. As a first step, determining the potential benefit of reducing flooding on Wishkah Road will provide guidance on the range of actions to be consider.

To determine the potential benefit of reducing flooding on Wishkah Road, WSE assessed the economic impact of road closures under the present condition. For the purpose of this analysis, it is assumed that the road is closed at each location when the water level at that location is at or above the lowest point in the road (except at Miller Hill, where the road is assumed closed when the water level is at the lowest point along the centerline of the road). Using a 2D hydraulic model created for this project, WSE identified locations along Wishkah Road that were impacted by flooding, and assessed the length of time that the road would be closed for the 2-year, 10-year, and 100-year event. Flooding along Wishkah Road is caused by both tidal events and river flow events, and selected combinations of flow and tide were examined for each event at each location (see hydraulic summary table) and the combination with the maximum road impact time was used as the closure time for each location and event. Near Baretich Road, there are four places where water overtops the roadway; the longest impact is considered the closure time.

For each location, the duration of the closure time for each event was multiplied by the annual probability of that event to determine the expected annual impact. As an example, an event that happens once every 10 years has an annual probability of 0.1. If that event closes the road for 20 hours, then the average annual closure time for that event would be $20 \times 0.1 = 2$ hours. The total expected annual closure at each location is the sum of the expected closure time for all flood events. This was determined by plotting the expected annual closure for the 2-year, 10-year and 100-year events, finding a best-fit curve for each plot in Microsoft Excel, and calculating the integral of that curve. Expected annual closures at each location are shown in Table 1 below.

Table 1 - Closure times derived from 2D hydraulic model

Location	Expected annual closure (hr)
Baretich Road ¹	3.7
Ellison Dip	6.8
Leutz Road	8.5
Long Swamp	10.5
Wyman Creek	3.4
Miller Hill	3.1
¹ Includes 4 closure locations in vicinity	

To assess the economic impact of these closures, WSE used the following process:

- 1) Determine the number of vehicles (cars and trucks) impacted by closures at each location. This was done using daily traffic load data gathered by the County at various locations on Wishkah Road since 2000. Daily traffic was divided by 24 to determine the average hourly traffic load at each location. Average hourly traffic loads are multiplied by the closure times at each location to determine the number of vehicles impacted.
- 2) Estimate the likely response to closures. In general, it is assumed that people will detour around the closure whenever possible. In some locations, however, residences are isolated by floodwater in both directions, making a detour impossible. In those cases it is assumed trips are delayed until one route is open.
- 3) Calculate the cost (in terms of both time and mileage) of the closures. For trips involving a detour, it is assumed that the detour is through Montesano. The detour time and mileage is estimated using Google Maps drive times from Baretich Road to 3rd Avenue and subtracting the difference between a direct path via Wishkah Road and one routed through Montesano via Wynochee-Wishkah Road. Average delay times are calculated as $\frac{1}{2}$ the closure time. Cost per vehicle is multiplied by the number of vehicles impacted.

Traffic data included information from four locations relevant to the project: Bench Drive, Ellison Dip, Wyman Creek, and Turner Bridge, and indicated the percentage of overall traffic that consisted of trucks. Total daily traffic counts were converted to average hourly car and truck traffic at each location. See Table 2 below.

Table 2 - Traffic counts from County data gathered since 2000

Traffic Summary				
	Turner Bridge	Wyman Creek	Ellison Dip	Bench Drive
Average Cars/hr	38.9	53.4	68.3	73.3
Average Trucks/hr	11.6	14.2	6.8	11.9

To estimate the response to closures (i.e. whether the trip is delayed or detoured) it is important to know where the traffic is generated. Traffic counted at Turner Bridge is assumed to be vehicles going to or coming from properties upstream of Turner Bridge, and therefore generated upstream of Turner Bridge. For other areas, the traffic generated in each area is the difference between the downstream and upstream traffic counts. For example, the traffic generated between Ellison Dip and Wyman Creek is the difference between the traffic counts at Ellison Dip and Wyman Creek.

In some cases, flooding locations do not match traffic count locations, but are similar. The Miller Hill closure location is about $\frac{3}{4}$ of a mile south of the Turner Bridge. However, there are fewer than 10 residential properties between Miller Hill and Turner Bridge, so we assume that the traffic generated in that segment is primarily generated between Wyman Creek and Miller Hill, and therefore unable to travel north when Miller Hill is flooded. This may tend to slightly overestimate flood impacts. Similarly,

no traffic data is available for Baretich Road, but we assume that most of the traffic at Bench Road is generated in the Baretich Road vicinity. Again, this may tend to overestimate potential impacts.

Traffic generated upstream of Tuner Bridge is assumed to detour in all cases, since the detour route is always open. Traffic generated between Turner Bridge and Wyman Creek (Miller Hill) is trapped by flooding at two locations – Long Swamp and Miller Hill. When both routes are closed, traffic is delayed. When Miller Hill opens, traffic can detour. Between Ellison Dip and Wyman Creek, traffic is trapped between Long Swamp and Ellison Dip. However, Ellison Dip is only closed for 5.9 hours, allowing traffic to resumes its normal course once Ellison Dip opens, even though Long Swamp is still closed. Finally, between Ellison Dip and Baretich Road, traffic is trapped between the two locations until Baretich Road opens.

Table 3 summarize the traffic generated at each location as well as the expected response at each location.

Table 3 - Traffic generated in each area

Traffic Generated				
	Above Turner Bridge	Turner Bridge to Wyman Creek	Wyman Creek to Ellison Dip	Ellison Dip to Bench Drive
Average Cars/hr	38.9	14.5	14.9	17
Response	All detour	Delay until Detour Route open	Delay until primary route open	Delay until primary route open

Costs for each detour/delay were determined using the same hourly and mileage hours used in similar economic analyses in the region (Hallenbeck, 2014). See Table 5

Table 4 - Cost for delay and mileage

Costs (after Hallenbeck, 2014)	Per Hour	Per Mile
Car - Local	\$12.00	\$0.21
Trucks	\$24.70	\$1.10

Using this, the total annual cost of closures was calculated by multiplying the cost per vehicle times the number of vehicles impacted per year. The net present value of the annual cost over a 50 year life-span for a typical project was calculated using an average inflation rate of 1.5%, derived from the Washington Department of Ecology guidance being used in the ongoing Chehalis Basin studies (ESS, 2016). Table 5 summarizes these calculations:

Table 5 - Summary of Damage Calculations

Damage Summary	
Above Turner Bridge/Miller Hill	
Cars Impacted/hr	38.9
Time Primary Route Closed (hr)	10.5
Total Cars Detoured	408.5
Delay Time per Detour (hr)	0.7
Mileage per Detour	27.0
Cost/Detour (Time + Mileage)	\$13.47
Total Annual Cost - Above Turner/Miller	\$5,502.09
Wyman to Turner Bridge/Miller Hill	
Cars Impacted/hr	14.5
Time Primary & Alt Routes Closed (hr)	3.1
Time Primary Route Only Closed (hr)	7.4
Total Cars Trapped (Prim & Alt Routes Closed)	44.6
Total Cars Detoured (Primary Only Closed)	107.9
Delay Time per Trap (hr)	1.5
Delay Time per Detour (hr)	0.7
Mileage per Detour	27.0
Cost/Trap (Time cost)	\$18.44
Cost/Detour (Time + Mileage)	\$13.47
Total Annual Cost - Wyman to Turner/Miller	\$2,276.82
Ellison Dip to Wyman Creek	
Cars Impacted/hr	14.9
Time Primary & Alt Routes Closed (hr)	6.8
Time Primary Route Only Closed (hr)	0.0
Total Cars Trapped (Prim & Alt Routes Closed)	101.2
Total Cars Detoured (Primary Only Closed)	0.0
Delay Time per Trap (hr)	3.4
Delay Time per Detour (hr)	0.7
Mileage per Detour	27.0
Cost/Trap (Time cost)	\$40.78
Cost/Detour (Time + Mileage)	\$13.47
Total Annual Cost - Ellison to Wyman	\$4,127.77
Baretich/Bench Road to Ellison Dip	
Cars Impacted/hr	5.0
Time Primary & Alt Routes Closed (hr)	3.7
Total Cars Trapped	18.5
Delay Time per Trap (hr)	1.8
Cost/Trap (Time cost)	\$22.07
Total Annual Cost - Baretich/Bench to Ellison	\$409.00
Trucks	
Trucks Impacted/hr	14.2
Time Detoured (hr) (Assume all)	10.5
Total Trucks Detoured	149.1
Delay Time per Detour (hr)	0.7
Mileage per Detour	27.0
Cost/Detour (Time + Mileage)	\$45.76
Total Annual Cost - Trucks	\$6,823.77
Total Cost Per Year (All Locations; Cars & Trucks)	\$19,139
Net Present Value - Annual Cost Over Life of Potential Project (50 years)	(\$669,874.68)

Another important factor to consider is the interruption in emergency services caused by road closures. To estimate this, data from the 911 call center for Grays Harbor County was used in conjunction with US Census data to determine the number of emergency calls (broken down between police and fire) that can be expected to be delayed during road closures. To simplify this estimate, it is assumed that 1) all 911 calls lead to a dispatch, and 2) that a dispatch is delayed in the project area whenever there is any closure on the corridor. Both of these simplifications will overestimate the impact of closures. In a typical year, this methodology indicates that 0.6 police calls and 0.09 fire department calls will be delayed. Over the 50 year life of an expected project, approximately 30 police calls and 5 fire department calls are expected to be delayed. Table 6 summarizes these results:

Table 6 - Emergency Response data

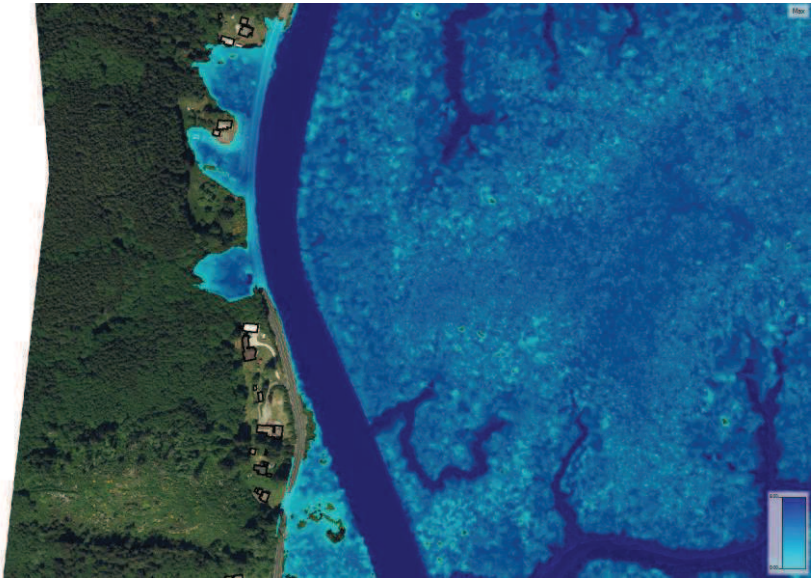
Emergency Services Potential Impact	
Total residences impacted (est.)	330.0
Hours Impacted (Max)	10.5
Police	
Avg Calls/Hour/Residence	0.000318
Calls per hour in impacted area	0.1049
Calls expected during closure	1.1021
Calls delayed over 50 year	55.1
Fire	
Avg Calls/Hour/Residence	0.000051
Calls per hour in impacted area	0.0167
Calls expected during closure	0.1756
Calls delayed over 50 year	8.8

Appendix D

Study Area #1 – Ellison Dip (M.P. 3.8)

Includes two potential flood locations

Road Flooding Information: Length of Road Flooded in 100-year Flood –1,200 feet Maximum depth – 4.9 feet	Cost of Road Closures¹: \$322,000	Est. Cost to Correct: \$1,250,000 to \$1,800,000+
¹ Estimated net present value of cost of road flooding over a 50-year life cycle (assuming this was the only location of Wishkah Road flooding)		



Flood Observations: Minimum Road Elevation: 10.8 feet January 2015 Water Level: 12.8 feet December 2015 Water Level: 13.0 feet January 2009 Water Level: 15.2 feet	Flood Simulation Statistics:		
	100-year Event Max Level: 16.0 feet Duration: 36 Hours	10-year Event Max Level: 14.0 feet Duration: 18.5 Hours	2-year Event Max Level: 11.9 feet Duration: 5.8 Hours

Potential Project Alternatives

Flood reduction alternatives considered for this location include:

1. A floodwall along the east side of Wishkah Road,
2. Relocating Wishkah Road farther to the west at a higher elevation, or
3. Raising the road using walls and light-weight fill

A preliminary estimate for construction of a floodwall can be obtained from the estimated cost of the Baretich Road flood wall which is expected to cost about \$2,000 per lineal foot. Assuming the floodwall at this location would need to be 1,200 feet long the estimated cost would be \$2,400,000, plus costs for design, environmental documentation, and permitting. Additional costs would be incurred if there are wetland impacts and associated mitigation, culvert replacements, or property acquisition associated with the project.

A second option considered at this location would be to construct a new road to the west, either in front of or behind the existing homes. The new road would need to be elevated above the 100-year flood (estimated elevation 15.6 feet NAVD) and would need to be up to 1/3 of a mile long. To construct a new road would require easements or property acquisition which could be very expensive. There would also likely be significant permitting effort as it appears that there may be wetland and/or stream channel impacts. It is estimated that permitting costs for a realigned road could be as high as \$100,000 and mitigation and monitoring costs could easily exceed \$100,000, depending on the extend of impact. The existing Wishkah Road would also need to be removed as mitigation, and additional mitigation may also be required. Overall a new road alignment at this location is expected to cost at least \$1,800,000.

The third option would include raising the roadway within the current roadway prism. To accomplish this, mechanically stabilized earth (MSE) retaining walls on either side of the roadway would be installed and light-weight fill placed between the walls. Most of the soils in the Wishkah River Flood plain are soft and likely cannot support the necessary fill to raise the roadway. Walls, light-weight fill and a new pavement surface would likely cost between \$850 and \$1,250 per lineal foot of roadway, for an estimated range in costs for this option of \$1,000,000 - \$1,500,000.

These costs do not include design, permitting and other soft costs. A 25% contingency should be added to cover such costs and current project unknowns, putting the range at \$1,250,000 to \$1,800,000. Additional costs would be incurred if there are wetland impacts and associated mitigation, culvert replacements, or property acquisition associated with the project.

Study Area #2 – Near Leutz Road (M.P. 4.0 and 4.4)

Includes two potential flood locations (not included in original project scope)

Road Flooding Information:

Length of Road Flooded in 100-year Flood – 1,200 feet
Maximum depth – 5.6 feet

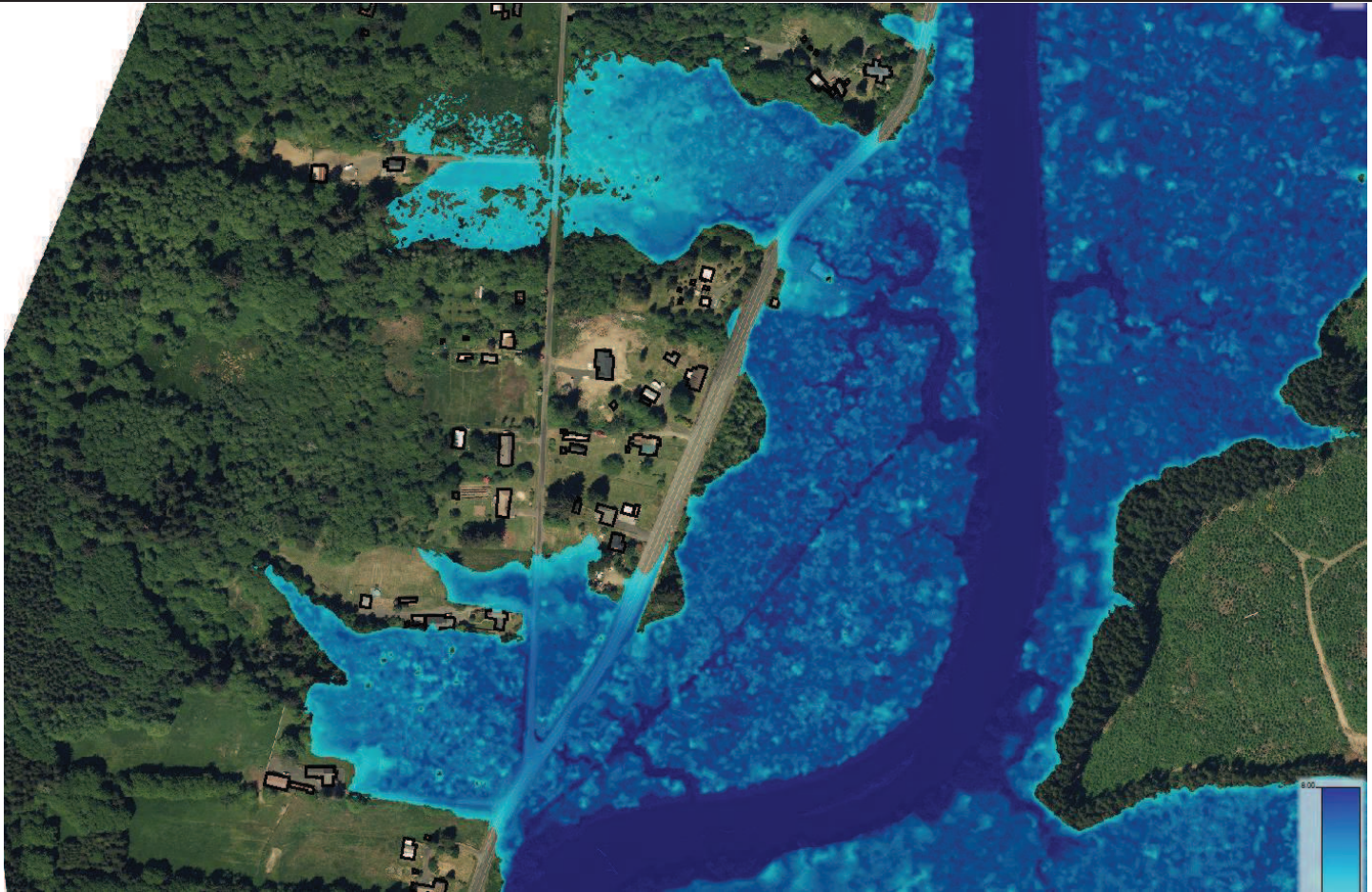
Cost of Road Closures¹:

\$250,000

Est. Cost to Correct:

\$2,500,000

¹Estimated net present value of cost of road flooding over a 50-year life cycle (assuming this was the only location of Wishkah Road flooding)



Flood Observations:

Minimum Road Elevation: 10.4 feet
January 2015 Water Level: 13.0 feet
December 2015 Water Level: 13.2 feet
January 2009 Water Level: 15.5 feet

Flood Simulation Statistics:

100-year Event

Max Level: 16.3 feet
Duration: 42 Hours

10-year Event

Max Level: 14.3 feet
Duration: 24 Hours

2-year Event

Max Level: 12.2 feet
Duration: 7.25 Hours

Potential Project Alternatives

Simulated flooding in a 100-year flood is projected to be up to 5.6 feet deep and up to 1,200 feet long at these two locations near Leutz Road. Flood reduction alternatives at these locations would likely include raising the road on Mechanically Stabilized Earth (MSE) fills as these would require the least property and have the least impact on adjacent properties (albeit at a higher cost than traditional fill with sloping sides). Raising Wishkah Road by 6 feet or more would require the road be brought up to current safety standards including shoulders, guardrails and other features. In addition to the road raise there are two streams in this project area that would need to be passed under the road fill, and these passages would need to be designed according to current WDFW fish passage guidelines which would require either very large culverts or perhaps a bridge. Permitting and environmental documentation requirements associated with the stream crossings could easily cost \$100,000 or more. It is estimated that a project to raise the Wishkah Road and provide fish passable culverts for the two streams would cost at least \$2,000,000. Adding a 25% contingency to cover unforeseen issues, puts the estimated cost of improvements at this site at \$2,500,000.

An alternative to raising the road over both of these flooding locations might be to raise Wishkah Road and Leutz Road at just the south location and then use Leutz Road as a detour to travel further up the Wishkah valley. This detour alternative would reduce the cost of Wishkah Road improvements but might require additional safety or other improvements to Leutz Road, which have not yet been estimated.

Study Area #3 - Long Swamp (M.P. 4.6 - 5.3)

Deepest flooding over greatest length of road

Road Flooding Information:

Length of Road Flooded in 100-year Flood – 3,550 feet

Maximum depth – 5.9 feet

Cost of Road Closures¹:

\$500,000

Est. Cost to Correct:

\$2,250,000 to \$12,000,000

¹Estimated net present value of cost of road flooding over a 50-year life cycle (assuming this was the only location of Wishkah Road flooding)



Flood Observations:

Minimum Road Elevation: 11.7 feet

January 2015 Water Level: 13.8 feet

December 2015 Water Level: 14.2 feet

January 2009 Water Level: 16.9 feet

Flood Simulation Statistics:

100-year Event

Max Level: 17.6 feet

Duration: 48 Hours

10-year Event

Max Level: 15.5 feet

Duration: 30 Hours

2-year Event

Max Level: 13.5 feet

Duration: 9.5 Hours

Potential Project Alternatives

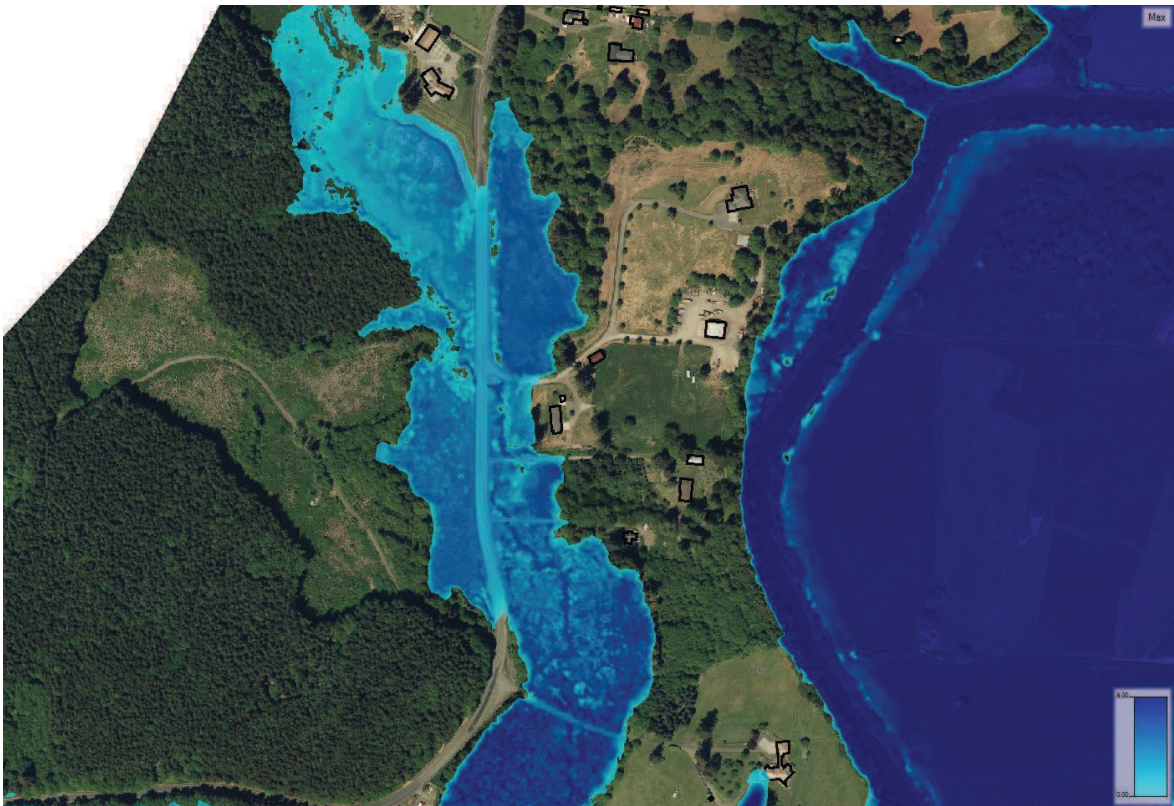
The Long Swamp location has the deepest and longest section of roadway flooding of any of the sites investigated. Observed flooding in January 2015 was about 2.75 feet deep. Flooding in a 100-year flood is projected to be up to 6 feet deep and extend up to 3,550 feet along Wishkah Road. Flood reduction alternatives considered include raising Wishkah Road by up to 6 feet and adding a floodwall along approximately 1,100 feet of the Wishkah River where the road is very close to the river. The raised road might be constructed on Mechanically Stabilized Earth fills to minimize wetland impacts although MSE fills would be higher cost than traditional sloping earth fills. It is not clear whether the additional weight due to a road fill of 6 feet or more could be accomplished without significant geotechnical stabilization of the road grade. Based on recent projects near this location it is expected that wetland loss would need to be mitigated at a ratio of 4:1 (i.e. 4 acres of wetland would need to be created for every 1 acre of fill) and the estimated cost for wetland creation could be \$500,000 to \$1,000,000 per acre with property acquisition. A traditional road fill, assuming wetland presence along the length of the improvement and an average height of 4 feet and 2:1 side slopes along the entire 3,500 foot length of road (minus the floodwall section), could require up to 2.2 acres of wetland fill. Given the mitigation ratio and cost described above, wetland mitigation alone could approach \$8,000,000. With the fill and flood wall, this project could cost more than \$12,000,000.

Because of the high potential cost for raising this section of Wishkah Road an alternative was considered that would create a bypass route along the hillslope adjacent to the low lying area immediately west and north of the current Wishkah Road, possibly along the alignment of an existing private driveway. This alternative would require acquisition of property or an easement for the entire route and engineering and construction of approximately one mile of new roadway at the east end. Estimating the cost for such a project is not possible without additional information but it is anticipated that if an easement can be obtained this would be less costly than the road raising alternative. However, the bypass route would be more than 4,500 feet long so even at a relatively low roadway cost of \$400/LF, this option would exceed \$1,800,000. Including a 25% contingency, which may be low given the unknowns of this route, the cost is likely to be at least \$2,250,000.

Study Area #4 - Wyman Creek (M.P. 5.8)

Additional flooding may be due to local drainage issues and beaver dams

Road Flooding Information: Length of Road Flooded in 100-year Flood – 1,350 feet Maximum depth – 2.7 feet	Cost of Road Closures¹: \$163,100	Est. Cost to Correct: \$1,350,000+
¹ Estimated net present value of cost of road flooding over a 50-year life cycle (assuming this was the only location of Wishkah Road flooding)		



Flood Observations:	Flood Simulation Statistics:		
Minimum Road Elevation: 15.6 feet January 2015 Water Level: 15.8 feet December 2015 Water Level: 15.6 feet January 2009 Water Level: 14.5 feet	100-year Event Max Level: 18.3 feet Duration: 27 Hours	10-year Event Max Level: 16.2 feet Duration: 11 Hours	2-year Event Max Level: 15.6 feet Duration: 0 Hours

Potential Project Alternatives

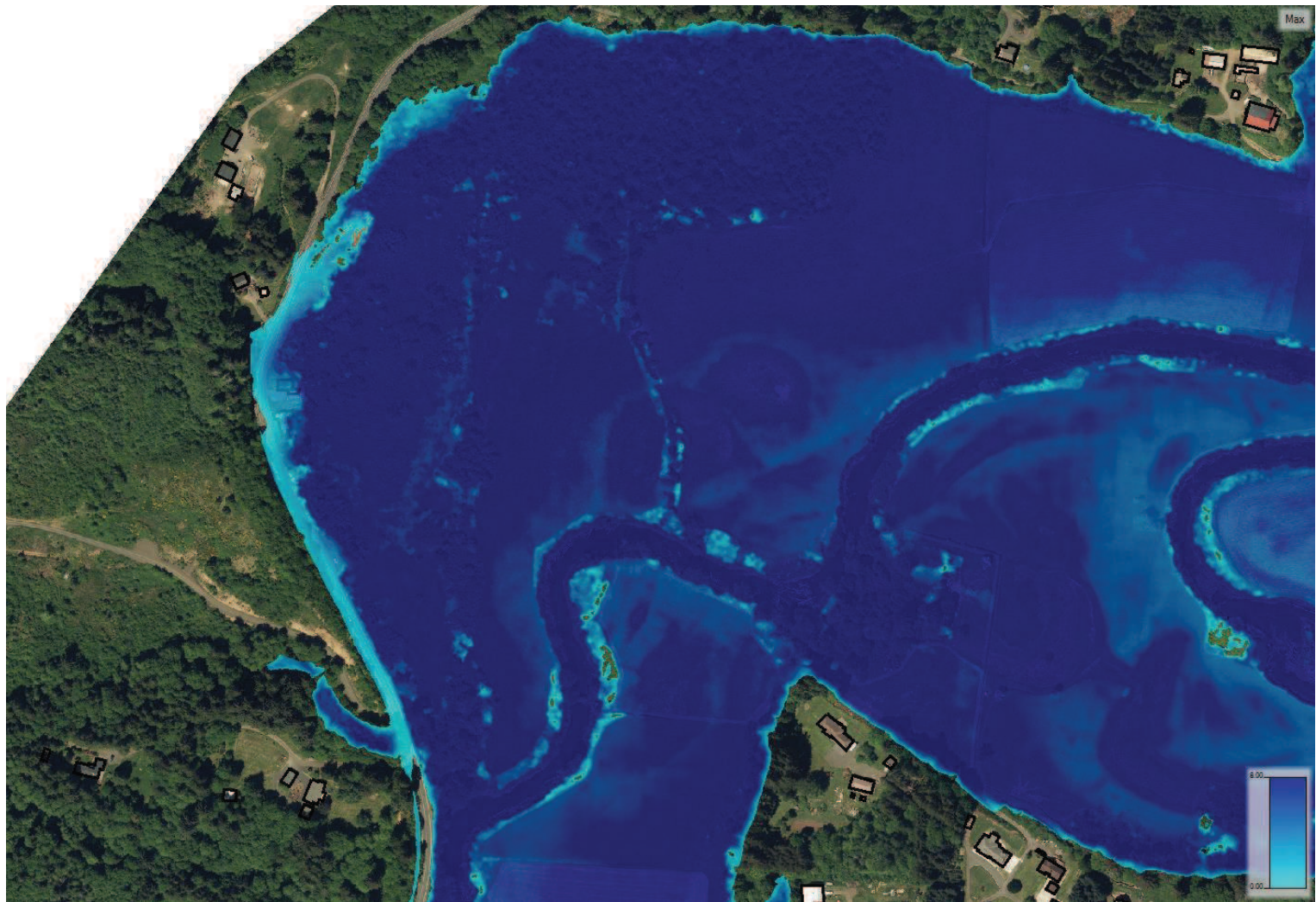
Simulated flooding near the Wyman Creek culvert crossing was not as significant as many of the other identified flood locations. Note however that the analysis only considered flooding associated with the Wishkah River and did not include detailed modeling of Wyman Creek itself. Conversation with local residents lead us to believe that frequent flooding near the Wyman Creek culvert at Wishkah Road may be occurring as a result of limited capacity in Wyman Creek and specifically as a result of beaver dams in the channel downstream of the culvert crossing. That issue has not been evaluated in this study. The least expensive alternative for eliminating flooding near Wyman Creek due to backwater from the Wishkah River would likely be to raise the road and add culvert capacity. A new culvert on Wyman Creek would need to be designed per current WDFW fish passage guidelines, meaning it would likely be significantly larger than the current culvert. Typically a wide box culvert would be the best alternative. Wishkah Road would need to be raised up to 2.7 feet over a length of approximately 1,350 feet to be above the 100-year flood level. To accomplish a road raise of 3 feet without significant wetland impacts would best be done using Mechanically Stabilized Earth fill. There may still be some wetland fill required which would necessitate mitigation, which could be costly. Permitting and environmental documentation of the project could be relatively involved due to the stream crossing and wetlands issues. It is estimated that the cost to raise 1,350 feet of roadway and replace the Wyman Creek culvert would be at least \$1,350,000, but likely higher.

There are at least two private driveway crossings on Wyman Creek downstream of Wishkah Road; both would be flooded in a 100-year event. Enlarging the Wishkah Road culvert could allow higher flows to pass downstream and exacerbate flooding of these driveways. If the driveways need to be raised it the culverts under them might need to be upsized to be fish passable as well. The costs to replace culverts at the downstream driveways have not been included here. Detailed modeling of Wyman Creek would be necessary to evaluate potential flood issues and/or to design improvements at the downstream culverts.

Study Area #5 – Miller Hill (M.P. 7.5)

Modeling and observations less certain at this location

Road Flooding Information:	Cost of Road Closures¹:	Est. Cost to Correct:
Length of Road Flooded in 100-year Flood – 1,550 feet	\$126,200 ¹	\$500,000 to \$1,000,000
Maximum depth – 3.1 feet	¹ Estimated net present value of cost of road flooding over a 50-year life cycle (assuming this was the only location of Wishkah Road flooding)	

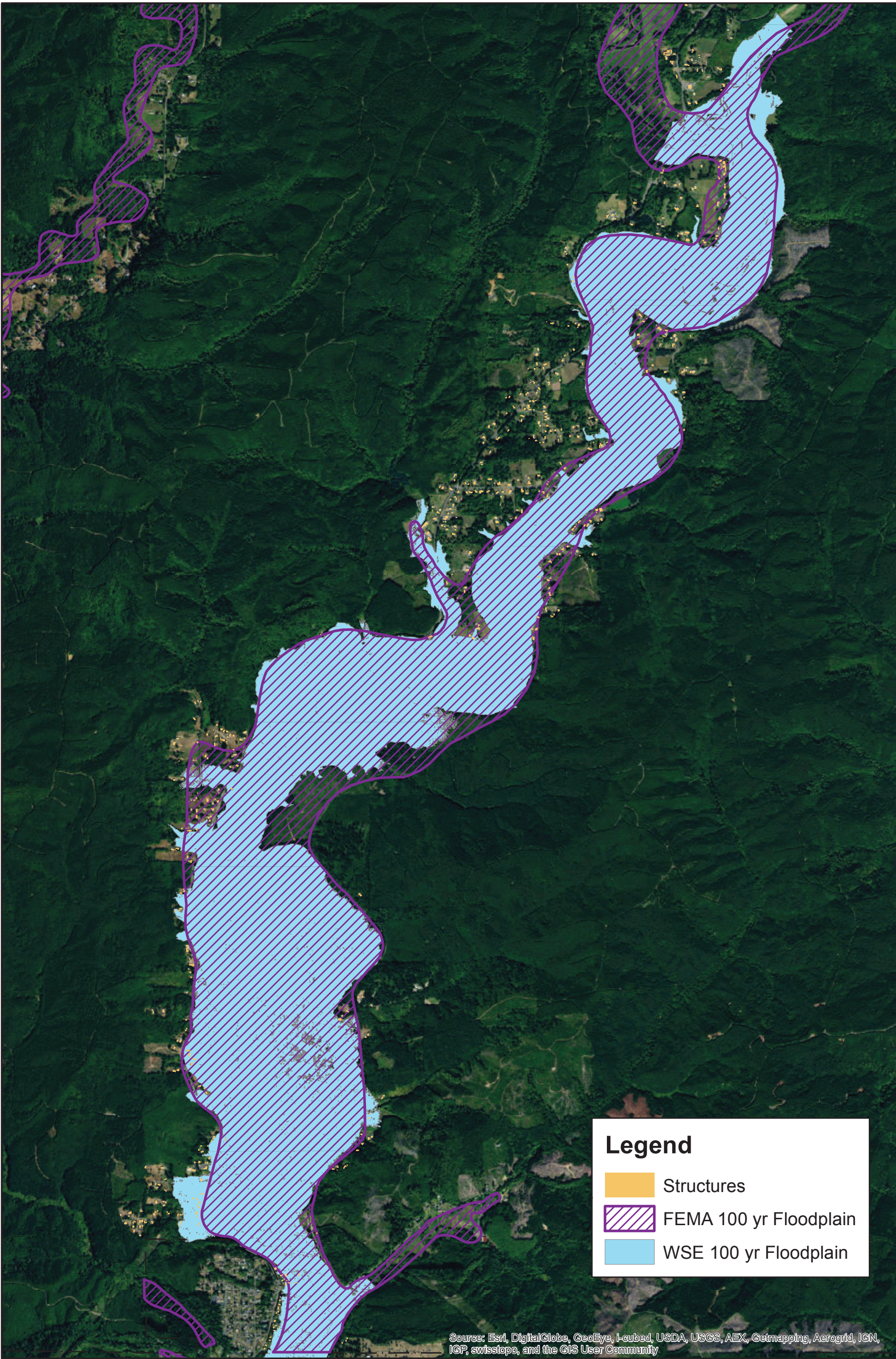


Flood Observations:	Flood Simulation Statistics:		
Minimum Road Elevation: 19.9 feet	100-year Event	10-year Event	2-year Event
January 2015 Water Level: 19.9 feet	Max Level: 23.0 feet	Max Level: 21.0 feet	Max Level: 19.1 feet
December 2015 Water Level: 19.9 feet	Duration: 25 Hours	Duration: 10 Hours	Duration: 0 Hours
January 2009 Water Level: 22.1 feet			

Potential Project Alternatives

Simulated flooding at this location is generally the shallowest of any of the flooding locations studied (except Study Area #2) and the modeling is also the most uncertain at this location because there are no photographs or high water marks for calibration of the model. Wishkah Road along this flood area is generally constructed on a fill slope along its east margin and cut into the hillslope along the west. The simplest solution to flooding in this area would likely be to shift the road slightly farther to the west, cut into the hillslope, and use the cut material to raise the road as needed. Shifting the road may require the purchase of portions of up to five properties. Assuming these could be obtained the project should be relatively straightforward to design and construct. However, additional information, including a right of way survey and geotechnical review would be required before a preliminary cost estimate can be developed for this project. An estimated range in cost for the scenario described above is \$500,000-\$1,000,000.

Appendix E



**Wishkah Road Comprehensive Flood Study
Comparison of FEMA and WSE Modeled Floodplain**

0 2,500 5,000 Feet

Scale: 1:38,366
WGS 1984 Web
Mercator Auxiliary
Sphere

05 May 2017

WATERSHED
SCIENCE & ENGINEERING

C:\Egnyte\Private\shana16-022 Wishkah Comprehensive Flood Study\GIS\WSE and FEMA 100-Year Floodplains Comparison Figure.mxd 5/5/2017 12:02:06 PM

Figure #