MF NOOKSACK CHANNEL MONITORING & ADAPTIVE MANAGEMENTAPPENDIX B

AS-BUILT CONDITIONS HYDRAULIC MODEL DEVELOPMENT AND CALIBRATION

Memorandum

To: NHC File 2005776

From: Aminana McEwen and Andrew Nelson

Date: 4/5/2021

Re: Middle Fork Nooksack River Dam Removal: As Built Conditions Hydraulic Model

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The adaptive monitoring and management plan for the middle fork Nooksack River Dam removal project specifies monitoring of water surface changes through time. To provide a baseline water surface against which to compare future monitoring under variable discharge conditions, NHC developed a hydraulic model of the project site. To do this, NHC used a HEC-RAS (version 5.0.6) two-dimensional (2D) unsteady model to evaluate as-built conditions of the Middle Fork Nooksack dam removal project site immediately following the end of construction.

To calibrate the model, we relied on one image of the project site, taken by a game camera. The image, captured on September 23, 2020 at 7:31 AM PDT, showed flow patterns within the as-built area immediately following construction, but before the first large flow event later that same day (Figure 1). We also identified a USGS stream gage on the Middle Fork Nooksack (gage # 12208000) about two miles downstream of the project site that recorded stream flow every 15 minutes. Taking the timestamp from the image, and accounting for the average velocity of the river and distance to the stream gage, we identified that the flow in the image was approximately 170 cfs. We used this value as the baseline quasi-steady flow and adjusted the Manning's n value and mesh cell size in the HEC-RAS until the flow resembled that in the image.

HEC-RAS requires an underlying terrain to successfully run 2D models. These terrains are developed from topographic and bathymetric survey data typically collected from LiDAR, topographic surveys, photogrammetry, or other means. For this model, we developed terrain data using a combination of several different surfaces representing the as-built conditions immediately following construction (Figure 2). Five separate data sources were integrated to produce a terrain covering the model domain representing conditions at the time channel grading work was completed:

- 2013 LiDAR was used for areas outside of the channel and areas of bedrock above the water surface near the channel. These areas are believed to have not changed meaningfully since 2013, except in the area of ongoing grading activity on the left bank floodplain/terrace.
- 2007 ground-based survey of the channel provided by Wilson was used for submerged bathymetry outside of areas of project grading.
- Wilson TLS scans of the channel through the project area.

    - In the area of project grading, TLS data was gathered during a (mostly) dewatered condition in August and September.
    - Upstream and downstream of the project regrade, TLS data was collected on October 28th, 2020. It only covered the subaerially exposed portion of the channel and was integrated with the 2007 ground-based survey.
- NHC UAV overflight of the project area, completed on October 8, 2020.
- Wilson UAV overflight of the project area, completed on December 3, 2020

The domain where each of these data sources was used is shown in Figure 3.

The mesh size of the 2D flow areas upstream and downstream of project site was 10 feet by 10 feet, with a refinement area in the entire as-built portion (Figure 3). We adjusted the refinement area from a coarse grid of 10 feet by 10 feet during the initial model development phase, to the final mesh size of 2.5 feet by 2.5 feet. The 10-foot by 10-foot mesh spacing upstream and downstream of the project site remained the same throughout the model development phases. We added break lines around natural grade breaks and flow splits to further refine the model's geometry.

We also fine-tuned the channel's roughness by adjusting the Manning's n values within the model domain. We applied a constant Manning's n value throughout the entire model domain, with no Manning's n override regions. A we were developing the model, we varied the Manning's roughness values from n = 0.04 to 0.10. Through a series of iterative simulations, we selected a final Manning's n = 0.05 as bearing the most resemblance to the flow captured in the September 23rd image.

Due to the highly detailed nature of the model's terrain, NHC was able to identify key boulders, cobbles, and other features between the September 23rd image and model. Slight adjustments in the model's Manning's n value or the mesh size caused certain key cobbles and boulders to either be submerged or visible in the model at a quasi-steady flow rate of 170 cfs. Through a series of iterations of adjusting the mesh size and Manning's n value, we identified that a mesh size of 2.5 feet by 2.5 feet and a Manning's n value = 0.05 best resembled the flow pattern in the image. Flow patterns within interpolated portion of the terrain near the right bank were not accurately represented in the model. Due to the relatively small area of the interpolated area, we decided to not further refine the terrain's elevation in the interpolated area in order to avoid over constraining or overfitting the model. This was the only area of the model where the results varied meaningfully from the image, and this was entirely due to a lack of precise topographic data in that area.

Results between the Saint Venant full momentum and diffusion wave equations were not significantly different. As such, we opted to use the default diffusion wave equation. Additionally, we selected a fixed time step of 0.1 seconds, which allowed the model to run stably. Results showed that velocities were typically less than 5 feet per second over most of the domain with local velocities up to about 9 feet per second (Figure 4), and the typical depth was less than 3 feet (Figure 5). Because roughness varies based on depth, NHC advises using this calibrated model for flows in the same order of magnitude as 170 cfs. Given how sensitive the model was to sight adjustments in the Manning's n value, the n value of 0.05 may be less applicable at significantly higher or lower flow events.

Figure 1. Image of flow at project site on September 23, 2020 at 7:31 AM PDT showing a flow of approximately 170 cfs.

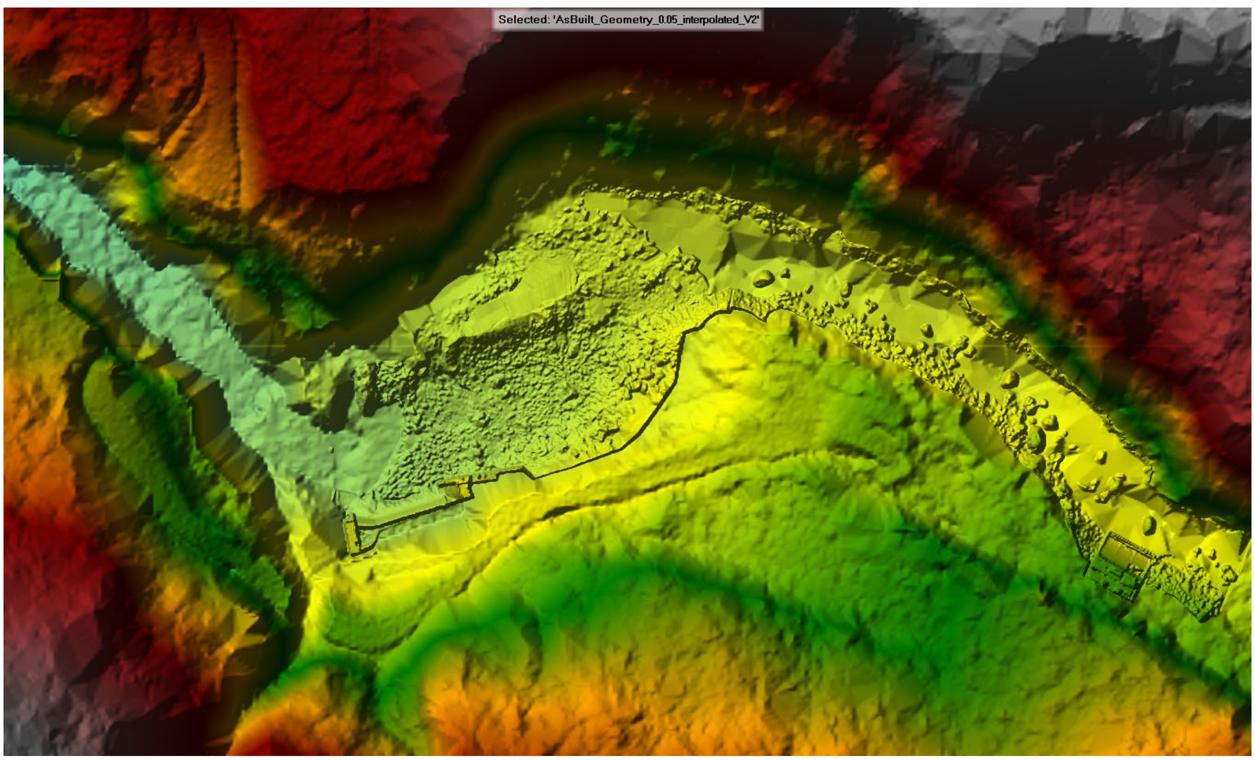

Figure 2. HEC-RAS 2D terrain of project area immediately post-construction

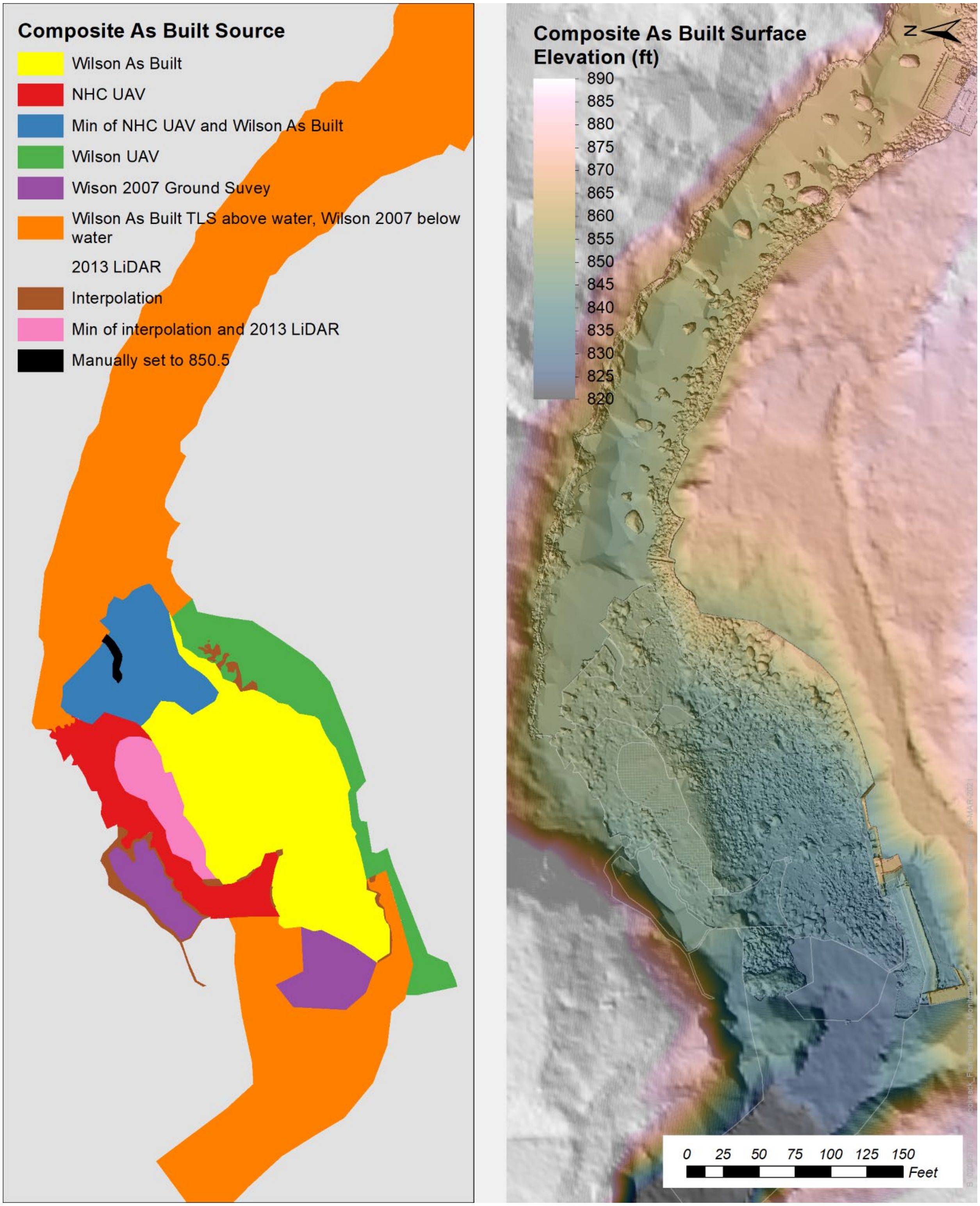

Figure 3: Detail of Composite As Built Surface and illustration of data sources used to produce the composite.

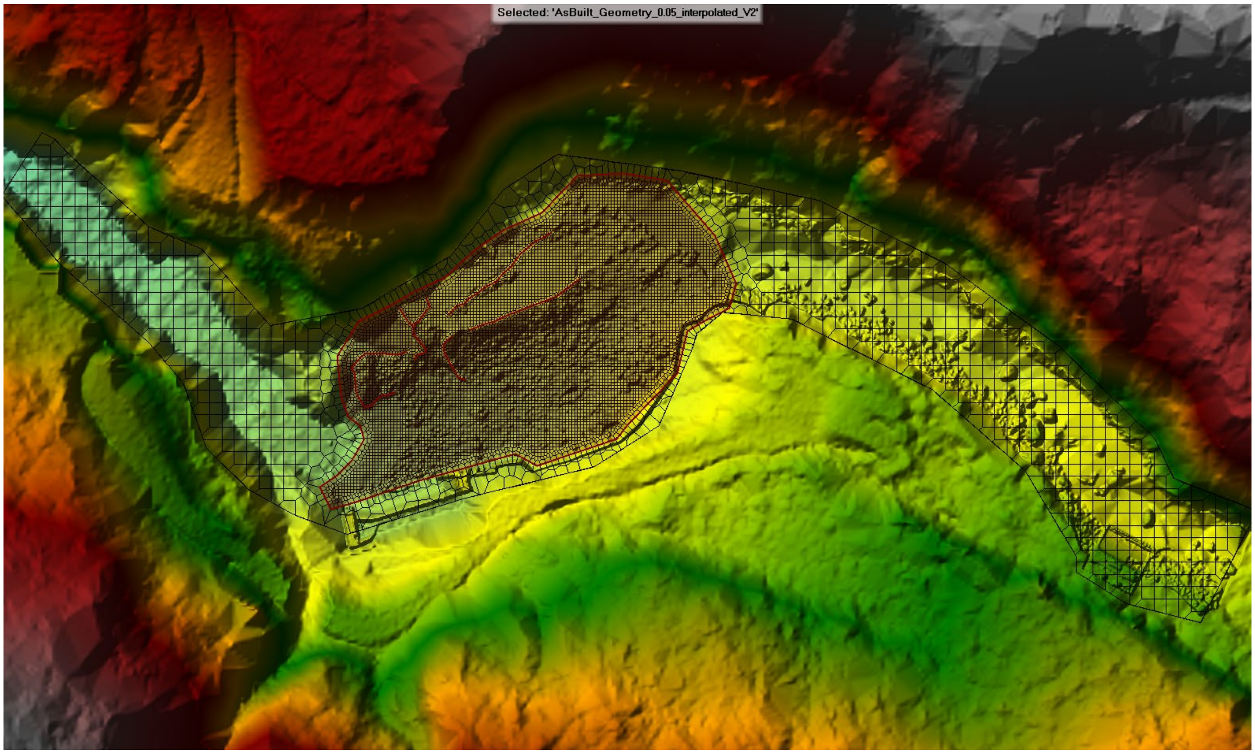

Figure 4. HEC-RAS 2D mesh with 10 ft x 10 ft gid sizing upstream and downstream; 2.5 ft x 2.5 ft gid spacing withing area of interest

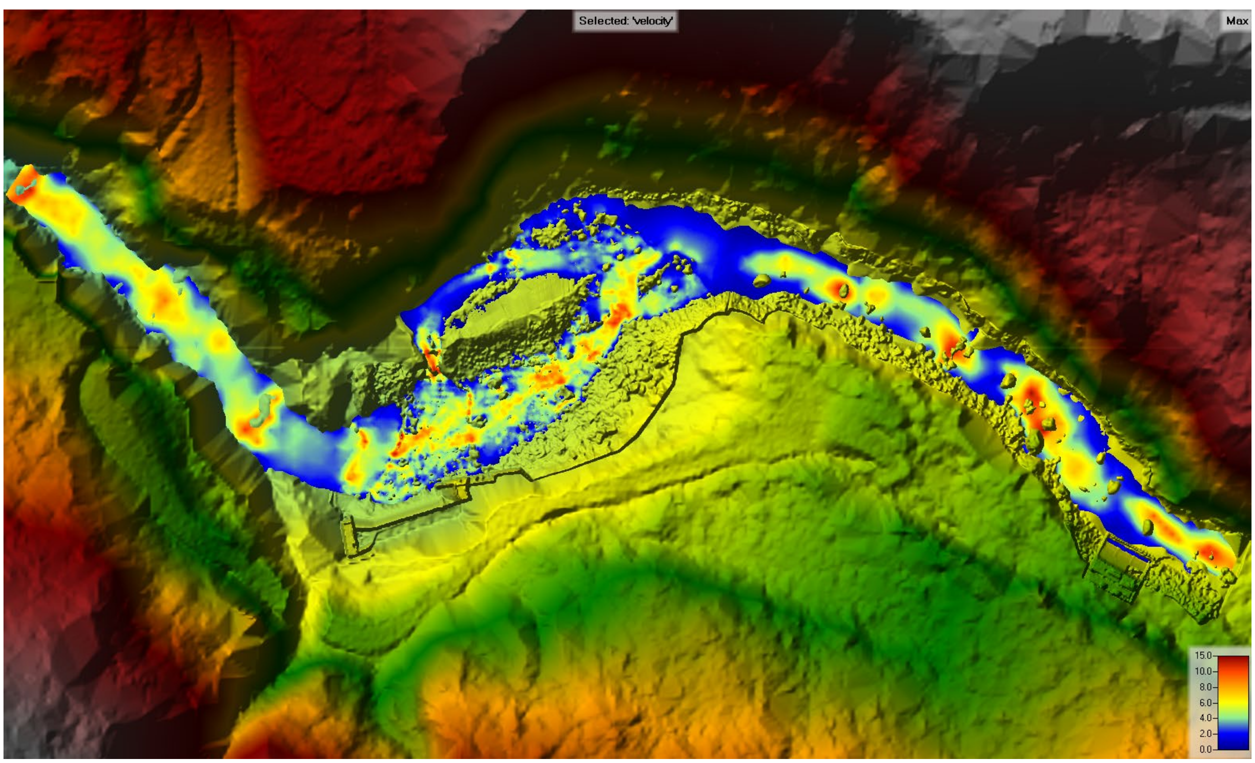

Figure 5. HEC-RAS 2D results showing velocity at 170 cfs. Flow is from right to left.

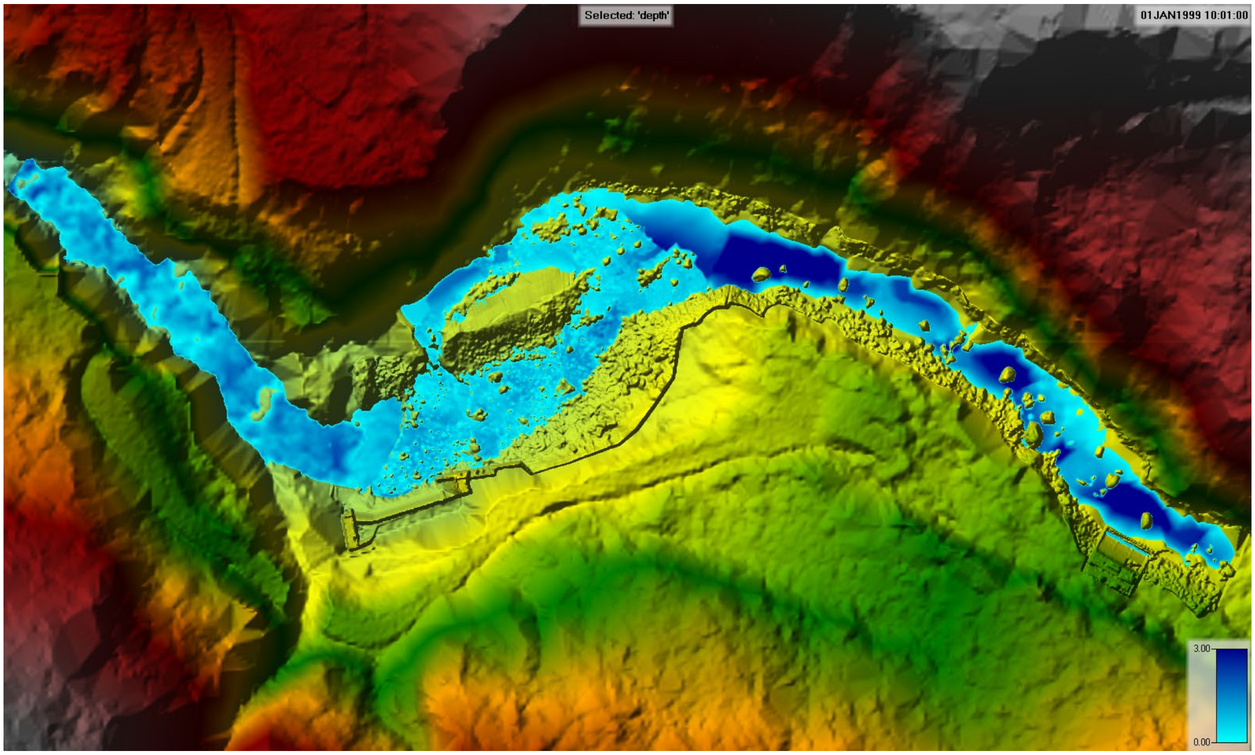

Figure 6. HEC-RAS 2D results showing depth at 170 cfs. Flow is from right to left.