Follow-up on Washington State Academy of Sciences Peer Review

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Prepared for: Skagit Water Task Force: Scoping Workgroup

Proposal (What)

The Skagit Drainage and Irrigation Districts Consortium LLC (Consortium) would like to propose additional modeling and technical evaluation to address the following issues identified by the Washington State Academy of Sciences (WSAS) in their Peer Review of the 1999 Duke Engineering Study.

- "The two study sites selected for tidal period habitat analysis do not capture the variability across the Skagit estuary in the influence of tides and non-tidal residuals. In addition, water surface elevations were related to estimated tidal variability at a nearby site on Whidbey Island and not at the Skagit River delta."
- "While data for the study period were collected between April and November, tidal period habitat analysis was conducted using a February to August time period and the analysis was averaged over this time period to develop a single recommended flow level. The study did not report the error caused by averaging or by using different months for data collection and analysis."
- "The study used multiple linear regression analysis to describe the relationship between water surface elevation and discharge, which is not generally expected to be a linear function. Linear regression analysis does not capture the influence of nonlinear tidal, flow, and non-tidal residual processes."
- "The study does not effectively address error and uncertainty; for example, instrument accuracies are not propagated through the analysis, errors associated with averaging are not reported, and extrapolations outside the range of data have inadequately reported uncertainty."
- "The study is unable to capture the duration of lower-flow conditions, given the use of 10,000 cfs as a threshold condition. The study also did not estimate inundated area, which is a major weakness, and tidal variation was not included in estimates of overland flow."
- "The study does not estimate abundance of habitat in channels or overbank areas, nor does it differentiate between fish species. This is likely because there was much less species-specific information about fish habitat available at the time of the study."

Importance (Why)

The purpose of this study is to ensure technical methods for modeling and analyses of physical processes, technical assumptions, and evaluation of habitat indicators are based on best available science, well vetted, thoroughly reviewed, and used to inform sound policy regarding water supply and demand in the Skagit River estuary.

Methods Proposal (How)

The Consortium proposes that the WWRC and WSAS utilize the Skagit Hydrodynamic Model (SHDM) developed by Pacific Northwest National Laboratory (PNNL) as a mathematical tool to re-evaluate the Skagit River below the Mount Vernon gage. In addition, the Consortium would like to propose collection of summer low flow water surface elevation data to validate of the SHDM for low flow conditions. The Consortium believes the SHDM is a cost-effective and appropriate tool for this analysis because of its ability to address and inform the key issues listed in the previous section.

Background information on PNNL Skagit Delta Hydrodynamic Model

Excerpt from Khangaonkar et al. 2017:

> "Researchers at the Pacific Northwest National Laboratory (PNNL) developed a three-dimensional hydrodynamic model of the Skagit River delta region based on a prior version of the model developed at PNNL. The model is based on the Finite Volume Community Ocean Model (FVCOM), which solves the three-dimensional momentum, continuity, temperature, salinity, and density equations in an integral form by computing fluxes between non-overlapping, horizontal, and triangular control volumes. The new unstructured grid is the highest resolution yet produced by the PNNL modeling group for the Skagit River delta; it consists of 131,471 elements that vary in size from 400 meters (1,312 feet) to less than 10 meters (33 feet). Bathymetry was updated with recent Lidar and boat-based surveys available from sources including the U.S. Geological Survey (USGS) and the U.S. Army Corps of Engineers (USACE). Skagit River flow was determined by a USGS gauge near Mount Vernon and the flow distribution between North and South Forks of the river were calibrated with five short-term stage gauges maintained by WDFW. The model was forced with tides and resulting outputs were validated against the WDFW and SRSC monitoring stations. Simulations were conducted over a 7-month period from November 2014 through May 2015, which coincided with the WDFW and SRSC stream gauge deployment and encompassed several 2-year floods and a majority of the fish outmigration period."

Task 1: Update and Validate the SHDM for summer low flow

The objective of this task is to establish a physical baseline condition and a baseline hydrodynamic modeling scenario and time period for analysis.

The existing SHDM model would be validated with a low flow water surface elevation data. PNNL could also update the geometry of the SHDM will recently completed habitat restoration projects.

Task 2: Develop methods for quantitatively evaluating habitat conditions

The objective of this task is to work with experts to develop methods to quantify habitat. Output from the SHDM could then be used to calculate parameters representing habitat within the lower Skagit Delta.

In addition, to quantitative modeling output, the temporal data regarding the presence and abundance/density of indicator fish species could be reported as a way to inform future conversations regarding the significance of any modeled changes in physical habitat parameters. The 1999 Duke Study used the duration of inundated habitat as a key indicator of impacts to suitable habitat as a proxy for fish habitat. Despite duration being the key indicator of habitat, the 1999 Duke Study relied only on a linear regression model which had no way to accurately model joint probability of tides and flow, natural seasonal variability, or compute duration. In addition, the 1999 Duke Study only evaluated flows between 10,000 and 25,000 cfs and used a 500 cfs threshold for significance.

As part of the Skagit Fish Farm and Flood Initiative, the Skagit HDM project management team developed metrics to quantitatively characterize habitat using output from the SHDM as a way to compare restoration alternatives. A potential example was the indicator called total number of acre-hours of suitable habitat. This indicator was developed using the following methods and assumptions.

> Excerpt from Skagit HDM: "Juvenile Chinook salmon can only use channels that have a water depth ranging from 20 cm (0.66 ft) to 2 m (6.56 ft) with a velocity less than 1.3ft/sec (Beamer et al, 2005). Because the Skagit delta is a tidal system, the total acres of suitable channel habitat available for juveniles fluctuates depending on river flow and tides as well as the surface elevation of the project concept. While the scope of this project did not allow for an analysis of velocity, the spatial and temporal component of suitable water depths were calculated during the out-migration window (March 1 to May 22)."
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> "To calculate acre*hours, the elevation of each project concept was broken down into 1-ft elevation bins using GIS analysis of the PNNL surface model. The total

number of acres within each 1-ft elevation bin were then summed for each project concept."

"For each project concept, one sample spot was identified waterward of the site at which the water surface elevation was calculated in 15 minute increments from March 1 through May 22 from the PNNL model output."

"For each elevation bin, number of hours that the WSE was at or up to 6-ft above the ground elevation was calculated. That time period of suitable inundation was then multiplied by the total acres within that elevation bin for an acre*hour calculation. The acre*hours of suitable inundation were then summed across all of the elevation bins of a site for the total acre*hours of suitable inundation using the following equation:

$$\sum_{elevation\ x}^{elevation\ z} (hours\ inundated(x\ to\ x+6ft) \quad * acres\ x)$$

Output from the SHDM could be used to calculate parameters representing habitat, as illustrated in the example above. Relative error could also be reported.

Data Uses, Outcomes, Recommendations

The SHDM could be used to evaluate a range of water management scenarios using best available science to fully understand trade-off between all designated uses defined by Ecology (Table 1). This work could inform future decisions about how to best meet existing and future water supply needs in the Skagit.

Table 1. Designated uses for waters of the state

Aquatic life uses	Recreational uses	Water supply uses	Miscellaneous uses
▪ Char spawning and rearing ▪ Core summer salmonid habitat ▪ Salmonid spawning, rearing, and migration ▪ Salmonid rearing and migration only	▪ Primary contact	▪ Domestic water supply ▪ Industrial water supply ▪ Agricultural water supply ▪ Stock watering	▪ Wildlife habitat ▪ Fish harvesting ▪ Commerce and navigation ▪ Boating ▪ Aesthetic values

REFERENCES

Duke Engineering. 1999 Duke Estuary Study, which is Section 3 of the "Final Technical Report: Lower Skagit River Instream Flow Studies".

Friebel, J. Hicks, and J. Baker. 2017. An Alternatives Analysis of Restoration Project Concepts across Farm, Fish and Flood Interests: Skagit Hydrodynamic Model Project Phase 2 Report

Whiting, J., T. Wang, and T. Khangaonkar. 2017. Pacific Northwest National Lab. Hydrodynamic Model Development and Application for Restoration Alternatives – Skagit Delta Hydrodynamic Modeling Project Final Report. PNNL-26867. prepared for the U.S. Department of Energy under Contract DE-AC05-76RL1830.

WSAS (Washington State Academy of Sciences) 2001. Independent Peer Review of the Estuary Study Portion of the 1999 Duke Engineering "Final Technical Report: Lower Skagit River Instream Flow Studies" Prepared for the Washington State Joint Legislative Task Force on Water Supply. January 2021.