To: **Quinault Indian Nation**

From: Natural Systems Design, Inc.

Date: October 28, 2020

Re: Critical Review of Proposed Chehalis River Basin Flood Damage Reduction Project NEPA DEIS: Addendum to Cascade of FRE Ecosystems Effects Technical Memo

EXECUTIVE SUMMARY

A qualified technical team of Professional Wetland Scientists, geomorphologists, biologists, hydraulic engineers, and hydrologists reviewed the NEPA Draft Environmental Impact Statement (DEIS), along with related documents prepared to support the proposed Flood Retention Expandable (FRE) facility and Airport Levee Improvements project (proposed project) being reviewed by the U.S. Army Corps of Engineers (Corps) under the National Environmental Policy Act (NEPA). Hydraulic analyses were reviewed by Leif Embertson, PE and Megan Nelson PE, MS. Analysis of climate change and flow frequency and duration was completed by Susan Dickerson-Lange, PhD; analysis of geomorphic processes, floodplains, and wetlands was completed by Tim Abbe, PhD, PEG, PHG; PG; Kevin Fetherston PhD, PWS; Scott Katz, MS; and Torrey Luiting, MS, PWS. Andrew Annanie, BS provided input regarding impacts to mussels and amphibians.

The team reviewed the NEPA DEIS, as well as the Discipline Reports for Water Quantity and Quality (Appendix G), Geology and Geologic Hazards (Appendix H), Geomorphology (Appendix I), Wetlands and Other Waters (Appendix J), and Aquatic Species and Habitats (Appendix K). The team also reviewed the description of the alternatives in Appendix D and the Impact Thresholds presented in Appendix E. Particular attention was paid to the methods and conclusions of the impact analyses relative to the suite of natural resources considered in the DEIS, their interrelationship, and the mechanisms by which impacts to one or more of the physical processes which shape fluvial environments affect the formation of habitats that support wetlands, waters, and fish and wildlife species and habitats upstream and downstream of the proposed FRE facility.

The totality of these analyses was examined together to specifically consider the linkages between riverine, riparian, and wetland physical and biologic processes and to assess the degree to which the NEPA DEIS accurately identifies and quantifies the cascade of effects on physical processes, habitat formation, and fish and wildlife communities that would occur as a result of the construction of the proposed project and operation of the FRE facility over the DEIS's stated 50-year impact analysis period.

Overall, the team concluded that numerous direct and indirect impacts have been underestimated or insufficiently analyzed. The team concluded that the critical assumptions, omissions, and errors present in the NEPA DEIS and associated discipline reports result in a gross underestimation of the potential for impacts to waters and wetlands, fish and wildlife species and habitats, and of the very processes that create and sustain functional rivers and floodplains through time.

Furthermore, the team concluded that no meaningful analysis was accurately applied to quantify the interaction of the processes affected by the proposed project in an ecosystem framework. Given the well-established interactions between geomorphic, hydrologic, and ecological processes that form and maintain high quality aquatic habitat, the impairment of several of these individual processes will set in motion a much larger "cascade" of impacts which will amplify over time. The synchronous alteration to multiple, connected natural processes that sustain aquatic habitat sets up a positive feedback loop in which the overall impact to ecosystems is amplified relative to the alteration of any one process.

Neither the cascade of effects, nor the amplification of effects are adequately or appropriately analyzed in the NEPA DEIS and its associated discipline reports. **The result is a DEIS which presents only cursory analysis and a gross underestimation of the potential for impacts to waters and wetlands, fish and wildlife species and habitats, and to the very processes that create and sustain functional rivers and floodplains through time.**

The failures and omissions disregard the amplification of impacts which will occur over time if the proposed project is approved and result in a project for which impacts to waters and wetlands and their aquatic species and habitats cannot be mitigated.

Many of the same technical issues, errors, and omissions identified in the review of the State Environmental Policy Act (SEPA) DEIS and supporting documents also occur in the NEPA DEIS. Therefore, we incorporate herein by reference the following SEPA Technical Memoranda which provide detailed explanations of the basis for these conclusions:

- *Cascade of FRE Facility Ecosystem Effects Technical Memo* (SEPA Cascade of Ecosystem Effects Technical Memo) (NSD 2020a)
- *Hydrology Technical Memo 1: Observed and Predicted Flows Relative to FRE Facility Operation* (SEPA Hydrology Technical Memo 1) (NSD 2020b)
- *Hydrology Technical Memo 2: Hydrology and Climate Change Technical Analyses Review* (SEPA Hydrology 2 Technical Memo) (NSD 2020c)
- *Earth Discipline Report – Geology Technical Analyses Review* (SEPA Geology Technical Memo) (NSD and Saturna Watershed Sciences 2020)

Several additional addenda to the SEPA technical memoranda have been prepared in response to the NEPA DEIS and are incorporated herein by reference as follows:

- *Critical Review of Proposed Chehalis River Basin Flood Damage Reduction Project NEPA DEIS: Climate Change Impacts* (NEPA Climate Change Addendum) (NSD 2020d)

In summary our NEPA DEIS review finds that:

1. **The NEPA DEIS inaccurately and misleadingly refers to the FRE facility as having a “temporary” reservoir** and cites its temporary nature as a key consideration in the analysis of the proposed project impacts.
    a. The reservoir would be a permanent feature on the landscape that continuously has a backwater effect and periodically impounds the river to form a temporary pool.
    b. The impoundment of the river, the effect on the river’s hydraulics and sediment transport, and the effect on the 856 acres of reservoir would be permanent and would repeatedly occur as long as the FRE facility is in operation.
2. **The NEPA DEIS fails to consider, analyze, or appropriately characterize the physical and ecological process linkages inherent in riverine ecosystems. The DEIS fails to consider the impacts of the cascade of ecosystem effects and the amplification of those effects over time that will directly result from operation of the proposed project.**
    a. The compounding impacts that result from the interactions and feedback between processes was not considered and those natural interactions and feedback processes will amplify the scale and intensity of ecosystem impacts both upstream and downstream of the FRE facility.
    b. The proposed project will result in a cascade of impacts to the Chehalis River, its existing floodplain/off-channel water bodies and wetlands both upstream and downstream of the FRE facility, as well as to the physical processes that create and sustain the future formation of

aquatic habitat, floodplain wetlands and floodplain/off-channel water bodies, resulting in significant, unmitigable impacts and in the amplification of impacts over time.

3. **The NEPA DEIS underestimates all impacts to geomorphic processes and those dependent on the conclusions of the geomorphic analyses because they are based on flawed hydraulic and geomorphic modeling.**
    a. The sediment transport model is fundamentally flawed and contains many errors, omissions, flawed assumptions, an inappropriate calibration, a flawed sensitivity analysis, and fails to apply the best available science. The model is one of the primary analysis tools used to assess how impacts to geomorphic processes impact aquatic and terrestrial species and habitats. Because the model is fundamentally flawed, so too are all the impact assessments that rely upon it.
    b. The analysis of impact on ecological processes and aquatic and terrestrial habitats and species is also underestimated due to inadequate and flawed analysis approaches, including but not limited to sediment supply, sediment mobilization, and fine sediment impacts both in the proposed reservoir and downstream of the proposed FRE facility.
4. **The NEPA DEIS used a flawed sediment transport model which did not explicitly evaluate fine sediment; thus, it cannot be used to determine fine sediment related impacts to aquatic species or habitats.**
    a. The NEPA DEIS statements regarding fine sediment related impacts to aquatic species and habitats are unsubstantiated by any analysis and cannot be used to draw conclusions regarding intensity, scale, or duration of impacts to aquatic species or habitats.
5. **The NEPA DEIS fails to account for climate change and thus for the ways in which impacts of lower summer streamflow will be amplified** by downstream impacts of the FRE facility to floodplain inundation, groundwater recharge, and result in increased severity of impacts to aquatic habitats with the exacerbation of lower summer streamflow and higher summer stream temperatures.
6. **The NEPA DEIS fails to account for the ways in which climate change projections for increased frequency and magnitude of peak flows of all sizes will affect sediment transport** and therefore will exacerbate downstream channel incision and related impacts to habitat-forming processes and habitat quality.
7. **The NEPA DEIS underestimates impacts to the hydrologic and sediment supply processes that shape upstream riverine, wetland, and floodplain ecosystems.**
    a. The frequency and duration of reservoir impoundment are underestimated for both current and future climate conditions.
    b. Increases in the frequency and magnitude of landslides and hillslope erosion, and therefore sediment delivery, are drastically underestimated.
    c. Underestimating impacts to physical processes leads to underestimation of impacts to channel morphology, sediment transport, wetlands, riparian vegetation, and aquatic habitat within the reservoir area.
    d. Compounding impacts that result from the interactions and feedback between processes and the consequent amplification of impacts over time are not considered.
8. **The NEPA DEIS underestimates the impacts to waters and wetlands because it contains significant errors and/or underestimations in the following impacts to the physical processes that shape the downstream riverine, wetland, and floodplain ecosystems:**
    a. The downstream impact assessment to channel and floodplain morphology and hydrologic connectivity is not evaluated.

b. Reductions to groundwater recharge are underestimated based on underestimated frequency of peak flow events that would trigger FRE operation and underestimated recharge rates.
c. The hydrologic connection between groundwater and surface water is inadequately and inappropriately analyzed, resulting in underestimated impacts to floodplain water bodies, wetlands, and baseflow. Inappropriate groundwater recharge rates and a rudimentary groundwater-surface water analysis were improperly utilized to consider impacts.
d. Impacts to downstream sediment transport processes and coarse sediment supply are underestimated due to flawed modeling assumptions.
e. The increase in fine sediment supply from increased frequency and magnitude of landslides and hillslope erosion, and thus, downstream impacts of fine sediment to aquatic habitats are underestimated.
f. The magnitude and nature of impacts wetlands and waters is inaccurately and inconsistently reported in the DEIS and its supporting documents and the analyses inaccurately characterize linkages between flood events and the formation and maintenance of floodplain water bodies and wetlands.
g. Underestimating impacts to physical processes leads to underestimation of impacts to channel morphology, sediment transport, wetlands, riparian vegetation, and aquatic habitat downstream of the FRE facility.

INTRODUCTION

An expandable flood retention (FRE) facility and airport levee improvements have been proposed as an alternative to accomplish flood damage reduction on the Chehalis River, Washington. Several alternative concepts were proposed, but the Flood Retention Expandable (FRE) facility has been advanced as Alternative 1 for environmental review under NEPA. The stated purpose of the facility "is to reduce the risk of flood damage in the Chehalis/Centralia area from catastrophic flooding" (NEPA DEIS Section 2.1, p. 11). The 'target area' is the 100-year floodplain of the Chehalis River from Adna to Grand Mound. A 'catastrophic flood' is defined as a 100-year flood (I.e. a flood having a 1% chance of occurring each year). As such, the FRE facility is designed for a 100-year hydrologic event, such as the 1996 flood, but is not designed to retain larger floods such as the 2007 flood.

ANALYSIS

The team applied the process-based hierarchical framework (modified from Jorde et al. 2008; Burke et al. 2009, Naiman et al. 2005; Ward and Stanford 1995) for considering and characterizing the potential for a "cascade of effects" to the construction and operation of a flood retention facility in the Chehalis River of the nature and scale presented as Alternative 1 in the NEPA DEIS.

As presented in our team's *SEPA Cascade of Ecosystem Effects Technical Memo* prepared in response to the Washington State Department of Ecology's February 27, 2020 State Environmental Policy Act (SEPA) DEIS, this hierarchical concept outlines the physical processes which support and sustain the biological systems and process which then feedback into the habitat forming processes of the ecosystem.

The assumptions, omissions, errors, and consequences for the Chehalis River ecosystem previously documented in our *SEPA Cascade of Ecosystem Effects Technical Memo* are incorporated herein by reference. The issues of accurate, sufficient, and appropriate analysis and conclusions and the consequences for the natural environment and for informed decision making outlined in that memo also apply to the NEPA DEIS.

As detailed below, the NEPA DEIS presents a suite of additional errors, inconsistencies, omissions, and failures of analysis which grossly underestimate the potential for impacts to hydrology, hydraulics, geomorphology, wetlands, waters, fish and wildlife species and habitats, and to the very processes that create and sustain functional rivers and floodplains through time. The failures and omissions disregard the amplification of impacts which will occur over time if the proposed project is approved and result in a project for which impacts to waters and wetlands and their aquatic species and habitats cannot be mitigated.

Hydrology, Hydraulics, and Geomorphic Processes

The fundamental flaws, errors, and issues presented in the *SEPA Cascade of Ecosystem Effects Technical Memo* still exist within the NEPA DEIS. In that analysis, our team described how impacts to the flow and sediment supply (first order processes) "cascade" through the river system to impact geomorphology and hydraulics (second order processes) which in turn impact aquatic and terrestrial species (third order processes).

Thus, by underestimating impacts to the first order processes of sediment and flow regimes, all other processes such as floodplain morphology, surface and groundwater interactions, and the formation and maintenance of wetlands are in turn underestimated. **This means that impacts to wetlands, waters, aquatic habitat and fish and wildlife species (including declining populations of Chehalis basin salmonids) are expected to be greater than disclosed in the NEPA DEIS.**

Frequency and Duration of Impacts to Flow Regime are Underestimated

Alterations of the natural flow regime of the Chehalis River by the proposed FRE facility through impounding water from flood events represent a primary mechanism for impacts to the physical and ecological processes upon which the ecosystem depends. **By disrupting the natural flow regime, the proposed FRE facility will subsequently impact all other river processes related to geomorphology, aquatic habitat, wetlands, and water quality.** Despite the fundamental importance of accurately representing impacts to the flow regime in all impact assessments, the NEPA DEIS underestimates the frequency and duration of impacts and **thus all subsequent impact assessments are underestimated**. Below is an excerpt from the *SEPA Hydrology Technical Memo 1* describing this fatal flaw relative to the reservoir impoundment:

> "*The frequency and duration of reservoir impoundment are underestimated for current conditions. The analysis of peak flows that trigger FRE operation under current conditions utilized annual flood frequency analysis and does not consider the observed occurrence of years in which multiple, independent peak flows exceed the threshold for FRE operation*." (See *SEPA Hydrology Technical Memo 1*).

By underestimating the frequency and duration of reservoir impoundment, the NEPA DEIS subsequently underestimates impacts to the downstream flow regime as water would be held back by the reservoir (and not passed downstream) more frequently and for longer than disclosed in the NEPA DEIS. A more detailed explanation of the underestimation of impacts related to the frequency and duration of impoundment can be found in the *SEPA Hydrology Technical Memos 1 and 2*.

In addition to underestimating the frequency and duration of reservoir impoundment under current conditions, the NEPA DEIS fails to incorporate the best available science on climate change impacts on future projected flows in the Chehalis River basin. This exclusion leads to the further underestimation of impacts caused by the proposed FRE facility which is expected to operate more frequently under predicted future climate scenarios (*NEPA Climate Change Addendum, SEPA Hydrology Technical Memo 2*). This flaw in the NEPA DEIS influences all flow and sediment-based impact assessments. The exclusion of climate change from the NEPA DEIS impact assessment is described further in the *NEPA Climate Change Addendum*.

Impacts to the Sediment Regime are Based on Flawed Model and Analyses and Omit Major Sediment Inputs

The Sediment Transport Model Used as the Basis for the Impact Assessment is Fundamentally Flawed

The sediment transport model presented in Appendix I of the NEPA DEIS is fundamentally flawed and contains many errors, omissions, flawed assumptions, an inappropriate calibration, a sensitivity analysis that does not reflect the variability and uncertainty in sediment transport predictions and fails to apply the best available science. The model is the primary analysis tool used to assess impacts to geomorphic processes as a result of the proposed FRE facility and serves as the quantitative basis for assessing how changes to those processes impact aquatic habitat and fish populations (Appendix K) and wetlands (Appendix J). **Because the sediment transport model is fundamentally flawed, so too are all of the impact assessments that rely upon it, particularly the NEPA DEIS interpretation of the magnitude and intensity of impacts to the physical processes that create and sustain riverine, floodplain, and associated wetland habitats and their associated fish and wildlife species.**

Our review of the sediment transport model demonstrates that the model significantly underestimates the amount of coarse sediment that would be stored behind the proposed FRE facility and the amount of fine sediment that would be transported downstream as a result of its operation. The implications of these underestimated impacts include likely greater impacts to geomorphic processes, aquatic habitat, and wetlands than are disclosed in the NEPA DEIS. These include, but are not limited to, greater degrees of downstream channel incision (which disconnects the river from its floodplain, results in decreases in floodplain habitat and the loss of associated wetland area and function), loss of salmonid spawning habitat through increases in siltation from fine sediment and increases in bed scour, and increased simplification of in-channel habitats (see *SEPA Cascade of Ecosystem Effects Technical Memo*, specifically Figure 4 for full explanation of ecosystem impacts).

The sediment transport model is flawed in the following ways:

1. The modeling approach significantly under-estimates the sediment load from the 2007 storm event by omitting ~90% of the estimated sediment load (Watershed GeoDynamics and Anchor QEA 2017). This sediment volume is greater than the entire sediment load from non-landslide sources for the entire length of the model so excluding it calls into question any model predictions associated with the time period following the 2007 flood. The model developers qualify the exclusion of the sediment load by stating that an event like the 2007 flood with high concentrations of sediment is "not modeled well by the sediment transport equations within the HEC-RAS program" and that "one model run was attempted for the 2007 storm...but resulted in unrealistic accumulations at each of the sediment input points," (Watershed GeoDynamics and Anchor QEA 2017, pg 17). They then note that "the final sediment input rating curves resulted in a much lower 2007 input (411,000 tons) than the mass wasting input estimate (nearly 4,500,00 tons) and conclude that "**The HEC-RAS model results are not representative of the actual 2007 storm event inputs and transport**," (Watershed GeoDynamics and Anchor QEA 2017, pg 17).
    a. Despite these admitted shortcomings in the sediment transport model, a discussion noting the immense underestimation of the 2007 sediment load and the subsequent implications on geomorphic processes was never presented to decisionmakers in the NEPA DEIS but instead the results were falsely treated as an accurate representation of sediment transport conditions despite the known underestimations. In addition, the NEPA DEIS attempts to parse out the influence of the 2007 flood by presenting results from before and after that time-point in their simulation but continues to obfuscate that the model does not accurately represent conditions following that flood event. **By omitting the major sediment input from the 2007 flood from their analysis, the NEPA DEIS underestimates the changes in coarse and fine sediment that would occur both upstream and downstream of the proposed facility and does not accurately present that shortcoming to decisionmakers.** This represents a fatal flaw in the methodology and interpretation of the sediment transport model. The additional modeling and analyses presented in Attachment 1 of Appendix I in the NEPA DEIS underscore the sensitivity of the sediment transport model to changes in sediment inputs. The results demonstrate that increases in sediment load in the model lead to increases in sediment storage above the dam and thus if the full sediment load from the 2007 storm event was accurately included in the model, additional sediment storage behind the FRE facility would be expected. **This underscores that by omitting the majority of the sediment from the 2007 storm event, impacts to sediment are underestimated in the DEIS.**
2. The model does not account for increases in the frequency and magnitude of landslides due to reservoir operations (*SEPA Geology Technical Memo*). By omitting this input, the model underestimates the change to coarse and fine sediment that would occur both upstream and downstream of the FRE facility.

3. Sediment transport results presented in the NEPA DEIS are not supported by observations of the actual conditions that occurred within the Chehalis River over the course of the simulation (1988-2018) and are contrary to fundamental geomorphic principles and literature demonstrating the effects of dams on river processes.
    a. The sediment transport model predicts roughly 500,000 tons of cumulative sediment storage from 1988-2018 within the confined channel section downstream from the proposed FRE facility between river miles 106.5-108 under both baseline and proposed conditions (Appendix I; Figure 6.2-3, Figure 6.2-6). If projected across the channel within this area, that volume of sediment would result in the channel bed elevation increasing ~19 feet across the 1.5 miles of river – a result that does not match what occurred in the river during this time where no appreciable change in channel elevations was observed through comparing lidar digital elevation models from 2019 and 2006. This example illustrates how the NEPA DEIS analysis blindly applies inappropriate quantitative modeling without supporting the results with observations of what actually occurred in the river during the period of their simulation. This is a fundamental flaw in the analysis and brings into question all the model's results and conclusions.
    b. The sediment transport model also predicts similar quantities of sediment storage in this reach with the proposed FRE facility, a finding that is contrary to what has occurred downstream of many dams where the reduction in upstream sediment load coupled with continued flow releases above the threshold for bedload transport result in channel incision and armoring of the channel bed (Kondolf, 1997; Graf, 2006; and Schmidt and Wilcock, 2008). For example, downstream of Glen Canyon Dam (Colorado River, AZ) which cut off the river's sediment supply from downstream reaches, 2.5 meters of incision occurred within one year following flow releases that exceeded the threshold for sediment transport (Grams et al., 2007). Even though some sediment will pass through the proposed tunnels, both the SEPA DEIS and NEPA DEIS indicate there will be significant long-term sediment storage in the reservoir. Because of this, sediment in the channel immediately downstream from the proposed FRE facility is likely to be degraded – a consequence that is similar to what has occurred downstream from most other large dams. The NEPA DEIS sediment transport model predictions that sediment will be stored immediately downstream from the proposed FRE facility are opposite of the likely occurrence and in this regard are unrealistic and unreasonable.
4. Predicted changes in subsurface grain size demonstrate that the sediment transport model is not stable and predicts unrealistic changes that demonstrate inaccuracies that cannot be discounted by simply "smoothing" the results with running averages. Results presented in Figure 6.2-7A, 6.2-7B, 6.2-8A, and 6.2-8B of Appendix I show that the model predicts the median grain size of the sub-surface layer to be reduced by ~1,100mm at two locations in the model near RM 98 and RM 117. This amount of change is physically impossible because the median grain size of the channel bed at those locations is 38mm and 74mm respectively and a decrease of ~1,100 mm would lead to negative values. This demonstrates that the selected transport equations (Ackers-White) are unstable and inappropriate in these locations. The erroneous results are specifically noted in the NEPA DEIS which states that "there are some notable large changes to sediment substrate predicted at some single cross-sections in the model (I.e., near RM 98) which may be attributed to model uncertainties," (Appendix I; pg. 56). **However, the authors continue to use all the model results in their assessment without addressing how the errors and uncertainties lead to additional uncertainties in other results presented in the NEPA DEIS.**
5. Sediment transport model results presented throughout the NEPA DEIS are not consistent with one another, which draws the entirety of the results into question.
    a. Figure 6.2-6 of Appendix I presents predictions of cumulative sediment storage along the length of the model for the entirety of the baseline and with-FRE model scenarios. These results,

however, do not match those presented in Figure 6.2-3, which show the difference in sediment storage between baseline and with-FRE scenarios. For example, Figure 6.2-6 shows that a difference of ~250,000 tons in cumulative sediment storage between the two scenarios is predicted at the FRE structure location. However, results presented in Figure 6.2-3 only show a total cumulative change of ~130,000 tons, or roughly half of what is shown in Figure 6.2-6.

b. The difference between the figures was not explained in the NEPA DEIS and it is unknown whether any of the other results presented for the model are accurate or consistent with one another. This discrepancy highlights another example of pervasive issues with the model and resulting interpretation of the magnitude and intensity of impacts to the physical processes that create and sustain riverine, floodplain, and associated wetland habitats and their associated fish and wildlife species.

6. The model is not calibrated with bedload measurements and therefore the accuracy of the model is unknown - underscoring the fact that the entire model is inappropriately used to assess impacts. Sediment transport measurements are strongly advised in the scientific literature to evaluate any major river engineering project (e.g., Gaeuman et al. 2009) in order to determine the accuracy of the quantitative analyses used to assess the project's impacts. By not calibrating the model with bedload measurements, the accuracy of the model is unknown and so too are the conclusions about impacts based on it.
7. No measurements of suspended sediment have been taken since those reported by the USGS in 1971 and therefore it is unknown whether changes that have taken place in the watershed (e.g. timber harvest, road construction, development, landslides etc.) have influenced the sediment load. Because these measurements comprise the only field measurements used in the sediment load and rating curve calculations, their accuracy is unknown and so too are the conclusions reached by the model.
8. The sediment transport function in the model (Ackers-White) underestimates bed scour compared to scour monitor observations presented in the 2017 sediment transport report (Watershed GeoDynamics and Anchor QEA 2017). Because of this, more sediment transport would be expected to occur than what is simulated by the model. This would result in greater amounts of channel incision and less sediment storage downstream of the FRE facility than what is predicted by the model - further disconnecting the river from its floodplain.
9. The NEPA DEIS does not adequately communicate known uncertainties in sediment transport modeling to decisionmakers and presents the results as fact instead of qualifying them with error estimates. There are significant quantities of research on sediment transport theory and modeling that stresses the complexity and uncertainty of predicting sediment transport for natural rivers, particularly for long time periods. Sediment transport varies by orders of magnitudes due to exponential relationships influenced by factors such as grain size distributions, flow regimes and channel morphology (e.g., Hossain and Rahman 1998; Bisantino et al. 2010; Lu et al. 2020). This is reflected by conclusions of a study testing sediment transport formulas by Nakato (1990): "*The computed values, however, are found to deviate significantly from the measured values except for a very few cases. The test results clearly demonstrate how difficult a task it is to predict sediment discharges in natural rivers*." One example of the NEPA DEIS inadequately characterizing the potential uncertainty in the sediment transport model's results is in the use of the Ackers-White transport equations.

   Predictions made using the Ackers-White equations, like others in sediment transport, have a great deal of scatter when compared to actual sediment transport measurements, a fact that is only casually discussed in Appendix I. The uncertainty in predictions is far greater than the 20% used in the Appendix I sensitivity analysis. The Ackers-White equation is also very sensitive to the threshold of mobility which can be a source of substantial error (Meyer et al., 2009). However, the NEPA DEIS never attempts to quantify the sensitivity of the results due to the mobility threshold nor qualify the model's conclusions. The uncertainty is reflected in a recent publication by Petkovsek (2020) with recommendations to improve the accuracy and range of conditions in which the Ackers White equations can be used. By not addressing nor quantifying the error and uncertainty inherent in the transport equation used, the NEPA DEIS inappropriately presents the results of the model to decision makers and uses the findings to under-represent impacts to the riverine system.

Further, the model methodology makes no mention of the fact that it is well established that as the sand content in gravel bed rivers increases, it results in a major increase in bedload mobility (Wilcock et al. 2001; Wilcock and Crowe 2003; Curran and Wilcock 2005; Parker et al. 2007; Pitlick et al. 2009). This is very important to the sediment transport regime under proposed conditions with the FRE facility because the increase in fine sediment caused by the proposed facility would in turn increase bedload mobility in the river which would cause greater levels of incision to occur. Because the sediment transport model does not account for how increases in the sand content would influence bedload mobility, the results are inaccurate and cause impacts to be underestimated.

Finally, the model's assumption that bedload constitutes 10% of the total sediment load is contrary to the sensitivity analysis conducted for the model in the 2017 and 2019 sediment transport reports which assume 6% and 5% respectively (Watershed Geodynamics and Anchor QEA 2017; Watershed GeoDynamics 2019). The doubling of the bedload proportion assumption was done without explanation in the NEPA DEIS and would act to dampen the effects of the FRE facility on channel bed elevations by increasing the simulated amount of bed-forming coarse sediment delivered to the mainstem river through tributary inputs. If the values previously reported in the 2017 and 2019 reports were used, more channel incision and less sediment storage would be expected downstream of the proposed FRE facility.

10. The model fails to account for how changes to large wood loading within the Chehalis River as a result of proposed FRE operations would impact sediment transport. It is well known that wood influences sediment transport and storage, yet it is not addressed at all in Appendix I. The DEIS states that there would be high impacts to large wood loading, however this change was not incorporated into the sediment transport model. Reducing large wood loads would cause decreases in channel roughness and increases in sediment transport which would lead to habitat simplification and further degrees of channel incision and thus increased losses of floodplain connectivity – causing further amplification of impacts to waters, wetlands, and aquatic habitats. By omitting these changes from the model, the DEIS underestimates decreases in sediment storage downstream of the proposed FRE facility.
11. The model and assessment fail to analyze and include bank erosion as a source of sediment. The Chehalis River includes many banks composed of fine sediments that have mobility (erosion) flow thresholds well below those needed to mobilize bedload, yet no measurements of bank materials or analysis was done in the NEPA DEIS other than the analysis of historical channel migration which showed that bank erosion readily occurs at frequent peak flows (one to two-year recurrence or less - Appendix I; pg. 36). This type of analysis is particularly important for the reservoir area since it will have very large bank deposits of fine sediment and periodically lack vegetation. The exclusion of bank erosion as a source of sediment is another fatal flaw of the sediment transport model presented in the NEPA DEIS.

The Sediment Mobility Threshold is Flawed; Underrepresents Impacts to Sediment Transport, and Is Not Supported by Data

In addition to the flawed sediment transport model, the NEPA DEIS also utilizes an analysis of the sediment mobility threshold to quantify impacts to the sediment transport regime (Appendix I, 6.2.2.2, p. 44-46). This analysis too is flawed, underrepresents the actual impacts of the proposed FRE facility on sediment transport, and is contradicted by data presented in the NEPA DEIS and supporting background documents (Watershed Geodynamics and Anchor QEA 2017). **As detailed below, these errors result in underestimating impacts caused by the proposed FRE facility on sediment transport.**

The sediment mobility analysis fails to account for the non-linear relationship between flow and sediment transport by focusing only on the amount of time that sediment mobilizing flows would be disrupted by the FRE facility. The analysis also identifies a sediment mobility threshold that is higher than what is supported by the data and thus the impacts to sediment mobility presented in the NEPA DEIS are underestimated. If a more accurate and lower threshold had been utilized in the analysis, the proposed FRE facility would reduce flows capable of mobilizing sediment for longer than what is disclosed in the NEPA DEIS. Additionally, the sediment mobility analysis completely ignores the linkage between sediment mobility and bank erosion – a flaw that if it had been appropriately included, would result in an increase in channel migration (and associated property damages) and an increase in fine sediment recruitment from banks.

In addition to the sediment transport issues detailed in the *SEPA Cascade of Ecosystem Effects Technical Memo* and presented herein, the NEPA DEIS presents multiple additional flaws specific to the analysis of sediment mobility:

1. The sediment mobility threshold analysis does not quantify the true impacts of the proposed FRE facility on sediment mobility by failing to incorporate the non-linear relationship between flow and sediment transport as shown in the sediment rating curve presented in the NEPA DEIS into the analysis (Appendix I; Figure 5.4-2). The analysis in the NEPA DEIS solely presents the difference between the amount of time the sediment mobility threshold would be exceeded under baseline and FRE conditions and states that because the impact is expected to average to 2.7 hours/year over the 30 period that *"...the effects of the flood retention facility (changes in sediment transport regime) would be limited to a short period of time per given year and would not likely be high,"* (Appendix I; pg. 46). While the NEPA DEIS does state that *"...sediment transport is not a linear dynamic and that the magnitude of flow above the transport threshold may or may not play a role in the long-term transport capacity of the river system,"* (Appendix I; pg. 46), it makes no effort to quantify the impact that would have on the river.

   To better quantify this impact, we estimated the total potential sediment load transported by the 1996 and 2009 storm events using the sediment rating curve (Appendix I; Figure 5.4-2) and the FRE operation outflow hydrographs presented in Figure 3.8 of Watershed Geodynamics and Anchor QEA 2017. Our results (Table 1) demonstrate that sediment transport capacity would be reduced between 63-65% for these two example storms – a **finding that demonstrates far greater impacts than what are disclosed in the NEPA DEIS**. This analysis underscores that by focusing solely on the duration of impact and not the magnitude in the sediment mobility threshold analysis, the NEPA DEIS underestimates the total impacts of the proposed FRE facility on sediment transport in the Chehalis River.

Table 1: Analysis of the proposed FRE facility's impact on sediment mobility for the 1996 and 2009 storm events*

STORM EVENT	TIME THAT FLOW IS ABOVE SEDIMENT MOBILITY THRESHOLD (4,000 CFS AT FRE SITE) (HOURS)		TIME THAT FLOW IS ABOVE SEDIMENT MOBILITY THRESHOLD IS REDUCED BY FRE OPERATIONS (HOURS)	ESTIMATED SEDIMENT LOAD FROM STORM EVENT (TONS)		PERCENT REDUCTION IN ESTIMATED SEDIMENT LOAD BY FRE OPERATIONS
	BASELINE CONDITION	*FRE CONDITIONS*		*BASELINE CONDITIONS*	*FRE CONDITIONS*	
1996	73.5	45	28.5	123,000	43,000	65%
2009	42.5	26	16.5	69,000	25,000	63%

*Analysis conducted by NSD as part of this memo.

2. The NEPA DEIS analysis also failed to consider how increases in the percentage of sand would influence the sediment mobility threshold despite the NEPA DEIS acknowledging that sand inputs to the river will increase as a result of FRE operations through an increase in landslides and fine sediment inputs (e.g. section 6.2.3.3 in Appendix I). It is well known that the percentage of sand on the channel bed directly influences the sediment mobility threshold in gravel bed rivers (as percentage of sand increase, total quantity of bedload transport increases (e.g., Wilcock et al. 2001; Wilcock & Crowe 2003; Curran and Wilcock 2005; Parker et al. 2007; Pitlick et al. 2009). Because of this, the acknowledged (though underestimated) increase in fine sediment (e.g. sand) as a result of FRE operations would decrease the sediment mobility threshold and thus increase the impacts on sediment transport caused by the proposed FRE facility. By not accounting for how sand influences sediment transport, the NEPA DEIS underestimates impacts on sediment transport.
3. The results of the 2015 scour monitor study demonstrate that sediment is mobilized at flows less than the 6,000 cfs threshold presented in the DEIS (Watershed Geodynamics and Anchor QEA 2017). In that study, a flow of 5,840 cfs at the Doty gage mobilized sediment as large as 64mm in the area downstream of the proposed FRE facility. Because the median grain size of the channel bed of the monitored reaches is below 64mm, this indicates that much of the channel bed was likely mobilized at a flow lower than 5,840 cfs – a threshold much lower than that presented in the NEPA DEIS. Using a more accurate, lower value for the sediment mobility threshold would increase the amount of time that FRE facility operation reduces geomorphically significant flows and thus by performing the impact analysis on the higher, inaccurate threshold, impacts are underestimated.
4. The sediment mobility threshold analysis ignores the linkage between sediment mobility and bank erosion. The NEPA DEIS states that bank erosion "*occurs even during small peak streamflows with a recurrence interval of 1 to 2 years*" (Appendix I; pg. 36) - flows that will still be experienced in the Chehalis River under proposed FRE facility operation. Because current bedload sediment will be stored behind the FRE facility, there will be more stream power within the river during these flows to act on the banks. This will likely cause an increase in bank erosion over baseline conditions. Despite these linkages, bank erosion was not analyzed as part of the sediment mobility analysis and thus impacts are underestimated.

NEPA DEIS Underestimates the Increase in Fine Sediment Caused by the FRE Facility

The NEPA DEIS states there will be 'low-to-high' impairment of aquatic habitat (Appendix K; pg. ES-6-7) due to increases in fine sediment and turbidity caused by the proposed FRE facility. However, because of flaws in the supporting analyses, underestimation of sediment input due to landslides and bank erosion, and improper application of conclusions presented elsewhere in the NEPA DEIS, **there is likely to be greater amounts of fine sediment transported downstream of the proposed FRE facility than what is disclosed in the NEPA DEIS**. Operating a reservoir in an area of extremely unstable and erodible geology will increase fine sediment (sand, silt, clay) inputs to the river that will be readily transported through the low level outlets at flows far below the threshold needed to mobilize coarse bedload (I.e. gravel, cobble). These fine sediment inputs will increase the frequency and duration of river turbidity, adversely impacting water quality, suffocating salmonid eggs, freshwater mussels, and amphibian larvae, and altering the nature and functions of floodplain wetlands – all of which would result in greater impacts to water quality, aquatic species, instream habitats, and floodplain wetlands than what is presented.

Studies have shown that many aquatic species exhibit varying degrees of sensitivity to increases in fine sediment. Anthropogenically induced siltation has been identified as a contributing factor to freshwater mussel declines in many watersheds across the country. It has been demonstrated that the species composition and abundance of Unionid mussels can be directly linked to bed sediment composition and distribution. The clogging of gills, interference in the filter-feeding process, hindering the ability to burrow, and the reduction of light available for photosynthesis by mussel prey items are among the many detrimental effects that can be attributed to increases in fine sediment (Box and Mossa 1999, Bogan 1993, Dennis 1984). Some in-stream and stream-associated amphibian species (including Tailed frogs, Western toads and some species of salamanders, among others) have been shown to be similarly susceptible to increases in fine sediment, affecting species distribution and abundance (Welsh et al 2019, Wood and Richardson 2009, Welsh and Lind 1996, Welsh and Hodgson 2008). This is especially true for individuals in the larval stage of development, as they are water dependent and can be detrimentally impacted by some of the same mechanisms as freshwater mussels. Studies have shown that sedimentation can reduce larval anuran abundance, growth, and development rates and, under high sediment load conditions, can even depress survival rates (Wood and Richardson 2009, Welsh et al 2019).

Because of the sensitivity of these resources to fine sediment, the flaws in the NEPA DEIS impact assessment of changes to fine sediment are presented explicitly below:

1. The NEPA DEIS sediment transport model is flawed (see above) and thus underestimates the input and transport of fine sediment both upstream and downstream of the proposed FRE facility.
2. Increases in the frequency and magnitude of landslides and hillslope erosion as a result of construction and operation of the FRE facility, and therefore sediment delivery to the portion of the Chehalis River within the reservoir footprint, are drastically underestimated.
    a. Vegetation clearing through the proposed reservoir and subsequent water fluctuations due to flood impoundment will decrease the stability of the surrounding hillslopes and cause a greater degree of landslides and hillslope erosion (see *SEPA Geology Technical Memo*, and *SEPA Cascade of Ecosystem Effects Technical Memo*). This will result in a greater amount of fine sediment delivered to the Chehalis River over baseline conditions and thus greater impacts to aquatic species and habitats and wetlands.
3. The NEPA DEIS analysis used to quantify the amount of fine sediment eroded from the reservoir during a rainstorm immediately after an impoundment is uncalibrated and does not produce realistic results (Appendix I; 6.2.3.3; from Watershed GeoDynamics 2019). The model was used to assess how much sand (as a surrogate for all fine sediment) would be transported into the river if a 10-year rainfall event occurred while the slopes of the reservoir were completely bare. The analysis uses low (5%) and high (60%) estimates of slope to bracket the results and predicts that 100 to 6,000 tons of sediment would be transported. It appears no effort was made to calibrate or contextualize these results and a commonsense evaluation reveals that they are unrealistic. If those levels of erosion occurred evenly across the entire reservoir, the depth of erosion would be miniscule (I.e. 0.0006 inch for the low scenario and 0.04 inch for the high scenario). Put into context, the upper bound erosion depth is the size of a grain of coarse sand. In reality, erosion depths would locally be much deeper with deep gullies likely forming in addition to surface flow of eroded material.
    a. Soil erosion potential for much of the reservoir area and its contributing hillslopes is considered "very severe" by the USDA Natural Resources Conservation Service (NRCS) (NRCS 2020). Based on the Web Soil Survey website estimates, average annual soil erosion from the reservoir slopes would be 2,000-3,000 tons under existing forested conditions. The bare slopes of the reservoir area would increase those numbers more than 10 to 1,000-fold and cause landslides and gullies to propagate well upslope of the maximum pool elevation (Cerda, 1999; Cerdan et al, 2010; *SEPA Geology Technical Memo*; *SEPA Cascade of Ecosystem Effects Technical Memo*).
    b. These estimates illustrate that the predictions put forth in the NEPA DEIS drastically underestimate the increase in fine sediment caused by the proposed FRE structure's presence

and operation. If erosion depths and rates were more realistic, far greater volumes of fine sediment transport into the river would be predicted from the reservoir – causing far greater impacts to aquatic habitat, wetlands, and geomorphic processes than are disclosed in the NEPA DEIS.

4. Inputs of fine sediment from potential increases in bank erosion caused by the proposed FRE facility are not acknowledged and not incorporated into the impact assessment. As discussed previously, it is likely that bank erosion will increase over baseline conditions because there will be more stream power to act on banks due to decreases in bedload sediments and flows capable of initiating bank erosion will still be passed by the facility. This will result in a greater amount of fine sediment delivered to the Chehalis River over baseline conditions.
5. Consequences of changes in downstream fine sediment from the sediment transport model were not explicitly presented in the Geomorphology discipline report (Appendix I). However, the Aquatic Species and Habitat impact assessment (Appendix K) specifically cites Appendix I while discussing the fine sediment related impacts and limiting the downstream extent of those impacts caused by the proposed FRE facility to river mile (RM) 86 (Appendix K; pg. 92). **Because the flawed sediment transport model did not explicitly evaluate fine sediment, it cannot be used to determine fine sediment related impacts to aquatic species and habitats, and thus the DEIS statements regarding fine sediment related impacts to aquatic species and habitats are unsubstantiated by any analysis and cannot be used to draw conclusions regarding intensity, scale, or duration of impacts.**

Impacts to Waters and Wetlands

NEPA DEIS Fails to Consistently and Accurately Quantify Impacts from Construction

All impacts to waters and wetlands must be quantified for impacts to be disclosed, considered, and adequate and appropriate mitigation developed. **The NEPA DEIS fails to quantify and characterize the permanent, temporary, indirect, and cumulative impacts from construction and operation of the proposed project consistently and accurately.** This prevents regulatory decision makers from having an accurate accounting of the impacts to acres, process, and function that would occur to waters and wetlands as a consequence of the proposed project, should it be authorized. For example:

1. The NEPA DEIS states that excavation, fill placement, dewatering and tree removal within the reservoir are direct, permanent impacts on wetlands (DEIS page 101, Table 4.4-1). However, only 1.23 AC of direct permanent impact to wetlands are included in Executive Summary (page ES-8), rather than 7.62 AC of permanent impacts to wetlands as calculated from the acres disclosed in DEIS Chapter 4.4 and Appendix J.
2. The NEPA DEIS states that excavation, fill placement, dewatering and tree removal within the reservoir are direct, permanent impacts on waters (DEIS page 104, Table 4.4-2). However, only 4.8 AC of direct permanent impact to waters are included in Executive Summary (page ES-8), rather than 96.3 AC of permanent impacts to waters as calculated from the acres disclosed in DEIS Chapter 4.4.
    a. Appendix J (page 69 Table 6.4-11) presents twice the area of direct impacts to waters from excavation, fill and haul (5.42 AC) and presents a calculated total of 99.07 AC of permanent impacts to waters as a result of excavation, fill placement, dewatering and tree removal within the reservoir.
    b. Impacts resulting in permanent loss or change in type or function of '10 or more acres of other waters' should be characterized as a HIGH impact, per Table 4, Appendix E, page E-5, rather than as 'MEDIUM' scale impacts as stated on page 104 of the DEIS.

3. The NEPA DEIS states that excavation and fill placement would result in 11.2 AC of direct impacts on buffers but reports these impacts to buffers from tree removal within the reservoir as 'disturbance' (DEIS page 105). Thus, only 11.2 AC of direct permanent impact to buffers are included in Executive Summary (page ES-8), rather than 351.56 AC of impacts to buffers as calculated from the acres disclosed in DEIS Chapter 4.4 and Appendix J (I.e. 11.2 + 340.44 AC 'disturbance').
    a. Impacts resulting in permanent loss or change in type or function of '10 or more acres of wetland or other water buffers' should be characterized as a HIGH impact, per Table 4, Appendix E, page E-5, rather than as 'MEDIUM' scale impacts as stated on page 105 of the DEIS.
4. The NEPA DEIS executive summary (page ES-8) fails to include the 4.54 acres of impacts to wetlands and 16.61 acres of impacts to buffers from the Airport Levee improvements that are disclosed in Appendix J (App J page 71 Section 6.4.1.2).
    a. The DEIS states that "*Although vegetation in the wetland buffer would be temporarily affected by such maintenance activities as mowing and weed control, no impact on wetlands are expected to occur*" (App J, page 74, Section 6.4.2.2) without any justification; this conclusion is contrary to best available science on the role of adequate buffers in maintaining the functions and services of wetlands (Hruby 2013).
5. The NEPA DEIS specifically acknowledged, but did not quantify, impacts from diversion of Mahaffey Creek during FRE facility construction (DEIS, page 105). The NEPA DEIS failed to quantify direct temporary impacts to the creek and temporary impacts to associated wetlands and buffers from vegetation clearing and diversion techniques (App J page 60). Similarly, the NEPA DEIS acknowledges there would be a *"higher potential for damage to the flow diversion structures in Mahaffey Creek due to the projected increase in the frequency of high flows"* but fails to analyze the implications of these impacts to wetlands, waters, or aquatic resources in any way (Appendix J, page 60).
6. The NEPA DEIS acknowledges, but fails to quantify, 'low' impacts from erosion/sedimentation/chemical releases and spread of invasive plant species for FRE facility construction or construction of the Airport Levee (DEIS page 106).

NEPA DEIS Fails to Appropriately Attribute Impacts to the Operation of the Facility

All impacts from operation of the FRE facility are directly attributable to the consequences of the facility and should have been given a 'hard look' under NEPA. **The NEPA DEIS inaccurately characterizes the impacts from reservoir inundation and recurrent tree harvest in the reservoir as 'indirect' operational impacts even though they are an integral and direct component of the operation of the FRE facility.** The DEIS also fails to accurately represent the scale and intensity of operational impacts based on the thresholds (I.e. low, moderate, or high) established in the NEPA DEIS in Appendix E. Such impacts should have been characterized as **permanent, directly attributable to the proposed project, and subject to requirements for compensatory mitigation of area and function**.

For example:

1. The NEPA DEIS executive summary fails to acknowledge ANY impacts to wetlands, waters, and their buffers from FRE facility operation (page ES-8), yet 9.62 AC of impact to wetlands, 112.78 AC to waters and 487.04 AC of impact to buffers are stated as a consequence of reservoir inundation and recurrent tree harvest during operation of the FRE facility in DEIS Chapter 4.4 and Appendix J.
2. The 112.78 AC of impacts to waters (total calculated from DEIS page 108) from reservoir inundation and recurrent tree harvest are improperly categorized in DEIS Chapter 4.4 and Appendix J as 'Low indirect' impacts. Based on the thresholds the DEIS established in Table 4, Appendix E, page E-5, the scale of such impacts is such that they should have been characterized as a HIGH impact (per Table 4 Appendix E,

"*impacts resulting in permanent loss or change in type or function of 10 or more acres of waters*" should be characterized as a HIGH impact).

3. The 487.04 AC of impact to buffers (total calculated from DEIS page 109) are incorrectly characterized in the DEIS as a 'Low to Medium indirect impact'. Based on the thresholds the DEIS established in Table 4, Appendix E, page E-5, the scale of such impacts are such that they should have been characterized as a HIGH impact (per Table 4 Appendix E, "Impacts resulting in permanent loss or change in type or function of 10 or more acres of wetland or waters buffers" are defined as a HIGH impact.
4. The NEPA DEIS fails to consider the potential additional impact to wetlands and waters of back-to-back floods when the FRE facility is in operation. This potential additional impact with back-to-back floods is acknowledged in the DEIS (DEIS pages 108-109, Section 4.4.3.3.2) but it is not factored into the impact determination or acres of impacts from the operation of the FRE facility. See also *NEPA Climate Change Addendum* regarding the underestimation of the frequency of peak flows that would trigger operation of the FRE facility under current conditions, and the failure of the NEPA DEIS to quantitatively incorporate the reality of climate change into the impacts analysis.
5. The NEPA DEIS acknowledges, but fails to quantify, the loss of wetlands, change in vegetation composition, and loss of water storage which would occur in event of landslides triggered during reservoir draw down and from sediment deposition during reservoir impoundment and draining (DEIS page 108; and see comments above regarding errors related to the geomorphic model, sediment transport, and fine sediment impacts). The NEPA DEIS instead incorrectly indicates in the DEIS Executive Summary (page ES-8) that ZERO impacts from FRE facility operation would occur.
6. The NEPA DEIS acknowledges, but fails to quantify, operations impact to wetlands and waters at the Airport Levee from continued vegetation disturbance in the form of mowing and weed control (DEIS page 109). In contrast, the SEPA DEIS acknowledged 44.2 acres of 'disturbance' impacts to wetlands and waters buffers as a result of operation of the Airport Levee.

DEIS Fails to Appropriately Represent Impacts to Riverine Processes within the 100-Year Floodplain

The NEPA DEIS relies on inaccurate hydraulic and geomorphic modeling to project impacts on downstream floodplain wetlands and waters, fails to utilize climate change projections to assess impacts, and presents a simplistic and inaccurate picture of the magnitude and intensity of impacts that will result from modifying the flow of water, sediment, and wood once the Chehalis River is confined to flowing through the low-level outlets of the proposed FRE facility.

The *SEPA Cascade of Ecosystem Effects Technical Memo* discusses in detail the flaws inherent in the methodology used for the downstream wetlands and waters impact analysis. **These same fundamental flaws in the impact analysis methodology also occur in the NEPA DEIS.** The NEPA DEIS states:

> *"For downstream areas, impact analysis was based on the Chehalis River Basin Flood Damage Reduction Project: Downstream Floodplain Wetland Analysis (Anchor QEA 2019c), which looked at **how changes in downstream flood inundation area** under both existing conditions and with the proposed flood retention facility and Airport Levee Improvements in place **could affect floodplain wetlands**" (*App J Section 6.2.2 page 51; emphasis added).

As was true in the SEPA DEIS, **the NEPA DEIS inappropriately represents changes to flood inundation area as being the sole factor indicative of impacts to the complex network of riverine processes within the 100-year floodplain that sustain existing wetlands and waters and continuously form new wetlands and waters over time.**

Further, **the NEPA DEIS underestimates the downstream impact on groundwater and wetlands by using inappropriate groundwater recharge rates and a rudimentary groundwater-surface water analysis.** The analyses fail to account for the ways in which reduced groundwater recharge and storage will amplify climate change projections for lower summer streamflow and higher summer stream temperatures affecting water quality, water quantity, and aquatic habitat, as well as the extent and nature of wetlands and waters. The *SEPA Hydrology Technical Memo 2* details the shortcomings of the groundwater analysis and the underestimation of downstream impacts to wetlands and aquatic habitat.

The NEPA DEIS fails to characterize the pervasive cascade of impacts to wetlands and waters downstream of the proposed FRE facility as operational impacts even though they are the direct result of the operation of the FRE facility. The DEIS also fails to accurately represent the scale and intensity of these impacts based on the thresholds (I.e. low, moderate, or high) established in the DEIS in Appendix E. Downstream impacts to the area and function of the 100-year floodplain, its wetlands and waters, and associated habitats should have been characterized as **permanent, directly attributable to the proposed project, and subject to requirements for compensatory mitigation of area and function**.

For example:

1. The NEPA DEIS characterizes 100-year floodplain impacts to wetlands as a low, 'indirect' impact and floodplain wetlands are characterized as not reliant on flooding as a 'supportive source of hydrology'. The DEIS states that no effect on groundwater would occur; therefore, there would be no loss of wetlands (DEIS page 109). This conclusion and the analysis on which it is based is fundamentally incorrect, is based on static inundation modelling, underestimated frequency of peak flow events that would trigger FRE operation, underestimated recharge rates, and reflects a lack of appropriate application of basic tenants of fluvial geomorphology (see the detailed explanation of these failings presented in the *SEPA Cascade of Ecosystem Effects Technical Memo*).
2. The NEPA DEIS statement that "groundwater, surface runoff, and precipitation would not be affected by FRE facility operation" (DEIS page 109) is grossly inaccurate and based on a fundamental misrepresentation of fluvial processes, the use of inappropriate groundwater recharge rates, and a rudimentary application of groundwater-surface water analysis – all applied without the integration of climate change projections (see detailed explanation presented in the *SEPA Cascade of Ecosystem Effects Technical Memo*).
3. The NEPA DEIS obfuscates the scale and intensity of downstream impacts on 100-year floodplain wetlands by failing to include these impacts in any of the impact tables for the proposed project, despite the fact such impacts were considered (albeit insufficiently as described further herein) and quantified within the DEIS in the text of Appendix J (pages 76-77, Tables 6.4-14 and 6.4-15, Section 6.4.2.3).
4. The NEPA DEIS inaccurately categorized operational impacts to hundreds of acres of floodplain wetlands (App J pages 76-77, Tables 6.4-14 and 6.4-15, Section 6.4.2.3) as a 'low indirect' impact (DEIS page 109). Impacts to hundreds of acres of floodplain wetlands as a direct consequence of the proposed project is a HIGH degree of impact per the thresholds established in the DEIS in Table 4, Appendix E, page E-5.
5. The NEPA DEIS stated that extent and depth of overbank flooding would be reduced but 'would not result in a measurable effect on wetland area and function'. This statement is made despite the fact that the proposed FRE facility would dramatically reduce the extent of floodplain inundation, a natural process that occurred for millennia in valleys of the Chehalis Basin as demonstrated by historic homesteader accounts, which clearly describe the frequent and extensive inundation that occurred in the Chehalis River valley, particularly in vicinity of Centralia and Chehalis, as well as numerous tributaries (Smith 1941). Appendix J, page 75, Section 6.4.2.3 similarly outlines the false premise that downstream wetlands would be unaffected as follows:

> *"For larger floods with a recurrence interval of 7 years or more, however, operation of the FRE facility would change flooding in wetlands and other waters in the outer portion of the floodplain. Areas located beyond the edge of the 7-year flood inundation extent are most likely to be affected by such changes. Those portions of the floodplain are only inundated during major or larger floods. Wetlands typically need water for 2 weeks of the growing season every year to exist so wetlands in these areas are not reliant on flooding for hydrology. Therefore, no wetlands would be eliminated due to lack of water in those locations. However, because the FRE facility would retain water during events that would flood those areas, the extent and depth of inundation in those wetlands and other waters would be less than under the No Action Alternative. Operation of the FRE facility would not completely eliminate flooding in those areas, as flows with the potential to generate major and catastrophic flooding in the Chehalis River can originate from other tributaries in the upper Chehalis Basin (e.g., Skookumchuck and Newaukum rivers)."* (Appendix J, page 75 Section 6.4.2.3)

However, Appendix J (pages 76-77, Tables 6.4-14 and 6.4-15, Section 6.4.2.3) quantifies the acres of wetlands within the 100-year floodplain that would no longer be inundated with the proposed project:

- "With FRE operation, between 223 and 373 AC of [downstream] floodplain wetlands would no longer be inundated by a 10-yr flood…
- …With FRE operation, between 334 and 532 AC of [downstream] floodplain wetlands would no longer be inundated by a 100-yr flood…
- …With FRE operation, 4.2 AC of [upstream] floodplain wetlands disturbed by prolonged inundation during operation…"

Floodplain waters and wetlands are dependent upon the underlying geomorphic and hydrologic processes that generate and maintain these dynamic riverine landscapes. The NEPA DEIS, and SEPA DEIS, both state that although hundreds of downstream acres will no longer be inundated as a direct result of the existence and operation of the proposed FRE facility, there will be 'no impact' to these waters and wetlands because they somehow only function when inundated by flood waters at a frequency greater than the 7-year return interval. Floodplain waters and wetlands are dynamic and dependent upon the regular hydrologic and geomorphic disturbance regime for their ecological state and functional characteristics. **To simply state there will be no resulting impacts over time is an egregious error, as these generating processes will be altered if the Chehalis River is forced to flow through the low-level outlets and its water and sediment regimes altered by the FRE facility.** To appropriately assess the implications to the area and function of downstream waters and wetlands would take a detailed study of the historic development of these waters and wetlands, that is, how they were formed and how they change in area and function over time.

Downstream geomorphic and hydrologic processes—erroneously characterized in the NEPA DEIS and supporting geomorphic studies—have direct impacts on the status and functioning of floodplain water bodies and wetlands which illustrate the cascade of effects resulting from impacts to the river's hydraulics and sediment supply:

1. Downstream channel incision results in a hydrologic disconnection of channel surface waters with side channels, sloughs and wetlands, resulting in impacts through alterations of hydroperiod (I.e. the frequency and duration of inundation and soil saturation) (Brummer et al. 2006; Cluer and Thorne 2014; Amoros and Bornette 2002). Changes in hydroperiod result in alterations in the suite of functions and services that can be performed by the wetland or water.
2. Channel incision leading to decoupling of direct surface water and floodplain hydrologic connectivity will result in loss of in-channel recharge from adjacent, formerly linked, shallow alluvial aquifers. The loss of both floodplain alluvial aquifer water storage and recharge functions indirectly leads to impacts on river baseflows, especially during summer low flows.

Implications for Compensatory Mitigation of Wetlands and Waters

Under Section 404 of the Clean Water Act, operational impacts to the area and function of downstream waters and wetlands would also result in a loss of wetlands and waters, just as direct discharge of fill, requiring compensatory mitigation. Without an adequate and accurate geomorphic and hydrologic analysis, an accurate assessment of the totality of impacts to wetlands and waters cannot be made. Therefore, the extent and nature of compensatory mitigation for potential loss of area and function of waters and wetlands cannot be formulated or evaluated.

However, it can be said *a priori* that alteration of floodplain water body and wetland inundation frequency and soil saturation will affect wetland physical, biogeochemical and habitat functions. **Impacts to downstream floodplain waters and wetlands as a direct result of the operation of the proposed FRE facility would be a HIGH degree of impact (per the thresholds established in the DEIS in Table 4, Appendix E, page E-5) and would compound and amplify over time, and therefore be unmitigable.**

The DEIS fails to accurately or consistently state the cause and type of impact (I.e. direct, indirect, compounded over time) to waters and wetlands. Gross inconsistencies, as described herein, between Chapter 4.4 and Appendix J render the decision maker incapable of understanding the true scope and scale of impacts to area and function. Mitigation cannot be appropriately proposed, or its potential efficacy considered, unless the mechanism of impact is accurately represented. Many impacts to both area and function of waters and wetlands have not been appropriately represented in the NEPA DEIS.

For example:

1. Permanent conversion of 6.39 AC of Category II and III forested wetlands to scrub-shrub emergent wetlands from tree removal activities is acknowledged (DEIS page 104), as is the removal of canopy cover which would make areas more susceptible to colonization of invasive species, and alterations in surface and subsurface drainage patterns routing water to wetlands. While the area of impacts is acknowledged, the functional loss is an <u>additional</u> impact that would require compensatory mitigation.
2. The majority of permanent, direct FRE facility construction impacts (1.15 AC of 1.23 AC as totaled in the NEPA DEIS) would occur to Slope wetlands (App J page 57, Table 6.4-4). Slope wetlands provide unique functions and can be challenging to mitigate for given their unique landscape position and complex hydrologic regimes (National Research Council 2001; Gwin et al 1999). Slope wetlands are a hydrogeomorphic class that is particularly challenging to recreate; compensatory mitigation is unlikely to completely mitigate for these types of wetlands and thus the proposed project is likely to cause a loss of area and function of slope wetlands.
3. While the acres of impact to buffers (340.44 AC as reported in Appendix J page 69; 487.03 AC as reported in Appendix J page 74) are acknowledged as a permanent impact, the significant consequence for the functioning of wetlands and waters as a result of 90% of their buffers being cleared of trees is not acknowledged and would need to be factored into compensatory mitigation.

CONCLUSIONS

The fundamental flaws, errors, and issues presented in the *SEPA Cascade of Ecosystem Effects Technical Memo* still exist within the NEPA DEIS. It is our conclusion that the impacts to the fundamental processes which create and sustain waters and wetlands, floodplains, and aquatic ecosystems are insufficiently and inaccurately analyzed, and are underrepresented in the NEPA DEIS, as are the consequent impacts to fish and wildlife species (including declining populations of Chehalis basin salmonids), communities, and habitats.

Overall, the NEPA DEIS fails to consider, analyze or characterize the physical and ecologic process linkages inherent in riverine ecosystems and thus fails to consider the consequent impacts of the cascade of ecosystem effects and the amplification of those effects over time that will result from the proposed project.

Significantly, the sediment transport model is fundamentally flawed and contains many errors, omissions, flawed assumptions, an inappropriate calibration, a sensitivity analysis that does not reflect the variability and uncertainty in sediment transport predictions and fails to apply the best available science. The model is the primary analysis tool used to assess impacts to geomorphic processes as a result of the proposed FRE facility and is thus also a fundamental quantitative tool used by which impacts to those processes are incorporated into the impact assessments on aquatic habitat, fish populations, and wetlands and waters. Because the sediment transport model is fundamentally flawed, so too are all the impact assessments that rely upon it, particularly the NEPA DEIS interpretation of the magnitude and intensity of impacts to the physical processes that create and sustain riverine, floodplain, and associated wetland habitats and their associated fish and wildlife species.

Further, the failure to incorporate climate change projections (see *NEPA Climate Change Addendum*), along with flawed hydrological analyses for current conditions, results in an underestimation of the frequency and duration of operation of the proposed FRE facility. By disrupting the natural flow regime, the proposed FRE facility will subsequently impact all other river processes related to geomorphology, aquatic habitat, wetlands, and water quality. Despite the fundamental importance of accurately representing impacts to the flow regime in all impact assessments, the NEPA DEIS underestimates the frequency and duration of impacts and thus all subsequent impacts are underestimated.

Therefore, it is our conclusion that the proposed project will result in a cascade of impacts to both existing floodplain/off-channel water bodies and wetlands, as well as a loss of the physical processes that create and sustain the future formation of floodplain wetlands and floodplain/off-channel water bodies, resulting in a significant, unmitigable amplification of impacts over time.

Specific Conclusions

Specifically, we conclude that:

1. The NEPA DEIS inaccurately and misleadingly refers to the FRE facility as having a "temporary" reservoir and uses on that characterization as a key factor in the analysis of the proposed project impacts.
    a. The impoundment of the river, the effect on its hydraulics and sediment transport, and the effects within the 856-acre reservoir area are significant and continuously recurring impacts for as long as the facility is in operation.
2. The NEPA DEIS fails to consider, analyze, or appropriately characterize the physical and ecological process linkages inherent in riverine ecosystems. The consequent cascade of ecosystem effects and the amplification of those effects over time that will directly result from operation of the proposed project are not adequately analyzed or disclosed.
    a. The NEPA DEIS underestimates impacts to the hydrologic and sediment supply processes.
        i. The frequency and duration of reservoir impoundment are underestimated for both current and future climate conditions.
        ii. Increases in the frequency and magnitude of landslides and hillslope erosion, and therefore sediment delivery, are drastically underestimated.
        iii. Impacts to channel morphology, sediment transport, wetlands, riparian vegetation, and aquatic habitat are consequently underestimated.
        iv. Compounding impacts that result from the interactions and feedback between processes and the consequent amplification of impacts over time are not considered.

3. The sediment transport model is fundamentally flawed and contains errors, omissions, flawed assumptions, an inappropriate calibration, a flawed sensitivity analysis, and fails to apply the best available science. The model is a primary analysis tool used to assess how impacts to geomorphic processes affect aquatic and terrestrial species and habitats. Because the model is fundamentally flawed, so too are all the impact assessments that rely upon it.
4. The NEPA DEIS fails to account for the ways in which climate change projections for increased frequency and magnitude of peak flows of all sizes will affect sediment transport and therefore will exacerbate downstream channel incision and all related impacts to habitat-forming processes and habitat quality.
5. The NEPA DEIS fails to account for climate change and thus for the ways in which impacts of lower summer streamflow will be amplified by downstream impacts of the FRE facility, including to floodplain inundation, groundwater recharge, and aquatic habitats with the exacerbation of lower summer streamflow and higher summer stream temperatures.
6. The magnitude and nature of impacts wetlands and waters is inaccurately and inconsistently reported in the DEIS and its supporting documents and the analyses inaccurately characterize linkages between flood events and the formation and maintenance of floodplain water bodies and wetlands.
7. The NEPA DEIS underestimates the impacts to waters and wetlands because it contains significant errors and underestimations in the impacts to the physical processes that shape the downstream riverine, wetland, and floodplain ecosystems.
    a. Reductions to groundwater recharge are underestimated based on underestimated frequency of peak flow events that would trigger FRE operation and underestimated recharge rates.
    b. The hydrologic connection between groundwater and surface water is inadequately and inappropriately analyzed, resulting in underestimated impacts to floodplain water bodies, wetlands, and baseflow. Inappropriate groundwater recharge rates and a rudimentary groundwater-surface water analysis were improperly utilized to consider impacts.
    c. Impacts to downstream sediment transport processes and coarse sediment supply are underestimated due to flawed modeling assumptions.
    d. The increase in fine sediment supply from increased frequency and magnitude of landslides and hillslope erosion, and thus, downstream impacts of fine sediment to aquatic habitats are underestimated.

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