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Comments on the Alaska Energy Authority's Initial Study Report, 2014 technical memorandum, and supplemental filings and recommended proposed modifications, Susitna-Watana Hydrologic Project No. 14241-000	**SuWa 294**

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Secretary
Federal Energy Regulatory Commission
888 First Street, NE
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June 23, 2016

RE: Comments on the Alaska Energy Authority's Initial Study Report, 2014 Technical Memorandum, and Supplemental Filings and Recommended Proposed Modifications, Susitna-Watana Hydrologic Project No. 14241-000.

On behalf of Susitna River Coalition, Talkeetna Community Council, Alaska Survival, Talkeetna Defense Fund, Alaska Center, Trout Unlimited, and Wild Salmon Center we offer comments and proposed modification to the Alaska Energy Authority's studies that support the development of the Riverine Model including Baseline Water Quality (5.5), Water Quality Modeling (5.6), Fluvial Geomorphology (6.5), Fluvial Geomorphology Modeling (6.6), Groundwater (7.5), Ice Processes (7.6), Fish and Aquatics Instream Flow (8.5) and Riparian Instream Flow (8.6).

AEA is in the process of conducting a total of 58 FERC approved studies to collect the information needed to support a license application. The studies are designed to collect baseline information on the Susitna River and the fish, wildlife, botanical resources and other recreational, aesthetic and cultural resources that may be impacted under post-project conditions. Perhaps even more importantly, the information collected will also be used to support the environmental analysis and describe cumulative adverse impacts to the Susitna River and critical habitats. 18 CRF §5.18(b). To assess the impacts of the proposed Susitna dam, AEA intends to use a variety of models to predict how conditions will change based on the baseline data collected during this study phase.

On June 4, 2014, the Alaska Energy Authority (AEA) filed its Initial Study Report (ISR). Pursuant to Federal Energy Regulatory Commission's (FERC) Integrated Licensing Process (ILP) regulations, the ISR details AEA's "overall progress" in implementing the FERC approved study plan and reports on the data collected. 18 CFR §5.15(c)(1). For this particular project, in addition to the initial ISR filing, FERC also determined that AEA's 2014 Technical Memorandum and other supplemental study implementation reports and study completion reports filed later by AEA also "serve the intent of the ISR" and are reviewable during this comment period.[1]

As the first of two major scientific peer-review ILP milestones, licensing participants now have the opportunity to review the ISR and file comments and proposed "modifications to

[1] FERC Letter, ILP Process Plan and Schedule, Project No. 14241-000, December 2, 2015.

ongoing studies or new studies." 18 CFR §5.15(c)(4). Proposed modifications must be made with a showing of "good cause" and must include a "demonstration that (1)[a]pproved studies were not conducted as provided for in the approved study plan; or (2) [t]he study was conducted under anomalous environmental conditions or that environmental conditions have changed in a material way." 18 CFR §5.15(d). Pursuant to the ILP, the default study period for most projects is 1-2 years. FERC may require potential applicants to extend this study period if additional study time is necessary.[2] FERC has indicated in the approved ILP schedule that additional years of data collection may be necessary to meet study objectives.

We offer comments on the studies that support the Riverine Model because it is illustrates the flaws in AEA's modeling approach. AEA has conducted each study independently but many are interrelated. We do not believe that this "silo" approach supports the development of models that can adequately predict the changes to the Susitna River and impacts to vital fish habitat under post-project conditions. For that reason, our summary comments contained in this letter and the more detailed comments of Abt Associates Inc., incorporated in Attachment A, focus on proposed modifications to AEA's modeling approach and additional data needs for each study as it relates to developing a valid and predictive Riverine Model.

Baseline Water Quality Study (5.5) and Water Quality Modeling Study (5.6)

The proposed Susitna dam has the potential to dramatically alter the water quality in the Susitna River and critical off-channel habitats that support salmon. Of great concern are the potential changes in temperature related to project operations, altered groundwater-surface water exchange in winter and summer, and impacts to salmonids related to the reduction of groundwater upwelling and the increase of downwelling of river water in off channel habitats.

The Baseline Water Quality Study (5.5) is designed to "assess the effects of the proposed Project and its operations on water quality in the Susitna River basin."[3] Study objectives include documenting historical water quality data, collecting temperature and meteorological data, characterizing surface water conditions, measuring baseline metals concentrations, and performing a thermal infrared imaging assessment on a portion of the Susitna River.[4] The data gathered in the Baseline Water Quality Study will be used to develop the Water Quality Model for study 5.6. Some of the information will also be used to develop the groundwater model (7.5) and ice processes model (7.6). Information collected in the Baseline Water Quality Study is of paramount importance given the potential post-project impacts.

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[2] A Guide to Understanding and Applying the Integrated Licensing Process Study Criteria, Federal Energy Regulatory Commission, March 2012, Page 13.
[3] AEA, Baseline Water Quality Study 5.5, Study Completion Report, November 2015 at 1.
[4] *Id.* at 2.

I. Variances reported in the Baseline Water Quality Study need to be addressed to meet study objectives and ensure the adequacy and quality of data used in the Water Quality Model.

AEA reported a number of variances for the Baseline Water Quality Study in the ISR and the Study Completion Report that could dramatically affect the Water Quality Model and the reliability of the model predictions of post-project conditions and impacts. The most problematic variances as identified by Abt Associates Inc.[5] include:

- Missing temperature data for some stations between 2012 and 2014. In particular, the lack of access in 2013 that resulted in no temperature data at eight sites between Project River Mile (PRM) 145.6 and PRM 209.2.[6]

- Lack of precipitation data due to access restrictions in 2013 and the inability to install one of the meteorological stations, ESM-1. Although two other gages, ESM-2 and ESM-3 collected data in 2013 and ESM-1 was installed in October of 2014, in combination there is less than a year of precipitation data collected contemporaneously at the three meteorological stations.[7]

- Water quality samples were not collected in the Susitna River below Tsusena Creek and collected only in the winter of 2013/2014 above Tsusena Creek.[8] In addition, although Tsusena Creek is an important tributary, the creek was only sampled during the summer of 2013. This leaves very little data to evaluate the baseline water quality in the creek.

- Some of the water quality samples at some locations were validated as “rejected” or “estimated” in 2013.

In sum, these variances from the approved study plan in sampling and data collection increase the uncertainty in the Water Quality Model and decrease the confidence in the modeling results. Without adequate baseline data, AEA will continue to have difficulty calibrating the model which could greatly skew the predicted impacts to the Susitna River and off channel habitats under post-project conditions.

II. The Baseline Water Quality Study should be modified to require the collection of additional temperature data to fill important data gaps and reduce uncertainty in the Water Quality Model.

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[5] Abt Associates, Comments on Riverine Modeling Studies for proposed Susitna-Watana Hydro Project, June 4, 2016 at 8.
[6] Alaska Energy Authority, Initial Study Report, Study 5.5, June 3, 2014.
[7] AEA, Study Completion Report, Study 5.5, November 2015.
[8] *Id* at Table 4.1-1.

Despite AEA's filing of the Study Completion Report for the Baseline Water Quality Study, we propose that the Baseline Water Quality Study be modified to require AEA to perform an additional full year of sampling to collect temperature data as prescribed by the FERC approved study plan. Temperature data is being used to calibrate the Water Quality Model despite the fact that no temperature data was collected for a very large stretch of the river in 2013. That means that despite sampling efforts in 2014 there is still a large gap and a lack of synchronous data. As observed by modeling experts at Abt Associates Inc.,

> *The lack of temperature data throughout the reach in 2013 will increase uncertainty and may hamper the ability to calibrate the [water quality] model to observed conditions, or changes in habitat quality under operational conditions.*[9]

Water temperatures in off-channel habitats are critical to salmon egg incubation and survival. Changes in summer *and* winter temperatures under post-project conditions to these off-channel habitats need to be reliably modeled to fully understand cumulative adverse impacts to salmon and other native fish species as required by FERC regulations and NEPA. 18 CFR §5.18(b). For that reason, we urge FERC to approve this modification request and mandate AEA to collect a full year (including winter sampling) of additional temperature data to fill data gaps and reduce model uncertainty.

III. The Water Quality Modeling Study should be modified to require AEA to develop a transparent, detailed conceptual water quality model, clearly describe linkages/coupling between the water quality model, groundwater model and ice processes model and address sources of uncertainty.

We hired modeling experts at Abt Associates Inc. to extensively review AEA's documents associated with the Water Quality Modeling Study (5.6) in addition to the Groundwater Study (7.5) and Ice Processes Study (7.6). However, Abt Associates were limited in their ability to comment on the models due to the lack of information about how the models will be developed, what data will be used and how each model will interact with other models. (*For a detailed analysis please see the attached Abt Associates Report at p. 9-11.*) Specific concerns raised by Abt Associates include:

1. <u>AEA has not described the linkage/coupling between the water quality model and the ice processes and groundwater models.</u>

   Comment: To date, methods to link/couple/integrate these models in space and time, which is critical to development of the models, have not been proposed.

[9] Abt Associates Inc. Report, at 10.

Understanding how linkages between models will be established is important to evaluating the adequacy of the data available to simulate important processes in the models, and couplings between them.[10]

2. AEA has not identified or addressed uncertainty in the EFDC model.

   Comment: Uncertainty in modeling needs to be addressed. We have not seen a presentation describing how the uncertainties in boundary conditions will be addressed. It is not common practice to use "visual comparison" to evaluate model performance, nor is it clear how this visual comparison will be done, and whether model uncertainty will be addressed in a quantitative fashion.[11]

3. AEA has not adequately described the use of groundwater data from the focus areas in the EFDC model or assessed the sufficiency of the data.

   Comment: Groundwater data from the FAs are providing input data for EFDC, but it is it unclear how these data are informing the EFDC model input, and what assumptions are being made about groundwater/surface water interactions in areas where no groundwater data are available. Thus, the sufficiency of the groundwater data for these purposes cannot be evaluated.[12]

4. AEA has not described or evaluated the model inputs, development methods, and calibration statistics so the model can be reviewed.

   Comment: We cannot review the EFDC water quality model because of insufficient model input and calibration statistics. To date, only discharge and temperature have been simulated, so it is not possible to evaluate other parameters, such as dissolved oxygen. We were unable to find a description of the model boundary conditions used in space and time or model calibration statistics for temperature and water levels. Modeling methods are not fully described in any reports.[13]

5. The ISR lacks the presentation of a detailed conceptual model for the water quality model.

   Comment: We have been unable to find a description of a detailed conceptual model incorporating the data that have been collected to date. A conceptual framework for the models that are under development should be prepared and expressed to ensure that the numerical models are consistent with the conceptual models.[14]

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[10] *Id* at 9.
[11] Abt Associates Report at 9.
[12] *Id.* at 10.
[13] *Id.*
[14] *Id.*

6. <u>AEA has not described linkages with the ice processes model.</u>

Comment: It appears that the output from the ice processes model will be used as input to the water quality model, and the output from the water quality model will be used as input to the ice processes model. The documents do not detail how this linkage between the models will be accomplished.[15]

Conclusion

AEA's lack of transparency at this stage in the ILP is of grave concern. Licensing participants need to fully understand whether AEA is implementing the FERC approved Water Quality Modeling Study and adequately evaluating the range of potential impacts associated with the proposed Susitna dam. It is critical that AEA develop transparent conceptual models and clearly describe linkages between models so licensing participants and FERC can determine additional data needs and comment on model calibration and integration. AEA should have completed the development of the conceptual models before data collection began. If that had been done AEA and licensing participants would have a better understanding of critical data gaps. For that reason, we request that FERC approve the requested modification and require AEA to develop a transparent, detailed conceptual water quality model, clearly describe linkages/coupling between the water quality model, groundwater model and ice processes model and address uncertainties in boundary conditions, data, model parameters and conceptualizations.

Fluvial Geomorphology (6.5) and Fluvial Geomorphology Modeling Study (6.6)

Potential impacts of the proposed Susitna dam on the geomorphology of the Susitna River are vast. The proposed Susitna dam will trap sediment in the reservoir, dramatically alter the seasonality of flows in the Susitna River and reduce the duration of peak flows.[16] Specifically, the dam would change the delivery of sediment and the ability of the river to transport sediment.[17] This in turn will likely alter the balance of flow and sediment which could result in the formation of deltas at tributary mouths and the reduction of large woody debris.[18] "Each of these dam-induced changes has implications for salmon habitat."[19]

The Fluvial Geomorphology Study (6.5) seeks to "characterize the geomorphology of the Susitna River, and to evaluate the effects of the Project on the geomorphology and dynamics of the river by predicting the trend and magnitude of geomorphic response."[20] Together with the

[15] *Id* at 11.
[16] Abt Associates Report at 11.
[17] *Id.* At 12.
[18] *Id.*
[19] *Id.*
[20] AEA, Initial Study Report, Geomorphology Study (6.5) Part A at 2.

Fluvial Geomorphology Modeling Study (6.6) the studies will assess potential changes to aquatic and riparian habitats. [21] AEA identified and FERC approved 11 objectives. For the purposes of this review, relevant objectives that we do not believe AEA has met or can meet given current data gaps include:

- Determine sediment supply and transport in Middle and Lower Susitna River Segments.
- Characterize the surface area versus flow relationships for riverine macrohabitat types (1980s main channel, side channel, side sloughs, upland sloughs, tributaries and tributary mouths) over a range of flows in the Middle Susitna River Segment.
- Conduct a reconnaissance-level geomorphic assessment of potential Project effects on the Lower and Middle Susitna River Segments considering Project-related changes to stream flow and sediment supply and a conceptual framework for geomorphic reach response.
- Assess large woody debris transport and recruitment, their influence on geomorphic forms and, in conjunction with the Fluvial Geomorphology Modeling below Watana Dam Study, effects related to the Project.[22]

We recognize that AEA is in the process of developing and calibrating one dimensional and two dimensional models that will simulate flows and sediment transport. However, we believe that there are some significant data gaps and model integration problems that will make it very difficult to appropriately calibrate the model and generate predictive results.

I. Variances reported in the Fluvial Geomorphology Study (6.5) need to be addressed to meet study objectives and ensure the adequacy and quality of data used in the Fluvial Geomorphology Modeling Study (6.6).

AEA reported two important variances in the ISR that influence AEA's ability to meet study objectives, understand the geomorphology of the Susitna River and the impacts the proposed Susitna dam will have on the system.

a. <u>AEA did not complete the aerial photography surveys as required by the FERC approved study plan.</u>

AEA was required to collect three sets of aerial photography to estimate habitat areas under a wide range of flow conditions: 23,000, 12.500 and 5,100 cfs. As noted by AEA, "[o]nly one set of aerials was actually obtained with the flow for 50 percent of the Middle River at 12,900 cfs and 50 percent of the Middle River at 17,000 cfs. In 2013, it was decided to acquire additional aerial photographs for only the 12,500-cfs target discharge in the Middle River.

[21] *Id.*
[22] *Id* at 3.

Aerials were obtained for about 60 percent of the Middle River at 11,300 cfs and 40 percent at 6,200 cfs."[23] As a result, only 40 percent of the Middle River was photographed during anticipated low winter flows.

Low flow photographs are needed throughout the Middle River to properly evaluate how post-project changes in flow will impact critical off-channel habitats. As noted by Abt Associates,

> *Under pre-Project conditions, the majority of the winter hydrograph in the Middle River is between ~ 1,000 and 4,000 cfs (see Figure 3), which is substantially lower than 6,200 cfs. This winter low flow period is when salmon eggs are incubating, primarily in off-channel habitats. Future regulated flows will greatly alter this hydrologic regime, so that winter flows will be closer to 5,000–10,000 cfs. A key question regarding impacts on salmonids is how off-channel habitats will be affected by these higher winter flows. The lack of baseline aerial imagery for current winter flow conditions may influence AEA's ability to evaluate proposed Project habitat changes from current winter conditions throughout the Middle River.*[24]

b. AEA did not complete the bed load sampling on the Susitna River at Tsusena Creek.

Bed load samples at Tsusena Creek were a required element of the FERC approved study plan due to the close proximity of the creek to the proposed dam site. The samples help characterize under pre-project conditions the size and quantity of sediment passing the site. AEA terminated the collection of bed load samples at Tsusena Creek after 2012 and did not collect samples in either 2013 or 2014. Although no sediment will pass through this section of the Middle River after project construction, it does represent a stretch of river that will be the most sediment starved and "is likely to be very dynamic in terms of adjustment of sediment load to post-dam conditions."[25] For that reason, a complete set of bed load data from the Tsusena Creek site is critical to characterize pre-project conditions and evaluate post project impacts.[26]

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[23] *Id* at 40.
[24] Abt Associates Report at 12-13.
[25] *Id.* at 14.
[26] *Id.*

II. The Fluvial Geomorphology Study (6.5) should be modified to require the collection of additional aerial photographs of the entire Middle River at low flows and/or collect stage-discharge information for the Middle River to fill important data gaps.

Despite AEA's decision to discontinue aerial photographs of the Middle River, additional effort is needed to fill important data gaps. We request that FERC mandate AEA to complete aerial surveys for the entire Middle River, especially during critical low flows, as described in the FERC approved study plan. In addition, we recommend that AEA collect additional data to support a stage-discharge analysis for the Middle River. Since many studies are interrelated, the aerial photographs of the Middle River are used to calibrate the hydraulic model which is important for both the Fluvial Geomorphology Model and the Ice Processes Model. To support this request, we highlight specific concerns related to the lack of data and recommendations raised by modeling experts at Abt Associates. (Please see the attached Abt Associates Report for more detailed information)

a. <u>AEA lacks sufficient data to characterize habitat vs. flow relationships.</u>

AEA reported in the ISR that rather than collecting observed field data from aerial surveys it will instead simulate low flows with models. As reported in the ISR, additional aerial photography was "not necessary for the 2013 study as the combination of the 2-D hydraulic modeling , bathymetry and topography collected in the Focus Areas can provide direct determination of the area of the various macrohabitat types over the range of flows of interest."[27]

> ***Abt Associates Comment:*** *AEA appears to be planning to use their 2-D hydraulic model to simulate habitat areas at low flow, since they do not have aerial photography at low flows. However, precisely because they do not have aerials, these low flows will be well outside the range where they will be able to calibrate their hydraulic model. It is not clear how AEA can make the case that they understand Project effects on salmon habitat, particularly during critical low flows over the winter months, when they lack these data. For example, if flows of 5,000–8,000 cfs (which appear to be the dominant winter flows in the OS-1 scenario) are sufficient to flood side-channel and off-channel habitats, this could dramatically change the conditions under which salmonids are incubating in those habitats.* <u>*AEA needs observational rather than modeled data to evaluate whether and where these habitats are flooded under dam operational scenarios.*</u>[28]

[27] ISR, Geomorphology Study (6.5) Part A at 40.
[28] Abt Associates Report at 17-18.

b. AEA's lacks data to support a stage-exceedance analysis of habitat v. stage relationship for the Middle River.

The lack of aerial photography at low flows for the Middle River prevents AEA from understanding and evaluating potential habitat impacts under post-project conditions. AEA can fill the data gap with additional aerial photography and/or by collecting additional data for the Middle River to support a stage-exceedance analysis as suggested by Abt Associates. It is not appropriate to fill the gap by applying the stage-exceedance analysis for the Lower River to the Middle River.

> ***Abt Associates Comment****: Because AEA is missing aerial photography for the lowest flows, one of the key unknowns under the dam operations scenario is how regulated winter flows will influence off-channel and side-channel winter habitats in the Middle River. Another way to address this problem is to use stage-exceedence relationships for observed flows, to evaluate which geomorphic features will be overtopped at which flows. AEA has done this for the Lower River where changes in stage will not be nearly as pronounced, but has not to our knowledge done this for the Middle River. Additional information regarding stage-discharge relationships in the Middle River would be illustrative.*

c. The data gap prevents AEA from understanding interactions of ice with main-channel and side-channel habitats and potential impacts to salmon habitat under post-project conditions.

One of the objectives of the Fluvial Geomorphology Modeling Study is to create geomorphic models to "[s]upport the evaluation of Project effects by other studies in their resource areas providing channel output data and assessment of potential changes in the geomorphic features that help comprise the aquatic and riparian habitats of the Susitna River."[29] The Ice Processes Study (7.6) relies on the data collected in the Geomorphology Study and the results of the hydraulic model to understand potential impacts during low flows to off-channel habitats and the impact of winter breaching flows under post-project conditions. This information will inform potential impacts to critical salmon habitat.

As described in a study conducted by the Alaska Department of Fish and Game (Vining et al., 1985) "river stage and discharge during the winter period can directly affect both spawning and egg incubation habitat." Specifically, "the typical pattern of decreased discharge in the winter resulted in the off-channel spawning and rearing habitat to warm due to the decreased input of cold river water and the increased contribution of relatively warm upwelling ground water… During the time of stable ice cover, some slough habitats may remain ice-covered and

[29] ISR, Fluvial Geomorphology Modeling Study (6.6) Part A at 4.

thus become insulated from extremely cold air temperatures, while in others open thermal leads may develop resulting from upwelling groundwater. Warmer water associated with the groundwater upwelling increases the rate of embryo development and decreases the overall hatching time. If the river discharge and thus stage drops too low, however, the slough can completely dewater, leading to freezing of the substrate and mortality of the eggs and hatchlings. In contrast, if the river discharge and stage increases to a point where the slough entrances can be overtopped/breached, this can cause a decrease in water temperature due to the sudden addition of colder river water which can slow development and delay hatching."[30]

> ***Abt Associates Comment****: This is critically important, but is not fully discussed in the ice processes report. How does a change from approximately 2,000 cfs flow to approximately 5,000–10,000 cfs flow during the winter affect flooding/ice formation/habitat in the side sloughs? It seems clear that flow in winter needs to be "just right" so that there is neither significant overtopping of side sloughs from the main channel, nor is there too little flow to keep the side sloughs from dewatering and freezing completely. The amount of flow in the side sloughs will depend on whether the discharge created by the dam is sufficient to flood the side sloughs, and by how much. This is why it is important to have documentation of habitat areas from aerial photographs under the actual range of flows that will occur during the winter, and to collect field data on stage-discharge relationships at each side slough where salmon habitat is important. AEA currently does not have full coverage of the Middle River from aerial photography, and appears to be missing basic data describing stage-discharge relationships adjacent to many side channels and side sloughs. It is not clear how the data that have been collected will be used to simulate and inform changes in these processes during Project operations. This is an important data gap that AEA needs to fill in order to have sufficient calibration data for their hydrodynamic models.*[31]

Conclusion

To adequately evaluate the potential post-project impacts to the Susitna River and critical off-channel habitats that support salmon, AEA needs to fill important data gaps related to the lack of data that will help determine impacts to habitat at critical low flows. For the aforementioned reasons, we request that FERC require AEA to collect additional aerial photographs of the entire Middle River at low flows and/or collect at least one full year of stage-discharge information for the Middle River to fill important data gaps.

III. The Fluvial Geomorphology Study (6.5) should be modified to require AEA to collect additional bed load sediment data at Tsusena Creek and other important tributaries.

[30] ISR, Ice Processes Study (7.6) Part C, Appendix C at 10.
[31] Abt Associates Report at 31.

Understanding the sediment balance and the sources of sediment in the Middle River is absolutely critical to evaluate how post-project changes to the geomorphology of the Susitna River will impact critical salmon habitat. "The size, quantity, and quality of sediment being transported through the Middle River helps control channel form, as well as the suitability of the channel substrate for spawning. A dam at the Watana site would completely cut off all bed load sediment and the majority of suspended sediment coming from upstream on the main river. A dam would also reduce the ability of the Susitna River to transport and redeposit sediment through this reach. Thus, it is critical that AEA fully understands all other sources of sediment to the Middle River."[32]

Abt Associates identified a number of examples where AEA needs to collect more data to properly understand the sediment balance of the Susitna River. (For more detail, *please see the attached Abt Associates Report at p. 14-21).* These examples are summarized below:

a. <u>AEA lacks the field data necessary to understand the sediment balance in the Middle River.</u>

One of the objectives of the Geomorphology Study (6.5) is to "[d]etermine sediment supply and transport in Middle and Lower Susitna River Segments."[33] However, "AEA has sediment transport data from only two tributaries to the Middle River – Indian Creek and Portage Creek – collected in the 1980s and summarized in Knott et al. (1986). For the other 22 tributaries to the Susitna River, AEA plans to model sediment inputs by assuming that (1) their model of hydraulics for each of these tributaries is accurate, and (2) sediment rating curves from 2 tributaries analyzed over 30 years ago can be used as a proxy for the other 22."[34] This limited data set is insufficient to understand the sediment balance in the Middle River.

> ***Abt Associates Comment****: AEA has collected insufficient tributary sediment transport data to evaluate the post-Project impacts on sediment transport and habitat quality. No data are available to evaluate sediment inputs from important tributaries, such as Devil Creek and Portage Creek. Rather, AEA appears to be relying on HEC-RAS modeling to simulate flow in the tributaries, and sediment rating curves from just two tributaries, to model sediment supply.* <u>*The tributary inputs are a critical component of the sediment balance, and AEA does not have enough data to evaluate tributary sediment supply, or how post-Project flows will transport the sediment delivered from these tributaries*</u>*.*[35]

[32] *Id.* at 14.
[33] ISR, Geomorphology Study (6.5), Part A at 3.
[34] Abt Associates Report at 15.
[35] *Id.*

b. AEA lacks the data necessary to understand how the morphology and habitat quality of the Susitna River will change at tributary mouths.

"A related issue to the overall sediment balance in the Middle River is the capacity of the Susitna River to move the sediment that will be delivered to the river at tributary junctions. Accumulation of fans and bars at tributary mouths could potentially create a significant impact to aquatic habitat downstream of the dam, by changing the accessibility of side-channel habitats or altering the local geomorphology of the mainstem Susitna River near tributary junctions. Because there is very little data related to the quantity and size distribution of tributary sediment inputs, any geomorphic models that AEA develops will be unable to project how the river might adjust to the sediment loads delivered at tributary mouths."[36]

In the ISR AEA also acknowledges the importance of characterizing sediment supply from tributaries and the sediment at tributary deltas to understand whether fish will have access to tributaries under post-project conditions.[37] However, rather than using observed field data, AEA intends to rely on models. AEA states, "[a]s a precursor to modeling geomorphic changes at select tributary deltas, the sediment supply to the deltas must be characterized; a numerical modeling approach is being used for this purpose…Simulated hydraulics will be calibrated where calibration datasets exist; lacking datasets to calibrate the simulated sediment transport, the modeled sediment transport capacities can only be reviewed and adjusted based on professional judgement."[38] This approach will not yield reliable results.

Abt Associates Comment: *The data collected from these tributary junctions are critical to understanding sediment supply in the mainstem, size distribution of the sediment coming out of these tributaries, ability of the mainstem to transport this sediment, and ability of migrating fish to reach tributary habitats. AEA apparently has actual sediment transport data from only two tributaries (collected over 30 years ago), which in our opinion is insufficient to model sediment transport at the tributary mouths throughout the Middle River. Instead, AEA must rely on "professional judgement." In order to evaluate potential Project effects on habitat in the mainstem and the tributaries, AEA should have actual sediment transport data on each of the tributaries where fish are present.*

c. AEA should collect additional data on tributaries above the dam site to evaluate sediment inflows to the reservoir.

[36] *Id.* at 16.
[37] ISR, Geomorphology Modeling Study (6.6), Part A at 27.
[38] *Id.* at 27-28.

AEA has not collected a full dataset at Tsusena Creek yet it intends to develop sediment rating curves for Tsusena Creek to estimate sediment entering the dam.[39] Not only is this problematic because of the very limited set of data but Tsusena Creek is also below the dam site.

Abt Associates Comment: *It is unclear why sediment rating curves from Tsusena Creek, at the downstream limit of the dam, are being used to estimate sediment entering the dam. AEA should consider collecting and evaluating bed load and suspended load data from upstream sources near Cantwell, and inputs from the Oshetna River, which may be more representative of sediment entering the reservoir.*[40]

Conclusion

Given the importance of tributaries and off channel habitats to salmon in the Susitna system, AEA should not rely on 30 year old sediment bed load data for only 2 out of 22 tributaries in the Middle River to model impacts to these critical habitats. To properly evaluate potential post-project effects on habitat in the mainstem and the tributaries and meet the FERC approved study objectives for 6.5 and 6.6, AEA should collect actual sediment transport data on each of the tributaries where fish are present. For that reason, we request that FERC require AEA collect additional bed load sediment data at Tsusena Creek and other important tributaries where fish are present.

IV. FERC should modify the Geomorphology Modeling Study (6.6) to require AEA to use different data to model sediment transport and design a transparent plan to integrate the transport of Large Woody Debris (LWD) and ice processes into the model.

Modeling experts at Abt Associates raised a number of concerns about AEA's approach to modeling sediment transport and the integration of its assessment of LWD and ice processes into the Geomorphology Modeling Study. The ability of the mainstem of the Susitna River to transport sediment and LWD will be dramatically reduced under post-project conditions. It is imperative that AEA fully understand tributary contributions and how changes in ice processes will affect both sediment transport and the presence of LWD in the Susitna River to understand impacts to fish habitat and habitat quality.

The Geomorphology Modeling Study is designed to "assess the potential impact of the Project on the behavior of the river downstream of the proposed dam, with particular focus on potential changes in instream and riparian habitat."[41] Early in the study design process FERC recommended that AEA modify the objectives of the study to fully study the interaction of

[39] ISR, Geomorphology Study (6.5), Part A at 55.
[40] Abt Associates Report at 18.
[41] ISR, Fluvial Geomorphology Modeling Study, Part A at 3.

geomorphic processes in the mainstem Susitna River and tributaries, with special emphasis on "evaluating geomorphic changes at the confluence of the Chulitna, Talkeetna and Susitna rivers."[42] In addition, FERC recommended that AEA include "a detailed description of the processes and methods by which ice and LWD would be incorporated into the [fluvial geomorphology] modeling approach."[43]

The following summary comments and the more detailed comments attached in the Abt Associates Report raise a number of concerns about AEA's ability to meet FERC's recommendations and the FERC approved study plan objectives.

a. AEA is not properly modeling sediment transport.

Abt Associates Comment: *AEA is using total annual runoff as a predictor of annual sediment transport. Total sediment load will depend much more on peak runoff than on total runoff. Bed load gravel transport in the Middle Susitna River largely occurs between 20,000 and 40,000 cfs (see Figure 4); scenarios based on total annual runoff may not capture this bed load transport efficacy. This could substantially under-predict the effects of dam operations on sediment transport, since it does not account for significant changes in peak flow post-Project.*[44]

b. AEA has not properly evaluated effective discharge and sediment transport to understand post-project impacts.

Abt Associates Comment: *Based on the published bed load gravel rating curve (Figure 5.2.4), the difference in transport between 27,000 and 9,000 cfs (pre vs post-Project flows in the Middle River) is approximately two orders of magnitude. For bed load sand the difference is almost two orders of magnitude, and for suspended load sand the difference is more than two orders of magnitude. This suggests that the ability of the Susitna River to transport sediment will decrease by roughly a factor of 100 across all size classes under post-Project conditions. Because there is a threshold discharge below which there is little to no bed load sediment transport, the total sediment load passing the gages will depend much more on the duration and magnitude of flows above this threshold than it will on "total runoff." AEA needs to evaluate post-Project sediment transport in the context of flows above the threshold for sediment motion, rather than average flows, in order to assess Project effects on habitat quality in the Susitna River.*[45]

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[42] *Id.* at 2
[43] *Id.* at 1
[44] Abt Associates Report at 18.
[45] *Id.* at 19

c. AEA lacks data and a defined modeling approach to understand the LWD budget in the Middle River and properly evaluate post-project impacts.

Under post-project conditions, sources of LWD will be eliminated upstream of the dam. LWD will largely come from tributaries and from bank erosion. However, based on observations LWD does not start mobilizing until flows reach > 40,000 cfs.[46]

Abt Associates Comment: *If LWD from upstream of the dam is eliminated post-Project, and bank erosion is the primary source of LWD post-Project, it is important to understand bank erosion processes. However, AEA's reach-scale hydrodynamic model cannot simulate bank erosion because it is a 1-D model. AEA notes that they are calculating a "bank erosion index," but does not provide sufficient detail in the ISR to critically evaluate how this index is being used. AEA needs to clarify how their 1-D model will be used to simulate bank erosion, and provide calibration and validation data demonstrating that their parameterization of 2-D bank erosion processes in their 1-D model is robust.*

In addition, it does not appear that the LWD study provided data that will allow AEA to assess the source of the LWD in the main channel, and whether it originates from tributaries downstream of the proposed dam, or from sources upstream of the dam. Thus, with the existing data AEA will not be able to evaluate the effect of the dam on the quantity of LWD below the dam.

Under post-Project conditions, flows of 40,000 cfs will essentially be eliminated in the Middle River. AEA needs to do a more thorough analysis of the sources of LWD to the Middle River and the implications for habitat if LWD is no longer able to be mobilized following Project construction.[47]

d. AEA should integrate ice processes into the geomorphology model and assessment.

Understanding the ice processes on the Susitna River is absolutely crucial to understanding the post-project impacts to critical off-channel habitats important for fish. FERC directed AEA to clearly describe how ice processes and LWD would be integrated into the Fluvial Geomorphology Study (6.6). There is no evidence that this has been done.

Abt Associates Comment: *So far, there is no evidence that AEA has sufficient data to make such an assessment. Since AEA has not developed a viable ice processes model for existing conditions, we cannot evaluate AEA's ability to assess changes under with-Project conditions.*[48]

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[46] ISR, Fluvial Geomorphology Study, Part A , at 98.
[47] Abt Associates Report at 20.
[48] *Id.* at 21.

e. AEA should reevaluate the use of some models if the selected model is not capable of simulating the natural system.

AEA has reported in the ISR for the Geomorphology Study (6.5) that "field data will either be modified to "fit" the model results, or that models (rather than field data) will be the primary source of information for basic hydraulic parameters."[49] Specifically, AEA stated, "[f]ield-based observations and measurements are used to guide model development and data needs and will be used to provide a reality check on model results. In turn, model outputs will be used to modify, refine, quantify and validate field-based observations and key geomorphic processes."[50]

Abt Associates Comment: *Field data and observations are the foundation of any scientific study. If a numerical model does not properly simulate what can be observed, it is because the model is not properly calibrated, or because the model is not simulating the full range of processes occurring in the natural system. In no case should model outputs be used to "modify" field-based observations.*[51]

f. AEA should use a single integrated model rather than piecing together a variety of process models.

AEA's choice to use a variety of models rather than a single integrated model is extremely problematic, increases uncertainty and decreases the reliability of the model results. "A by-product of using multiple models is that in some cases many different models are simulating the same processes, but there may be inconsistencies among the models. For example, Table 4.1-4 lists 6–7 different H&H models that are being used for different purposes in this study (HEC ResSim, HEC-RAS, River 1D, River 2D, EFDC, HEC-6T, and another model that is yet to be determined (either SRH-2D or River 2D)."[52]

Abt Associates identified a variety of examples across studies where the lack of model integration may impact the reliability of model results. An illustrative problem for the Fluvial Geomorphology Modeling Study (6.6) is described below. AEA will need to model the changes in channel width over time to understand post-project impacts. The following two passages from the ISR describe AEA's process.

"Local-scale models will be developed at the Focus Areas representing conditions at years-0, -25, and -50. If bed elevations or channel widths change over the 50 year period, the reach-scale model results will not only be used to alter the future (years-25 and -50) geometry, but will provide future downstream stage-discharge and upstream sediment supply rating curves to the local-scale models. The geometry and rating curve

[49] *Id.* at 21.
[50] ISR, Geomorphology Study (6.5), Part A at 6.
[51] Abt Associates Report at 21.
[52] Abt Associates Report at 22.

information must all be changed to maintain consistency between the models and to maintain internal consistency of the specific local-scale model." (Tetra Tech, 2013b, p. 11).

"With a target channel width determined for the new hydrologic regime, we will need to estimate the rate of width change over the 50-year license period. The rate of width adjustment may be greatest in the initial years after closure, so the time interval for simulating width change may be shorter during the initial periods of the simulation and increase with time during the simulation. The rate of width adjustment may also be limited by the supply of sediment available for deposition in the channel margins…One approach for developing the width versus time relationship is the application of rate law, which is an exponential decay function (Graf, 1977; Wu et al., 2012)." (Tetra Tech, 2013b, p. 34).

Abt Associates Comment*: This is a good example of a situation where AEA's choice of modeling packages may significantly affect their results. Based on the anticipated Project impacts to flow and sediment loads, channel geometry and rating curves will change along the entire Middle River. Currently, AEA has only a 1-D model to simulate the entire Middle River, which by definition cannot accurately simulate changes in channel width. Yet this model must be called upon to set the boundary conditions for the 2-D models in the FAs, so AEA plans to* ***prescribe*** *changes in channel width using an uncalibrated and unconstrained exponential function. AEA actually will have no way of knowing how well the 1-D model "width" changes are performing, which in turn means that the boundary conditions for their 2-D models will be unconstrained. These 2-D models will be called upon to simulate changes in key salmon habitat post-Project, but AEA will have no way of knowing whether these projections are realistic because boundary conditions that feed into them will be completely unconstrained.*

Conclusion

AEA should have completed the development of the conceptual models before data collection began. If that had been done AEA and licensing participants would have a better understanding of critical data gaps. For that reason, we request that FERC approve the requested modification and require AEA to develop a transparent, detailed conceptual fluvial geomorphology model, clearly describe linkages/coupling between related models and address uncertainties in boundary conditions, data, model parameters and conceptualizations.

Groundwater Study (7.5)

The proposed Susitna dam project will dramatically alter the flow of the Susitna River downstream of the dam. Although the magnitude of the change in flow will depend on the operation of the dam, the load following scenario that AEA is evaluating will result in much lower summer flows and much higher winter flows. "These flow changes will alter the interaction between groundwater and surface water, and may have significant impacts on off-channel (i.e., side channels and sloughs) habitats and habitats that are important for egg incubation and rearing of fish. In particular, the flow changes may:

- Modify the existing flow regime in off-channel habitats, resulting in changes to surface water and groundwater relationships
- Reduce or alter groundwater upwelling in off-channel habitats, resulting in changes in water temperature that may affect fish spawning success, egg incubation, fry emergence timing and success, and juvenile fish growth and survival
- Alter river and off-channel water quality, which may influence water quality in sediments affected by groundwater upwelling and downwelling.

In addition, higher river flows in the winter and the higher river stage may result in cold river water entering off-channel habitats. It may also create areas of downwelling of river water rather than upwelling of groundwater." [53]

The Groundwater Study (7.5) is interrelated with a variety of different studies. It is designed to "provide an overall understanding of groundwater/surface water interactions in support of the Aquatic Instream Flow Study, Riparian Instream Flow Study, Water Quality Study, Ice Processes Study and Geomorphology Study."[54] For that reason, the data collection, groundwater model selection, and plan to integrate the groundwater model with other studies is particularly important. AEA needs to understand changes in the groundwater/surface water interactions under post project conditions to assess impacts to critical off-channel habitats and proposed environmental measures that may be needed to address adverse impacts as required by FERC regulations. 18 CFR §5.18(b).

We recognize that AEA is still in the process of developing a preliminary groundwater flow model for FA-128 and has not yet developed models for the other Focus Areas. In addition, reported variances in the Groundwater Study due to delays in the ILP process and study implementation have also delayed model development to the point where our modeling experts were limited in their review due to lack of reported information. However, we believe that FERC should strongly consider the following summary comments and the more detailed comments by Abt Associates in Attachment A before AEA proceeds any further in developing a groundwater flow model as it is fundamental to understanding impacts to off-channel habitats important to fish.

[53] Abt Associates Report at 23.
[54] ISR, Groundwater Study (7.5), Part C at 1.

I. The Groundwater Study should be modified to require AEA to develop a detailed conceptual groundwater model, clearly describe linkages/coupling between the groundwater model and other dependent studies and address sources of uncertainty.

a. AEA should clearly describe linkages or couplings between models.

Modeling experts at Abt Associates reviewed AEA's description of how models were designed and integrated. However, the ISR, including all subsequently filed documents, contain only vague references about how the models will be linked. For example the ISR states,

> "[w]here applicable, GW models (MODFLOW) will be developed and linked with other resource models (e.g., Open-water Flow Routing Model [OWFRM] [Study 8.5], SRH-2D hydraulic model [Study 6.6], River1D and River2D Ice Processes models [Study 7.6], 2D Fish Habitat models [Study 8.5], and Riparian Floodplain Vegetation modeling [Study 8.6]) to evaluate different Project operational scenarios on GW/SW interactions and the resulting effects on riparian vegetation and fish and aquatics habitats."[55]

AEA continues its vague model description in the Groundwater Study Implementation Report (SIR) filed over a year later. In the SIR, AEA states that it has continued the "development and refinement" of models but then provides the following vague description.

> "Of particular note is the development of a preliminary three dimensional MODFLOW GW model for FA-128 (Slough 8A) (SIR Study 7.5; Appendix B). When fully calibrated, this model will utilize inputs from the OWFRM (SIR Study 8.5), SRH-2D hydraulic models (SIR Study 6.6), and the River1D and River2D (SIR Study 7.6) Ice Processes models for evaluating Project operational effects on GW/SW interactions. Output from the MODFLOW can then be linked with the 2-D Physical Habitat Simulation (PHABSIM) Fish Habitat Models for assessing Project effects on fish habitats dependent on/influenced by GW (e.g., spawning, egg incubation, juvenile overwintering). Similar MODFLOW models can be developed and utilized for FA-104 (Whiskers Slough), FA-115 (Slough 6A), and FA-138 (Gold Creek) (SIR Study 7.5)."[56]
>
> **Abt Associates *Comment***: *We were unable to find a description of how the Groundwater Model will be linked, spatially and temporally, with these six other models. <u>These linkages will be critical to the success of the modeling studies.</u> It does not appear that the linkages will be bi-directional, in the sense that the output from the hydraulic models will feed into the groundwater model, and the groundwater model will feed back into the hydraulic model. Particularly in the off-channel habitats, the surface water and groundwater will interact in space and time. <u>The surface water and groundwater</u>*

[5555] ISR, Groundwater Study (7.5), Part D at 2.
[56] Groundwater Study, Study Implementation Report at

processes should be coupled in space and time, rather than using the output from one model to feed into another separate model, which is then run separately.

As a reoccurring theme, similar vague references to the links between models across studies are found throughout the ISR and referenced multiple times in the Abt Associates Report. The Groundwater Study Plan recognizes that the study is "specifically linked with both the Riparian Instream Flow Study and the Fish and Aquatics Instream Flow Study since the ecological functionality of riparian and aquatic habitats can be directly influenced by GW/SW interactions."[57] A plan to link/couple models should not be an afterthought but rather one of the first steps to designing a study plan and making determinations about which model to use. The flaws in AEA's approach and the lack of a transparent model integration plan are now rising to the surface. If AEA proceeds on this course there is a very strong likelihood that the lack of a model integration plan will dramatically impact the model results and the ability of the models to predict post-project impacts as required by FERC regulations. 18 CFR §5.18(b).

b. AEA has not adequately developed a conceptual model for groundwater/surface water interactions.

The Groundwater Study Plan calls for AEA to develop a conceptual model for groundwater/surface water interactions. Although the development of conceptual models was planned, our experts were unable to find detailed conceptual models incorporating the data that have been collected to date.[58]

Abt Associates Comment: *A conceptual framework for the models that are under development should be prepared and expressed to ensure that the modeling is consistent with the conceptual site model. In the most general terms, we believe that AEA should improve upon and more clearly articulate their conceptual model for how the relevant hydrologic, geomorphic, and ecological processes in the Susitna River system interact. This conceptual model should be depicted in a clear, concise diagram that illustrates each of the relevant processes and the interactions between them. This figure would replace the series of figures currently depicted as Figures 5-8 in this memorandum, which we believe are too complicated for stakeholders to understand exactly how different physical processes interact in the Susitna system, or how the current models simulate these interactions in space and time. This conceptual model should then be used to guide and develop a fully integrated groundwater and surface water model of the entire system, which can accurately track and simulate the exchanges of water, heat, and other relevant parameters that occur between surface water and groundwater systems. Although the data collected in the focus areas would still provide key data for calibrating this revised model, an integrated modeling framework would more broadly inform AEA's*

[57] Groundwater Study, Revised Study Plan, December 2012 at 7-3.
[58] Abt Associates Report at 29.

understanding of surface water-groundwater interactions, heat exchange, and sediment transport throughout the Susitna system, rather than just within these focus areas.[59]

c. AEA should describe sources of data and model uncertainty.

The ISR does not describe "sources of uncertainty and how they will be addressed. Uncertainties include those resulting from evaluating groundwater/surface water relationships outside of FAs, in conditions that are beyond those used to calibrate the model, and under Project operations."[60]

Abt Associates Comment*: Methods that will be used to evaluate uncertainty are not presented. There are multiple sources of uncertainty: uncertainty in evaluating groundwater/surface water relationships outside of FAs, in conditions that are beyond those used to calibrate the model, and under Project operations.*[61]

Conclusion

In sum, across studies it is critical that AEA develop transparent conceptual models and clearly describe linkages between models and other relevant studies so licensing participants and FERC can determine additional data needs and comment on model calibration and integration. For that reason, we request that FERC approve the requested modification and require AEA to develop a transparent, detailed conceptual groundwater model, clearly describe linkages/coupling between the groundwater model and the Fish and Aquatic Instream Flow Study and Riparian Instream Flow Study and address uncertainties in boundary conditions, data, model parameters and conceptualizations.

II. The Groundwater Study should be modified to require AEA to describe how Focus Area models will be extrapolated to the rest of the Susitna River to assess additional data needs and post-project impacts.

AEA plans to use MODFLOW model results from the Focus Areas to predict groundwater/surface water interactions in other parts of the Susitna River. "Methods for extrapolating from areas where data have been collected to areas without data should be articulated, and this should be part of the considerations for data collection and model development."[62] AEA needs to complete this task now so licensing participants and FERC can determine whether more data needs to be collected or whether a regional groundwater model should be developed.

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[59] Abt Associates Report at 45.
[60] *Id.* at 28.
[61] *Id.*
[62] Abt Associates Report at 47.

Abt Associates Comment*: The consultants working on the groundwater/surface water studies in the 1980s concluded, "[d]etailed projections cannot be made of the slough discharge or temperature variations which might result from changes in mainstem conditions as a result of project operation. Because of the substantial differences among the sloughs in their hydraulic and thermal behavior, it would be necessary to construct mathematical models of each individual slough in order to make detailed predictions of the effects on the sloughs of changes in mainstem conditions." (R & M Consultants and Woodward-Clyde, 1985, p. 4-17).*

Since that time, extensive surface water and groundwater data have been collected in detail in one FA, FA-128, and some data have been collected in a few other FAs. It is difficult to evaluate whether these data are sufficient to develop an assessment of the impacts on FA-128, to say nothing of all individual off-channel habitats, many of which have no data.

The documents do not describe how extrapolation of data and models from FAs to the rest of the river system will be accomplished. MODFLOW models will be developed for four FAs. No regional groundwater model is planned. The study plans should describe how data and model results from these four FAs will be used to assess Project impacts for the groundwater/surface water interactions within the Susitna River. In addition, the methods that will be used to determine the representativeness of results from these four FAs for application to the rest of the river should be detailed.[63]

"In particular, AEA needs to address the issue raised by R&M and Woodward Clyde (1980) and described in Section 3.3.5 of this memorandum, that "it would be necessary to construct mathematical models of each individual slough in order to make detailed predictions of the effects on the sloughs of changes in mainstem conditions." (R & M Consultants and Woodward-Clyde, 1985, p. 4-17). Even if AEA had completed a simulation that accurately described baseline conditions throughout side sloughs, plans to move from current conditions to simulation of Project operations would need to be developed and described. To fully assess the sufficiency of the collected data and preliminary models, it is important to understand how these data will be used to assess Project operations. Despite an extensive, multiyear data collection effort, for many of these studies, the methods that will be used to evaluate the full extent of Project impacts on the river system have not been articulated."[64]

For the foregoing reasons, we request that FERC modify the Groundwater Study and require AEA to describe how Focus Area models will be extrapolated to the rest of the Susitna River to assess additional data needs and post-project impacts.

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[63] *Id.* at 28.
[64] Abt Associates Report at 47.

III. The Groundwater Study should be modified to require AEA to develop a fully integrated groundwater/surface water model to address the problems with the preliminary MODFLOW model for FA-128.

The MODFLOW "model's ability to represent observed conditions is a consideration in establishing the credibility and reliability of the model. The preliminary model does a poor job representing water levels in several wells, particularly those located away from the river, side channels, and sloughs [e.g., FA128-4, FA128-5, FA128-21, FA128-25, FA128-26, FA128-27 (see Figure 3-3, Figures B1-1 through B1-15, (AEA, 2015b, Study 7.5, and Appendix B). The ability of the model to simulate observed conditions informs the confidence that can be placed in the predictive capabilities of the model and its ability to represent Project conditions/dam operations."[65] For that reason, AEA should make the following changes.

a. <u>AEA should not use a storage coefficient value for a confined aquifer to calibrate the model.</u>

In the ISR, AEA reports that because it lacks studies that provide a storage coefficient value for an alluvial aquifer, the storage coefficient was adjusted from a confined to an unconfined value during calibration. "The storage coefficient was initially set to 0.2, but was eventually reduced to a value of 0.001 to achieve a better match to the observed GW elevation response. This value is somewhat low for an unconfined aquifer and may suggest the aquifer is semi-confined."[66]

> ***Abt Associates Comment:*** *The storage coefficient value used in the model to improve calibration is a confined aquifer value, which is inconsistent with the representation of the alluvial aquifer as an unconfined (water table) aquifer that interacts with the surface water. For example, the groundwater level maps prepared for the area are labeled "water table" maps, suggesting an unconfined water table aquifer. <u>AEA's choice to change this model parameter is inconsistent with a conceptual model of a water table aquifer</u>. Because many combinations of model parameters can result in a model that matches observed conditions, other parameters could have been adjusted instead during model calibration. Despite adjustment of the storage coefficient, the transient model calibration still was not a good match for many of the wells.*[67]

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[65] *Id.* at 26.
[66] ISR, Groundwater Study, Study Implementation Report B, Appendix B at 17.
[67] Abt Associates Report at 25-26.

b. AEA should conduct aquifer testing at the Focus Areas to estimate hydraulic conductivity.

"One of the most important parameters in a groundwater model is the hydraulic conductivity assumed for the aquifer. The preliminary MODFLOW model currently contains simplified parameters based on 1980s studies. Most of these aquifer parameters were obtained from locations that are not in the modeled area (FA-128), and values ranged widely. No additional aquifer testing was done during the 2013–2015 timeframe. The simplified parameters include application of a single groundwater recharge value per season, and a single value for hydraulic conductivity, storage coefficient, riverbed conductance, and regional groundwater influx to the alluvial aquifer boundaries."[68]

As AEA reports in the ISR, "[t]he hydraulic conductivity of the alluvial aquifer in the Susitna River floodplain is estimated to range from about 1 to 100 ft/day. These ranges are based on the following studies: a pumping test conducted on the water supply well at the Talkeetna Fire Hall (HESJV, 1984a); specific capacity data from several Talkeetna Wells (HESJV, 1984b); falling head borehole tests conducted at Slough 9 in the 1980s (R&M Consultants, 1985); and values reported for the lower Susitna River (USGS, 2013). An initial value of 66 ft/day was assigned to the alluvial aquifer and later adjusted during the steady state calibration."[69]

Abt Associates Comment*: The simplified model does not do a good job of simulating water levels within the model domain and will need to be refined. No aquifer testing has been done to estimate the hydraulic conductivity in FA-128 (Slough 8A); this parameter was estimated from testing done in other areas that may or may not represent conditions in Slough 8A.*[70]

c. AEA should use an integrated groundwater/surface water model that can simulate small head differences in groundwater and surface water elevations.

Abt Associates Comment: *Small head differences in groundwater and surface water elevation will drive changes in upwelling and downwelling. Although the primary objective of the model is to understand how Project operations might change these patterns of upwelling and downwelling, at this point, the current model does not appear to have the ability to simulate these small differences effectively. This could become a particular problem when simulating operational conditions since the transient river stages could oscillate by multiple feet over sub-daily timescales (see Figure 2).*[71]

[68] Abt Associates Report at 26.
[69] ISR, Groundwater Study, Supplemental Implementation Report, Appendix B at 6.
[70] Abt Associates Report at 26.
[71] Abt Associates Report at 26.

d. AEA should use an integrated groundwater/surface water model that can simulate changes in water temperature.

As previously raised in comments for the Water Quality Study we are particularly concerned with AEA's ability to evaluate and predict temperature changes in off-channel habitats under post-project conditions. Groundwater upwelling is particularly important because it can provide temperature warming effects and benefits that aid salmon egg survival in the winter. Not only does AEA not have sufficient temperature data for the Middle River, but it is also using MODFLOW, a model that is not capable of modeling temperature to predict groundwater/surface water interactions. The model results will be unreliable under AEA's current approach because MODFLOW lacks the ability to model observed conditions.

Abt Associates Comment: *We question the use of MODFLOW for groundwater-surface water evaluations. It is well known that MODFLOW only simulates saturated flow conditions, and oversimplifies plant transpiration processes. Better tools exist to model the subsurface variable saturation conditions and associated recharge/evapotranspiration dynamics. We recommend that AEA consider using more sophisticated, physically-based, and fully integrated tools that can much more readily incorporate surface water dynamics into this evaluation. As indicated above, MODFLOW also lacks the ability to simulate 3-D heat flow in groundwater, which is an important factor associated with the upwelling/downwelling associated with the salmon lifecycle. AEA should consider using a more appropriate code such as the Integrated Hydrology Model (InHM), Hydrogeosphere, or a similar code to evaluate the 3-D heat balance in groundwater. As described in the comments on Study 7.5, above, more work also needs to be done to consider how to upscale the FA groundwater/surface water coupling/modeling to the Project area.*[72]

Conclusion

The groundwater model predicts groundwater/surface water interactions and will serve as the foundation for a variety of other studies. Currently, AEA does not have enough data to properly calibrate the model. It is not appropriate to use short cuts or model manipulations to work around the lack of data. AEA should also strongly consider using an integrated groundwater/surface water model that can simulate groundwater flow *and* temperature so the results are more reliable. "Many codes can simulate processes relevant to the Susitna Watana modeling efforts, including snowmelt, ice, sediment transport, and fully integrated advective/dispersive fate/transport and water quality."[73] For the foregoing reasons, we request

[72] *Id.* at 43.
[73] Abt Associates Report at 45. (Instead of attempting to manually couple groundwater flow code MODFLOW with the OWFRM 1-D hydraulic model, EFDC, the 2-D SRH-2D and River 2D models, or Bed Evolution models, AEA could consider using readily available, fully coupled, hydrologic/hydraulic codes. Many codes are

that FERC require AEA to develop a fully integrated groundwater/surface water model to address the problems with the preliminary MODFLOW model for FA-128.

Ice Processes Study (7.6)

"Winter ice is an important element of the hydrology and geomorphology of the Susitna River system. Ice jams that occur during breakup in the spring contribute to the flooding of off-channel and side-channel habitats, and may play an important role in both the geomorphic evolution of those habitats and the outmigration of salmonids."[74] Ice formation in the winter also influences groundwater/ surface water interactions in off-channel habitats.

Under post-project conditions, higher oscillating winter flows will impact the timing of freeze up and the formation of ice pack in the Middle River. Of particular concern, "it is likely that daily oscillations in winter water levels and flows would slow ice formation in the early winter, would result in ice forming at a higher stage along the river bank, and would result in and overall thinner ice by the time of spring breakup."[75] The ice process changes under post-project conditions has the potential to dramatically alter the formation of off-channel habitats and the protections those habitats currently provide in winter months that contribute to salmon egg survival and development.

The Ice Process Study (7.6) is designed to understand ice formation and breakup and predict post-project impacts.[76] AEA is relying on data collected in the Ice Processes Study and other studies including the Water Quality Study and Fluvial Geomorphology Study to support the ice processes model calibration. The model results will help inform post-project impacts for the Aquatic Instream Flow Study and the Riparian Instream Flow Study. AEA is still at the early stages of model development for the open water flow model but the ice processes component has not yet been added. As indicated by comments contained in this document and the attached Abt Associates Report, "AEA currently does not have sufficient data to understand the basic relationships among winter mainstem flows, ice breakup, and the flooding of side-channel and side-slough habitats."[77] The lack of data and information prevents AEA from meeting the FERC approved study objectives.

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available, such as MIKESHE/MIKE11, or GSFLOW, Hydrogeosphere, Parflow, Coupled HEC-RAS-MODFLOW using OpenMI, or MODHMS.)

[74] Abt Associates Report at 30.

[75] *Id.*

[76] ISR, Ice Processes Study (7.6), Part A at 2.

[77] Abt Associates Report at 30.

I. The Ice Processes Study (7.6) should be modified to require AEA to collect additional stage-discharge data to understand winter flows, ice breakup and the flooding of off-channel habitats, to properly calibrate the model and address uncertainty.

One of the primary objectives of the Ice Processes Study requires AEA to "[d]ocument the timing, progression, and physical processes of freeze-up and break-up during 2012–2014 between tidewater and the Oshetna River confluence (PRM 235.2 [RM 233.4]), using historical data, aerial reconnaissance, stationary time-lapse cameras, and physical evidence" and [78] AEA has not met this objective and additional data and information needs to be collected.

a. AEA should collect stage-discharge data in the Middle River to understand breaching flows in off-channel habitats, under ice flows and main channel flows.

AEA needs to understand under ice flows and breaching flows to evaluate impacts to off-channel habitats under post-project conditions. To calibrate the ice processes model, stage-discharge data is needed. Instead, AEA plans to use modeled flows to provide the information rather than field data. AEA states, "[a] better understanding of breaching flows (i.e., flows at which surface flows from the main channel Susitna River begin to enter side channel and off-channel habitats) and relationships between under-ice stage and main channel flows within each of the Focus Areas will be possible once the open water and under ice 2-D hydraulic models are fully developed (AEA, 2012, Sections 6.6 and 7.6)."[79]

> **Abt Associates Comment:** *It is not clear why open water flow and 2-D hydraulics models are necessary to understand breaching flows. This could easily be characterized without a hydrodynamic model if AEA had a sufficient understanding of stage-discharge relationships at each of the side channels and off–channel areas of interest. This needs to be characterized through careful data collection, using measured cross-sections and water level gages in the vicinity of each side-channel and off-channel habitat area of importance. Relying on hydrodynamic models to provide this answer may be misguided, since without these field data the hydrodynamic models will be untestable. AEA should be collecting the data they need to understand stage-discharge relationships adjacent to important side-channel and off-channel habitats.*[80]

The lack of stage-discharge data is echoed in our comments on the Fluvial Geomorphology Study contained in this document. This is a critical information need that

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[78] ISR, Ice Processes Study (7.6), Part A at 2.
[79] ISR, Fish and Aquatics Study (8.5), Part C, Appendix L at 11.
[80] Abt Associates Report at 32.

impacts the ability to calibrate models across studies. For that reason, AEA should collect stage-discharge data for off-channel habitats.

b. Missing aerial photography and stage-discharge data prevents AEA from understanding and modeling interactions of ice with main-channel and side-channel habitats and potential impacts to salmon habitat under post-project conditions.

The Ice Processes Study is interrelated with a variety of other studies. Of particular importance one of the primary objectives is to "[d]evelop detailed models and characterizations of ice processes at instream flow Focus Areas in order to provide physical data on winter habitat for the Fish and Aquatics Instream Flow Study (Study 8.5)."

As described in our comments on the Geomorphology Study, AEA lacks both a complete set of aerial photographs for the Middle River at low flows or stage-discharge data to understand baseline conditions. To understand post-project impacts to critical off-channel habitats AEA needs to understand breaching flows.

Abt Associates Comment: *The amount of flow in the side sloughs will depend on whether the discharge created by the dam is sufficient to flood the side sloughs, and by how much. This is why it is important to have documentation of habitat areas from aerial photographs under the actual range of flows that will occur during the winter, and to collect field data on stage-discharge relationships at each side slough where salmon habitat is important. AEA currently does not have full coverage of the Middle River from aerial photography, and appears to be missing basic data describing stage-discharge relationships adjacent to many side channels and side sloughs.*

c. AEA needs to demonstrate that the ice processes model can simulate the inundation of off-channel habitats during break up.

Abt Associates Comment: *The side sloughs in the Middle River are very active during breakup, and are in some cases actually formed during breakup. Given the apparent importance of ice jams in generating and/or inundating side-channel habitat, there is currently little discussion of how changes in ice formation and breakup during proposed Project operations might influence these events. When AEA has completed the ice modeling, they need to demonstrate that their model can simulate the inundation of side channels during breakup under baseline conditions, and include discussion of how any changes in ice thickness or elevation might alter this periodic flooding under operational scenarios.*

d. AEA needs to address uncertainty introduced by modeling oscillating flows in the winter under post-project conditions.

Abt Associates Comment: *AEA's conceptual model of ice formation in the winter appears to be that ice will form at a higher elevation than natural conditions due to a higher "stable" water level. However, the available information would indicate that operational conditions will not result in "more stable discharge levels throughout the winter," but that discharge will oscillate and create changes in river stage of 1–2 feet each day (see Figure 2). Since oscillating flows of this sort do not occur under baseline conditions, AEA will need to describe the uncertainties introduced by modeling something far outside of their model calibration conditions.*

Conclusion

AEA currently lacks the data to support the development of a reliable ice processes model. To meet the FERC approved study objectives for the Ice Processes Study, AEA must understand the interaction between winter mainstem flows, ice breakup and the flooding of off-channel habitats. For the foregoing reasons, we request that FERC require AEA to collect at least one full year of stage-discharge data in Focus Areas, complete aerial photography data collection and address sources of model uncertainty.

Fish and Aquatics Instream Flow (8.5)

The proposed Susitna dam has the potential to dramatically impact fish habitat due to the changes in the magnitude, timing and variability of the Susitna River discharge under post-project conditions. "These changes in river discharge and associated river stage will result in changes in the depth and timing of inundation on side-channel and side-slough habitats, changes in the degree of groundwater/surface water exchange, changes in the ability of the system to transport sediment, and changes in stream temperatures and water quality. All of these instream flow changes will have impacts on fish and aquatic habitats."[81]

The Fish and Aquatics Instream Flow Study (8.5) is designed to evaluate existing habitats and determine impacts to aquatic habitats under post-project conditions. Relevant study objectives related to this review include:

- "Develop integrated aquatic habitat modes that produce a time series of data for a variety of biological metrics under existing conditions and alternative operational scenarios;
- Coordinate instream flow modeling and evaluation procedures with complementary study efforts including Riparian Instream Flow, Geomorphology, Groundwater, Baseline Water Quality, Fish Passage Barriers, and Ice Processes; and

[81] Abt Associates Report at 33.

- Develop a Decision Support System-type Framework to conduct a variety of postprocessing comparative analyses derived from the output metrics estimated under aquatic habitat models." [82]

Modeling experts at Abt Associates reviewed the Fish and Aquatics Instream Flow Study (8.5) for the purpose of assessing AEA's progress related to model development and integration. We recognize that AEA is still developing preliminary models but the lack of a clearly described instream flow framework at this point in the process makes it very difficult to comment on AEA's modeling approach or potential data gaps. The primary concerns include 1) the lack of a detailed conceptual model, 2) poorly described methods to link/couple models across studies, and 3) the overall failure to address model uncertainty. In addition, AEA has made no progress toward developing a Decision Support System as required by the FERC approved study plan.

I. The Fish and Aquatic Instream Flow Study (8.5) should be modified to require AEA to develop a detailed conceptual model, clearly describe linkages/coupling between the Fish and Aquatic Instream Flow Study and other dependent studies and address sources of uncertainty.

a. <u>AEA should clearly describe linkages or couplings between models</u>

The ISR for the Fish and Aquatic Instream Flow Study contains a number of diagrams that attempt to describe the relationship between dependent studies. The Instream Flow Study (ISF) framework that AEA has presented in the ISR is in Figure (4.1-1). According to AEA, "[t]he IFS framework represents a measurement-oriented approach to assessing the relationship of hydrologic and geomorphic variables to the biological and ecological resources of concern…. The IFS framework provides the tools to identify operational scenarios that balance resource interests and quantify any loss of aquatic resources and their habitats that result from Project operations."[83] While AEA has made an attempt to describe the relationship between studies, the diagram and related information is highly confusing.

Abt Associates Comment: *AEA should provide a clear and concise modeling flow chart that illustrates how all of their process models relate to one another. Here and elsewhere, it is unclear how the specific data, assumptions, parameters, boundary conditions, and outputs are transferred between models. It is much too confusing for any stakeholder/reviewer to get a clear idea of inputs, assumptions, modeling approaches, etc., when critical modeling details are divided up into so many different reports. This in itself is an important limitation of the existing studies. It also makes it extremely difficult*

[82] ISR, Fish and Aquatic Instream Flow Study (8.5), Part A at 3-4.
[83] ISR, Fish and Aquatic Instream Flow Study (8.5), Part A at 6.

to see how AEA will combine all of their models in a DSS framework to make meaningful decisions, or how AEA will assess uncertainty in their model outputs.

The flow diagrams in the ISR and SIR 8.5 IFS documents that attempt to show how the various studies and models relate to each other are highly confusing. This information is critical to demonstrate to FERC and stakeholders that all proposed modeling efforts are correctly integrated, consider uncertainty, and fully meet the stated objectives of the aquatic instream flow study (IFS) and riparian instream flow study (RIFS).[84]

It is imperative that AEA transparently describe how the objectives of the Fish and Aquatics Instream Flow Study can be met by the modeling efforts across interrelated studies. AEA should "provide better roadmaps showing how all models are integrated, across multiple, representative, and complete years."[85]

b. AEA should develop well-defined conceptual models and address sources of uncertainty.

As highlighted in other comments, AEA has not clearly defined a conceptual model for the Fish and Aquatic Instream Flow Study. The conceptual model should be designed before data collection begins so data needs are adequately addressed, sources of uncertainty are identified and the models are properly calibrated. This step should not be an afterthought. Rather, "this is standard procedure for any sort of modeling, as summarized by American Society for Testing and Materials (ASTM) standard ASTM D5979-96 (ASTM, 2014) and Kolm (1993)."[86]

Abt Associates Comment: *Specifically, AEA should carefully describe and define how all processes (e.g., flow, sediment transport, aqueous geochemistry, ice formation and degradation, surface water-groundwater interactions) interact with each physical domain (e.g., reservoir, mainstem Susitna River, side channels, fans, overland flow, unsaturated and saturated groundwater) through different times of the year. Alternative conceptualizations of how these processes and systems interact should then be developed and considered across all of AEA's modeling studies. Currently, the flow framework is not adequately described and the parameters that feed AEA's models all have very high uncertainties. These uncertainties are compounded by uncertainties related to the model conceptualization.*[87]

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[84] Abt Associates Report at 36 (For specific comments about problems with Figure 4.1 see page 37).
[85] *Id.*
[86] Abt Associates Report at 35
[87] *Id.*

Conclusion

To reduce model uncertainty and support model development and integration, FERC should modify the Fish and Aquatic Instream Flow Study (8.5) and require AEA to develop well-defined conceptual models across studies before moving forward with the modeling effort. Once the conceptual models are developed, AEA should file the documents with FERC and allow licensing participants the opportunity to review, comment and identify any additional data collection needs. In addition, AEA should reevaluate its model integration framework and provide a clearly-described "roadmap" that licensing participants can understand.

General Proposed Modifications to AEA's Modeling Approach

In addition to the study specific comments and recommendations for proposed modifications contained in the document, the Abt Associates Report also provided general proposed modifications that FERC should approve. These proposed modifications are pulled directly from the Abt Associates Report.[88] Under the current modeling approach, we do not believe that AEA can successfully meet the study objectives outlined in the FERC approved study plan. Specifically, we are concerned that without a shift in AEA's modeling approach it will not be able to accurately predict the impacts of the proposed Susitna dam on changes to river conditions and critical off-channel habitats that are important for fish. We respectfully request that FERC approve the following proposed modifications.

I. FERC should require AEA to provide a detailed framework for integrating process models.[89]

AEA has not provided detailed descriptions of their conceptual site model of the system, or how the multiple models they are developing will be integrated. Linking and integrating models with different spatial and temporal scales can be quite challenging. The available documents do not describe the methods that AEA plans to use to link these models. At a minimum, more work is needed to develop and vet methods that will be used to create an integrated tool to evaluate proposed Project impacts on multiple resources, and to support operational decisions for the Project.

We recommend that AEA consider developing a fully integrated groundwater and surface water model. The benefits of an integrated model include:

1. Avoiding complicated linkages of separate models in space and time. Instead of attempting to manually couple groundwater flow code MODFLOW with the OWFRM 1-D hydraulic model, EFDC, the 2-D SRH-2D and River 2D models, or Bed Evolution models, AEA could

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[88] Abt Associates Report at 45-48.
[89] Abt Associates Report at 45-46

consider using readily available, fully coupled, hydrologic/hydraulic codes. Many codes are available, such as MIKESHE/MIKE11, or GSFLOW, Hydrogeosphere, Parflow, Coupled HEC-RAS-MODFLOW using OpenMI, or MODHMS. Many of these codes can simulate processes relevant to the Susitna Watana modeling efforts, including snowmelt, ice, sediment transport, and fully integrated advective/dispersive fate/transport and water quality. Codes such as this would directly incorporate upstream inflows from the 1-D HEC-RAS OWFRM model as model boundary conditions. Fully integrated models are driven by event-based external climate conditions, which would allow easier simulation of climate change impacts, based directly on output from general circulation models (GCMs). Translation of 2-D hydraulic model results to MIKESHE is also possible via OpenMI, or simply done using dynamic boundary arrays for topography, vegetation, and flows.

2. Avoiding over-simplification of tributary inflows. An integrated hydrologic/hydraulic model avoids over-simplification of tributary inflows and distributed lateral “accretions” by calculating these based on physically-based inputs instead of basing them on highly-uncertain estimates, which are based on discharge relations with the basin area. This becomes important when modeling must evaluate future operational scenarios under the influence of climate change (i.e., glaciers melt out and the surface water/groundwater flow conditions change current tributary inflows).

3. Integrating water quality modeling capabilities**.** Integrated tools allow simulation of integrated fate/transport and water quality modeling, including more robust heat balance tools that simulate a more realistic heat balance, not just in the stream, but also in the subsurface. The current modeling tools only consider heat transport within the stream itself, because MODFLOW does not simulate heat transport. Moreover, groundwater modeling appears to only be planned in FAs and the MODFLOW model is not dynamically coupled to surface hydraulic models. This coupling is a complex process, involving flows through the unsaturated zone. No plan appears to have been offered in the studies reviewed, which attempt to model how either groundwater or heat flow within the subsurface changes due to changes in surface water flows, which respond to operational changes. This defect in the existing approach will not be easily addressed in the DSS scenario.

4. Avoiding oversimplification of baseflows. An integrated model calculates distributed baseflow and lateral tributary inflows based on differences in physical characteristics of each contributing subcatchment. It would incorporate important changes due to major changes in subsurface hydrogeology, or surface drainage complexity in each subcatchment. Baseflows (and associated stream temperatures) are critical to correctly assessing habitat-specific models and impacts to changes due to different operational scenarios. The current 1-D hydraulic models (i.e., OWFRM) appear to lump distributed overland flows and baseflows into “accretions,” which do not realistically simulate these processes.

II. FERC should require AEA to expand consideration of uncertainty.[90]

It is clear in reviewing reports that a minimal effort has been made to (1) clearly identify all sources of uncertainty (e.g., in data, model parameters, model boundary conditions, conceptualizations), and (2) to clearly show a methodology for tracking and accounting for all of these sources of uncertainty. Although AEA indicates that they will develop an example of how uncertainty will be handled in the DSS scenario, we are concerned that AEA will not be able to assess uncertainty in data and models (e.g., hydraulics, groundwater flow, water quality, sediment, dam operations), or address cumulative uncertainty in predictions of effects of different operational schemes on aquatic habitats.

Industry standard methods for developing/implementing a formal uncertainty analysis should be used to consider cumulative uncertainties from all sources (i.e., see Goodarzi et al., 2013, Ch. 2). Given the large sources and magnitudes of collective uncertainty that will be present in the DSS integrated model predictions, a much clearer approach and flow chart for dealing with uncertainty at all levels should also be developed. A major challenge for the existing set of tools in the DSS scenarios will be developing methods to incorporate all the sources of uncertainty into the various separate models and linking these to each other, and estimating a cumulative uncertainty in final predicted impacts to habitats/aquatic species. If integrated models are developed, this would provide an easier method to account for uncertainty.

III. FERC should require AEA to develop and describe methods for extrapolating from Focus Areas to the entire river system to evaluate project impacts.[91]

Methods for extrapolating from areas where data have been collected to areas without data should be articulated, and this should be part of the considerations for data collection and model development. In particular, AEA needs to address the issue raised by R&M and Woodward Clyde (1980) and described in Section 3.3.5 of this memorandum, that “it would be necessary to construct mathematical models of each individual slough in order to make detailed predictions of the effects on the sloughs of changes in mainstem conditions.” (R & M Consultants and Woodward-Clyde, 1985, p. 4-17). Even if AEA had completed a simulation that accurately described baseline conditions throughout side sloughs, plans to move from current conditions to simulation of Project operations would need to be developed and described. To fully assess the sufficiency of the collected data and preliminary models, it is important to understand how these data will be used to assess Project operations. Despite an extensive, multiyear data collection effort, for many of these studies, the methods that will be used to evaluate the full extent of Project impacts on the river system have not been articulated.

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[90] Abt Associates Report at 46
[91] Abt Associates Report at 47

IV. FERC should require AEA to incorporate climate change projections into the modeling framework.[92]

We recommend that AEA include climate change projections for the life of the proposed Project. A range of emissions scenarios and GCM output should be included in evaluations and simulations of Project impacts.

If an integrated model is developed, driven by actual variations in climate conditions, it could be used to assess climate change effects. It is difficult to imagine how the current 1-D hydraulic models could be used to simulate changes to the existing, natural hydrologic flow conditions due to climate change because all of the boundary flows are dependent on historical mainstem and tributary boundary inflows. For example, the loss of glaciers would strongly influence catchment hydrology, to the point that current estimates of tributary inflows based on catchment size would not be valid. Simulating flow conditions with a fully integrated flow model, with an appropriate snowmelt model component (i.e., MIKESHE), would permit evaluation of such conditions, driven by expected external climate changes. A number of studies have already been conducted using these advanced tools, including studies in Alaska (e.g., Prucha et al., 2012).

V. FERC should require AEA to begin DSS scenario evaluations as soon as possible.[93]

We recommend AEA consider using DSS software with a proven track record and capabilities rather than attempting to revise a simple USGS Excel file used in the Black Canyon of the Gunnison (i.e., Auble, 2009) to meet the much more complicated and unique Susitna system. For example, DHI has a DSS tool that could be applied (DHI, Undated). We recommended that AEA initiate DSS scenario evaluations as soon as possible, perhaps just with the major hydraulic indicators, to learn about the sensitivity of DSS results and associated decisions. This would allow AEA to convey information to various study groups, so that they can take the appropriate actions needed in data collection and final modeling efforts that are consistent with the final DSS simulations/needs.

VI. FERC should require AEA to simulate reservoir operations/releases under a full range of scenarios and consider this range across the various studies.[94]

We recommend that AEA simulate a range of reservoir operations/releases, and provide these results to the different studies as soon as possible, even if these values are available for only part of the year, and with the knowledge that these will be refined as the study progresses. With this information, different studies could consider an initial range of impacts that will need

[92] *Id.*
[93] Abt Associates Report at 47
[94] *Id.*

to be evaluated with the data and models. Each study appears to rely heavily on projected operational scenarios, which have not been fully assessed beyond proof of concept.

AEA should promote development and simulation of a more complete range of possible discharges from the dam, so that each group can fully appreciate/understand and assess their respective study areas within the maximum impacted areas. At present, the study groups do not know what the maximum impacted areas will be, and therefore cannot ensure that they are collecting adequate data or developing models that adequately capture the maximum range of impacts. For example, more progress could be made on both the IFS and RIFS studies with a projected range of hydraulic responses to reservoir operations. An initial possible range of hydraulic responses to Project operations could be estimated using initial 1-D hydraulic models that have been developed (i.e., OWFRM version 2.8). In addition, it would provide stakeholders with an understanding of what the maximum or worst-case impacts might be for any given operational scenario

Conclusion

We appreciate the opportunity to comment on AEA's ISR and related supplemental documents. While our review was limited to the studies that support the Riverine Model, we believe that there is ample support to require AEA to conduct additional data collection consistent with our requests and improve the conceptualization and integration of models across studies. For the aforementioned reasons, we respectfully request that FERC approve the proposed study modifications presented herein.

Sincerely,

Mike Wood
President
Susitna River Coalition

Whitney Wolff
Board President
Talkeetna Community Council

Judy Price
Board President
Alaska Survival

Ellen Wolf
Board Secretary
Talkeetna Defense Fund

Ryan Schryver
Deputy Director
Alaska Center

Sam Snyder
Alaska Engagement Director
Trout Unlimited

Emily Anderson
Alaska Sr. Program Manager
Wild Salmon Center

Attachment

Comments on Riverine Modeling Studies for proposed Susitna-Watana Hydro Project

Cameron Wobus and Connie Travers, Abt Associates;
and Robert Prucha, Integrated Hydro Systems

memorandum

Environment and Natural Resources

Date: 6/4/2016

To: Emily Anderson, Wild Salmon Center

From: Cameron Wobus and Connie Travers, Abt Associates; and Robert Prucha, Integrated Hydro Systems

Subject: Comments on Riverine Modeling Studies for proposed Susitna-Watana Hydro Project

1. Introduction

In March 2016, the Wild Salmon Center retained Abt Associates (Abt) and Integrated Hydro to review the Riverine Modeling Studies that the Alaska Energy Authority (AEA) completed to support the proposed Susitna-Watana Hydro Project (the Project) in Alaska. Specifically, we were tasked with evaluating the quality and completeness of data collected for these studies, the appropriateness of the methods employed by these studies, and the quality and appropriateness of the inputs used to support the modeling studies. This memorandum provides our comments on Parts A, B, and C of the initial study reports (ISRs), with a focus on studies related to groundwater hydrology, geomorphology, and instream flows. We also provide comments on the study implementation reports (SIRs) where appropriate, as these reports contain important new information for some study components that is not included in the ISRs. Because the ISRs and SIRs rely heavily on a series of other documents, including technical memoranda, we also comment on information contained in those documents where possible.

AEA has completed multiple seasons of field data collection, and has only recently begun to incorporate their field data into the hydrodynamic, groundwater, and ecosystem models that will ultimately frame their analysis of potential dam impacts. Because these models are not yet complete, we cannot comment extensively on the modeling results. However, because AEA will now be moving into a phase of study where they will complete these models and begin to use them to evaluate dam impacts, we do feel it is appropriate at this stage to comment on AEA’s conceptual model of the site, their plans for integrating their different numerical models, and the completeness of the data they have collected to drive those models. We also recognize that many of the study designs and modeling decisions AEA has made to date have been reached through a collaborative stakeholder process. While we comment on variances from those agreed-upon study designs where appropriate, our comments are primarily based on our understanding of the study results and their scientific merits.

The Susitna is a large and dynamic river system, which changes markedly from a relatively steep, mixed bedrock-alluvial channel between the proposed dam site and Talkeetna to a substantially wider, braided alluvial system downstream of the Three Rivers confluence. Because the Chulitna and Talkeetna rivers more than triple the size of the Susitna River at the Three Rivers confluence, the impacts of a proposed dam will be substantially lessened downstream of

Talkeetna. Upstream of Talkeetna, however, reservoir management and the elimination of sediment transport at the dam site will significantly alter the behavior of the Susitna River system. As a result, our comments in the sections that follow are generally focused on AEA's understanding of potential dam impacts in the Middle River.

This memorandum is organized as follows: Section 2 summarizes our general comments related to the overall study design and implementation, and the linkages among study components. Section 3 summarizes our specific comments related to individual study components, which we organize based on studies related to water quality (ISR Sections 5.5 and 5.6); fluvial geomorphology and fluvial geomorphology modeling studies (ISR Sections 6.5 and 6.6); groundwater (ISR Section 7.5); ice processes (ISR Section 7.6); and aquatic and riparian instream flows (ISR Sections 8.5 and 8.6). Section 4 provides a summary of proposed additional studies that could potentially fill data gaps.

1.1 Impacts of the Proposed Project on the Susitna River

The Pre-Application Document (AEA, 2011) describes two primary effects of the proposed Project operation on downstream flows in the Susitna River:

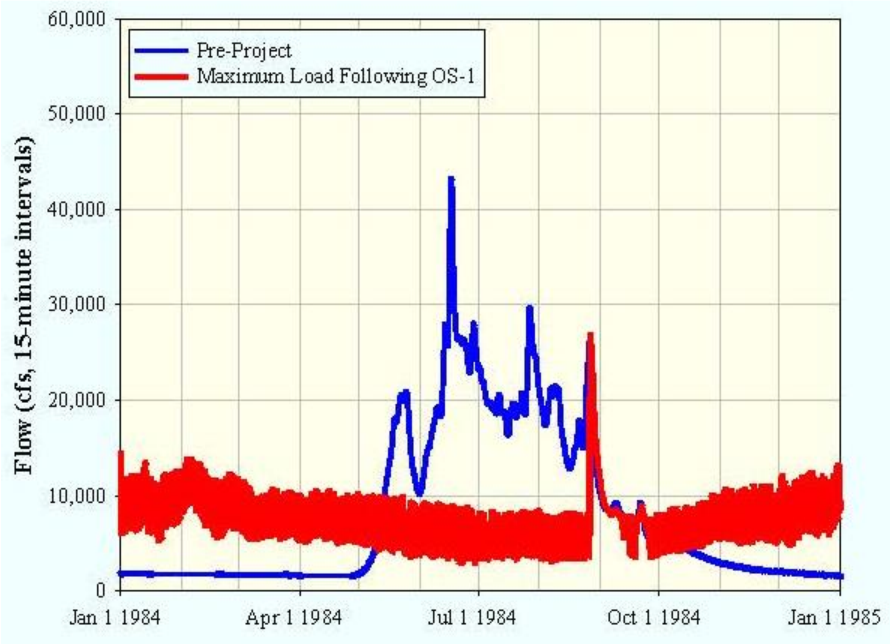
1. An increase in the average November to April flows, as the reservoir is drafted for power generation
2. A decrease in the average flow during the spring runoff from May to July, during reservoir refilling.

In addition, if the Project operates as planned in a "load following" mode (i.e., to focus on peak power demand rather than base load), discharges from the powerhouses would vary daily in the winter months, from a low of ~ 3,000 cfs to a high of 10,000 cfs (AEA, 2011). Figure 1 compares a typical annual hydrograph from pre-Project conditions with the hydrograph that would be typical of "load following" conditions during dam operations. Figure 2 compares the river stage from these same two scenarios.

This alteration in flows downstream of the dam could result in significant impacts to sediment availability, the ability of the system to move sediment, and fish habitat. Potential impacts include the following:

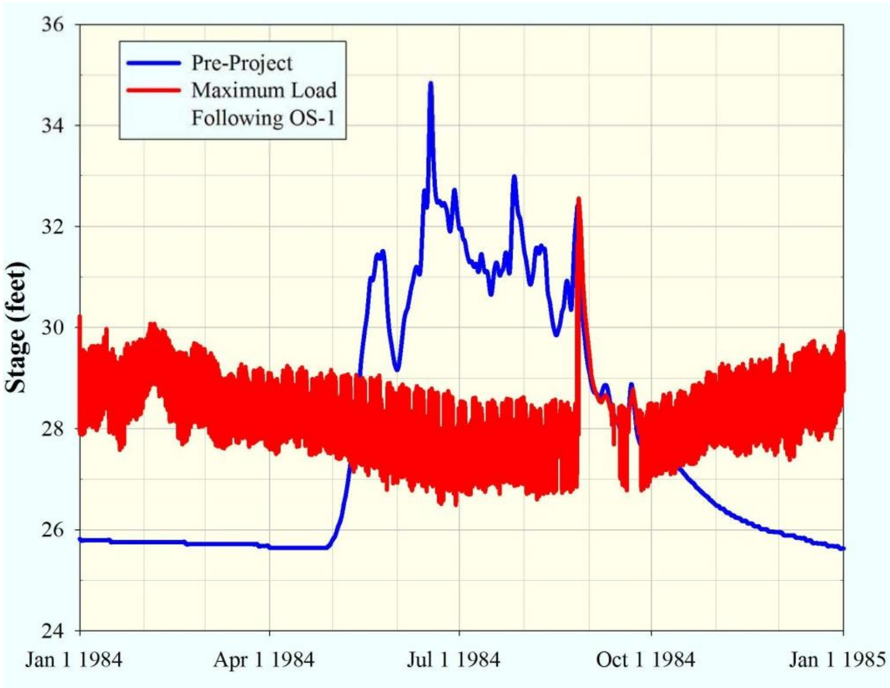
- Construction of the proposed dam would trap virtually all sediment greater than sand size that originates upstream of the dam. The river system downstream of the dam will be starved of coarse sediment until sufficient larger grain-size material is supplied by tributaries, which could have implications for habitat suitability in the river below the dam.
- Lower peak flows in the spring and summer will reduce the river's ability to move larger grain-size sediment downstream of the dam, and the river will potentially be unable to mobilize and rework its bed. Potential impacts could include increased armoring of the bed and formation of deltas at tributary mouths, which could influence habitat quality and access to tributary and off-channel habitats, respectively, in this section of the Susitna River.

Figure 1. Flow at the proposed Watana Dam site for the pre-Project and maximum load following operational scenario 1 (OS-1) for a modeled historical year.



Source: AEA, 2014, Fish and Aquatics Instream Flow Study (IFS) 8.5, Figure 5.4-1.

Figure 2. River stage at the proposed Watana Dam site for the pre-Project and maximum load following OS-1 scenario.



Source: R2 et al., 2013, Figure 5.4-1.

- Lower flows and limited peak flow may result in minimal or no flushing flows in main-channel and off-channel habitats. This could impact the availability of adequate substrate material for salmonid spawning. The reduction of peak flows in the spring and summer could also result in more fine-sediment deposition in off-channel habitats.

Changes in stream flow may affect the distribution, abundance, and habitat utilization of anadromous fish in the Susitna River. Spawning, rearing, and migration may be impacted. For example:

- Changes in the timing of flows and discharges from the reservoir could alter the temperature of the mainstem Susitna River and off-channel habitat, with potential adverse effects on cold water fisheries
- Modification of the existing flow regime may affect flow within off-channel habitats and connectivity between the mainstem Susitna River and the off-channel habitats. This may affect fish access to the off-channel habitats, including outmigration timing and success.
- Higher winter flows may change river stage by several feet, sending more river water into off-channel habitats. Based on data collected in the 1980s and in 2013–2015 [Vining et al., 1985; AEA, 2014 (Study 7.5, Part A), 2015b], winter river water is typically colder than groundwater, and upwelling warmer groundwater is important for egg incubation and survival (Vining et al., 1985). Higher winter river stages caused by dam operations may result in groundwater downwelling in areas where there was upwelling, with implications for egg incubation and survival, and timing of fry emergence.
- Daily variability in winter flows, resulting in rapid changes in river stage, could alter ice formation, with implications for the timing of ice formation, the timing and style of ice breakup, and associated changes in flooding and temperature of off-channel habitats.
- Load following and overly rapid changes in discharge could result in fish stranding and mortality.

2. General Comments

Because of the size and complexity of the Susitna River system and the scale of hydrologic alterations that a Project like the Susitna-Watana Hydro would create, AEA's ISR necessarily has an incredibly broad scope: the report comprises 58 separate studies, and includes input from approximately 350 scientists and other specialists from the 2013 field season alone (AEA, 2014, Overview). Because of this enormous scope, AEA had to make a number of difficult decisions regarding how to design and implement the ISR study components. In particular, AEA chose to implement a series of essentially independent studies to model different components of the Susitna system. They have only begun to tie those models together with a series of coordination meetings. Recognizing that the modeling studies are not yet complete, we do feel it is appropriate at this stage to comment on this conceptual modeling framework, as well as overarching issues related to how these choices might affect AEA's ability to simulate impacts from a proposed dam.

2.1 The Framework for Integrating Process Models is Insufficiently Described

Many of the individual study components rely on outputs from other study components, or are built using the same set of physical inputs. In the ISRs we have reviewed, these linkages among process models are either incompletely described, not fully acknowledged, or in some cases the proposed approach for integrating the models may be impractical. As one key example, groundwater-surface water interactions in side sloughs and side channels are a critical determinant of habitat quality, since groundwater upwelling controls temperature and water quality in spawning gravels (Vining et al., 1985). By using physical codes that focus on only individual processes (e.g., surface water routing, groundwater flow), AEA will have a very difficult time simulating the highly dynamic interactions between these systems, the alteration of which may be one of the most important influences of a dam and reservoir operations on habitat quality. Specifically, not simulating the dynamic coupling between surface water flows and three dimensional (3-D) groundwater flows makes it very different to assess important process couplings such as the relative impacts of changes in surface water flow on groundwater flow. More importantly, the current modeling framework does not allow simulation of the 3-D heat balance in the subsurface system and its dynamic interaction with surface water.

The current approach is to use river stage as a boundary condition to determine how groundwater and surface water interact in the focus areas (FAs). Lateral flow exchanges between groundwater and adjacent surface water must then be estimated through overly complicated and potentially unreliable calibration procedures, as was done with the Open Water Flow River Model (OWFRM). However, since load-following operational scenarios could create variations in river stage of multiple feet over sub-daily timescales, it will be difficult to simulate groundwater-surface water interactions using this varying boundary condition approach. This in turn means that the current modeling approach will limit AEA's ability to adequately simulate and understand how dam operations might influence habitat quality.

AEA has presented insufficient descriptions of the methods that will be used to integrate the various models created for different studies in a Decision Support System (DSS) as described in the Fish and Aquatics IFS (ISR Section 8.5), or how a DSS will be used to assess the translation of operational reservoir discharge scenarios. This DSS approach is particularly problematic considering the many sources of uncertainty and challenges associated with over-simplified boundary conditions and complicated interdependencies of each model.

2.2 There Is Insufficient Consideration of Model Uncertainty

The very limited and narrow scope of discussions related to uncertainty in each study suggests a fundamental confusion between natural variability and selective model parameter sensitivity vs. a more formal predictive model uncertainty analysis. The latter, which we feel is missing from the current modeling framework, would attempt to quantify a range of plausible model outcomes, given the significant sources and magnitudes of uncertainty in model inputs, boundary conditions, and calibration errors. Based on the preliminary modeling results we have reviewed, there is no evidence that AEA has identified or propagated key sources of uncertainty, or associated magnitudes, in any of the input data.

As with AEA's approach to model integration, a full evaluation of uncertainty appears to have been left for later evaluations with the DSS, but no details have been provided. Given the significant lack of data over such a large and complicated system, a detailed and formal uncertainty analysis must be made to provide an appropriate sense of the probability associated with model predictions. This would allow the Federal Energy Regulatory Commission (FERC) and other relevant regulatory agencies [e.g., the U.S. Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers (USACE)] to make decisions based on an informed understanding of risks. While results of a sensitivity analysis may provide a sense of those model inputs to which predictions are most sensitive, a sensitivity analysis does not bracket the full range of possible solutions, whereas a formal uncertainty analysis would. As such, a sensitivity analysis should not be used in lieu of a more robust, constrained predictive uncertainty analysis.

2.3 The Methods for Extrapolating from FAs to the Entire River System Are Not Articulated

For several of the Project studies, data have been collected in limited FAs to try to understand process details in small areas. However, AEA will need to evaluate the cumulative impacts of the proposed dam on hundreds of river miles within the Susitna River system, so data and modeling from these FAs will need to be extrapolated to areas without data. For example, groundwater and surface water data have been collected at four FAs and a preliminary model was developed for one FA (AEA, 2015b, Study 7.5). These FAs represent a small portion of the Middle River, and groundwater data are unavailable for the vast majority of the river. It does not appear that a regional groundwater model is proposed. Thus, Project documents do not provide the specific methods that will be used to assess Project impacts on groundwater/surface water interactions throughout the entire river. Without a clearly articulated plan to apply these data to an assessment of Project impacts on the entire river system, we are hampered in our ability to evaluate the sufficiency of data collected to date.

2.4 AEA's Process Models Are Not Complete Enough to Evaluate

To understand how hydrologic alterations from dam construction might influence the Susitna River system, AEA must first demonstrate that their models can characterize the existing conditions in the system. As described above, many of the physical and habitat models we reviewed are incomplete. Once these models are complete, AEA must then utilize these models to evaluate how reservoir operations might alter these existing conditions. Because AEA is not yet far enough along to demonstrate that their hydrodynamic, groundwater, and ice process models can simulate the baseline conditions in the Susitna River, it is too early to evaluate whether the existing data and modeling frameworks will be sufficient to simulate conditions after Project implementation.

2.5 AEA's Incorporation of Climate Change into Their Modeling Framework is Insufficient for Understanding Project Impacts

The proposed Project would have a lifetime of 100 years, during which time Alaska is likely to see significant changes in climate. While changes in precipitation may be difficult to project with confidence, increases in temperature are already occurring in Alaska and are very likely to increase through the 21st century (IPCC, 2013). These changes in temperature will increase surface water and groundwater temperatures in the Susitna watershed, they could significantly influence the timing and magnitude of spring runoff, and they could also influence groundwater flow and nutrient inputs via changes in the distribution of permafrost. An acknowledgement and understanding of this shifting baseline is therefore critical if AEA is to evaluate effects of the Project on streamflow, water temperature, and habitat quality. With the exception of the glacial and runoff changes study, which mentions climate change only as it might influence inflows to the reservoir, the ISRs we reviewed make virtually no mention of climate change.

3. Specific Comments on ISR Study Components

3.1 ISR Sections 5.5 and 5.6: Baseline Water Quality Study and Water Quality Modeling Study

3.1.1 Stated Study Objectives and Summary

The overall objective of the water quality studies is to "assess the effects of the proposed Project and its operations on water quality in the Susitna River basin" (AEA, 2015b, Section 5.5, p. 1). The objectives of the Baseline Water Quality Study include documenting baseline conditions by collecting temperature, water quality, meteorological data, and baseline metals concentrations in sediment and fish tissue, and collecting thermal infrared imagery (TIR) to map groundwater discharge areas.

These baseline water quality data will be used to develop a water quality model for the Watana Reservoir and downstream Susitna River using the Environmental Fluid Dynamics Code (EFDC) model (AEA, 2013). Modeling of the river will include temperature, suspended sediment and turbidity, chlorophyll-a, nutrients, and ice processes (AEA, 2015a, Part D, p. 2).

3.1.2 Study Status

AEA selected EFDC to be used for the reservoir and riverine modeling. The spatial configuration for the river and reservoir are completed (URS and Tetra Tech, 2016). A "proof of concept" model for hydrodynamics and temperature simulations has been conducted for the 3-D reservoir and 2-D riverine model. In addition, a model for FA-128 has been configured (URS and Tetra Tech, 2016).

3.1.3 Proposed Project Impacts Relevant to Water Quality

The proposed Project may alter water quality in the mainstem Susitna River as well as off-channel habitats (i.e., side channels and sloughs). These changes may result in changes in water temperature, dissolved oxygen, and sediment and metals concentrations. Examples of potential water quality changes include the following:

- Changes in mainstem and off-channel habitat flows and water temperature related to Project operations.
- Altered groundwater-surface water exchange in the Middle River. In particular, changes in river stage will reduce groundwater inflows in the winter, and increase groundwater inflows in the summer.
- Modifications to the existing flow regime in the off-channel habitats will result in changes to surface water and groundwater relationships. In particular, the reduction of groundwater upwelling in off-channel habitats will result in changes in water temperature and sediment dissolved oxygen that may affect fish spawning success, egg incubation, fry emergence timing and success, or juvenile fish growth and survival.

- Higher river flows in the winter and a higher river stage will result in cold river water entering off-channel habitats. This may also create areas of downwelling of river water rather than upwelling of groundwater.
- River and off-channel water quality could be altered, which may influence water quality in sediments affected by groundwater upwelling and downwelling.

The Baseline Water Quality Study (Study 5.5) and the Water Quality Modeling Study (Study 5.6) are proposed to assess current water quality in the Susitna River and off-channel habitats, and impacts caused by the proposed Project.

3.1.4 Variances and/or Reported Anomalous Environmental Conditions

The Baseline Water Quality Study ISR (AEA, 2014, Study 5.5) noted several variances in 2013, and these variances were discussed in the Baseline Water Quality Study Completion Report (AEA, 2015b, Study 5.5). Variances that could affect data adequacy and modeling include:

- Missing temperature data for some stations between 2012 and 2014. In particular, access problems in 2013 resulted in a large stretch of river without temperature monitoring, resulting in no temperature monitoring data at eight sites between Project River Mile (PRM) 145.6 and PRM 209.2 (AEA, 2014, Study 5.5).
- At one of the meteorological stations, ESM-1, located at the Watana Dam site, the planned rain gage could not have been installed in 2013 because site access was restricted. This gage, which was not installed until October 2014, is continuing to collect data. However, the other two gages installed in 2012, ESM-2 and ESM-3, began collecting precipitation data in 2013 but were discontinued in August 2015. Thus, there was less than a year of precipitation data collected contemporaneously at the three meteorological stations. According to the Study Completion Report for baseline water quality (AEA, 2015b, Study 5.5, p. 5), "This data will be used for calibrating the temperature model for the reservoir and river and for calibrating the ice model in the reservoir." The few months of contemporaneous precipitation at the three meteorological stations will increase uncertainty in the modeling, and may influence the calibration of the water quality model.
- Water quality samples were not collected in the Susitna River below Tsusena Creek, and were collected only in the winter of 2013/2014 above Tsusena Creek (AEA, 2015b, Study 5.5, Table 4.1-1). Tsusena Creek itself was only sampled in the summer of 2013. Tsusena Creek is an important tributary, and available data for evaluating baseline water quality in this creek are limited.
- Some water quality samples at some locations were validated as "rejected" or "estimated" in 2013. In general, sampling occurred in 2014 at select locations and for parameters that were rejected or estimated in 2014. While the missing data in 2013 result in a water quality dataset that is not synoptic, the resampling in 2014 did fill some of the data gaps created by the data with quality control problems.

The significance of these variances is increased uncertainty in the water quality modeling. The completed model should address uncertainty caused by variances to the study plan, as well as other sources of uncertainty.

3.1.5 Specific Comments

In this section, we summarize our comments on specific sections of ISR Studies 5.5 and 5.6. Where practical, we group these comments into broad thematic areas to facilitate review. In each case, we include specific quotations from ISR Studies 5.5–5.6 and supporting documents, followed by our comments in italics

1. **Linkage/coupling between water quality model, and ice processes and groundwater models, is not described**

Re: As described in the Revised Study Plan (RSP) in the section describing the integration of temperature from CE-QUAL-W2 or EFDC and the ice dynamics model, "fully predictive simulation within either model would require code modification to handle the interaction between temperature simulation, ice formation and transport, hydrodynamics and water quality simulation" (AEA, 2012, p. 5-51). We have been unable to find a description of how the ice cover and thickness from the ice processes model will be incorporated into the EFDC model, or how the EFDC model will inform the ice processes model.

During the March 23, 2016 meeting, Mr. Jon Ludwig of Tetra Tech stated, "One of the things that we're currently working on is, as I mentioned, in the slide, in terms of the future steps, is interfacing with the ice model, the current ice modeling that's going on and trying to figure out – and that's what we're trying to do right now, is trying to figure out how to interface the two models…" (AEA, 2016, p. 168).

Comment: To date, methods to link/couple/integrate these models in space and time, which is critical to development of the models, have not been proposed. Understanding how linkages between models will be established is important to evaluating the adequacy of the data available to simulate important processes in the models, and couplings between them.

2. **Uncertainty in the EFDC model needs to be identified and addressed**

Re: "The model determined that the simulated water temperatures in the Susitna River are sensitive to the magnitude and timing of temperature in the boundary conditions, indicating that the uncertainty in the boundary condition can influence the simulated temperature. Since the data available to accurately represent the boundary conditions are limited, considerable uncertainties are present in the simulated temperature, particularly the details in short-term behavior. In this case, the best way to evaluate model performance is through visual comparison, which looks at identifying the pattern and trend rather than point-to-point comparison. This process is used with hydrodynamic and water quality models across the country." (AEA, 2015b, Study 5.6, p. 5).

Comment: Uncertainty in modeling needs to be addressed. We have not seen a presentation describing how the uncertainties in boundary conditions will be addressed. It is not common practice to use "visual comparison" to evaluate model performance, nor is it clear how this visual comparison will be done, and whether model uncertainty will be addressed in a quantitative fashion (see general comment in Section 2).

3. **Use of groundwater data from the FAs in the EFDC model**

Re: During the ISR meetings on March 23, 2016, the comment was made that "Groundwater sampling occurred in focus area, four focus areas [sic]. These, mainly to supply the water quality model with some input data for calibration, temperature calibration." (AEA, 2016, p. 130).

Comment: Groundwater data from the FAs are providing input data for EFDC, but it is it unclear how these data are informing the EFDC model input, and what assumptions are being made about groundwater/surface water interactions in areas where no groundwater data are available. Thus, the sufficiency of the groundwater data for these purposes cannot be evaluated.

4. Lack of temperature data throughout many river miles along the river

Re: In comparison to the approved sampling plan, temperature data were not collected at some planned stations during some years between 2012 and 2014. In particular, access problems in 2013 resulted in a large stretch of river without temperature monitoring, resulting in no monitoring data at eight sites between PRM 145.6 and PRM 209.2 (AEA, 2014, Study 5.5, Part A, p. 7). Most of these sites were monitored in 2014, but there is still a gap for 2013 data.

Comment: It is not clear how this lack of synchronous data will be handled in the water quality model. The temperature data are being used to calibrate the model, and a large stretch of the river had no temperature data in 2013. The model will need to interpolate between these stations. The lack of temperature data throughout the reach in 2013 will increase uncertainty and may hamper the ability to calibrate the model to observed conditions, or changes in habitat quality under operational conditions.

5. Model input, development methods, and calibration statistics are not described sufficiently to be evaluated

Re: The RSP describes model calibration (Section B2) and model validation (Section D). However, we were unable to find a detailed description of the EFDC modeling specifics, including model boundary conditions applied, model calibration statistics, and what parameters (e.g., water levels, temperature) were used for model calibration (AEA, 2012).

Comment: We cannot review the EFDC water quality model because of insufficient model input and calibration statistics. To date, only discharge and temperature have been simulated, so it is not possible to evaluate other parameters, such as dissolved oxygen. We were unable to find a description of the model boundary conditions used in space and time or model calibration statistics for temperature and water levels. Modeling methods are not fully described in any reports.

6. Lack of presentation of detailed conceptual model for the water quality model

Re: Conceptual models for each of the models, including the water quality model, should be described, and the connections with the other models detailed.

Comment: We have been unable to find a description of a detailed conceptual model incorporating the data that have been collected to date. A conceptual framework for the models that are under development should be prepared and expressed to ensure that the numerical models are consistent with the conceptual models.

7. Model needs to simulate winter conditions, the most important season for egg incubation and survival

FA-128 modeling has only been conducted for the summer and fall (May–October 1976 and 1981 (URS and Tetra Tech, 2016, slide 13).

Comment: To date, the FA modeling has only evaluated temperature in the summer. Winter temperatures in off-channel habitats need to be evaluated with the model, as these temperatures are critical to incubation timing and success.

8. Linkages with the ice processes model are not described

Re: Steps to complete Study 5.6 are described as: "Import ice cover and thickness from ice processes model into the models. Conduct river temperature simulations for calibration. Provide output for development of the River 1D Ice Processes Model (Study 7.6)."

Comment: It appears that the output from the ice processes model will be used as input to the water quality model, and the output from the water quality model will be used as input to the ice processes model. The documents do not detail how this linkage between the models will be accomplished.

3.2 ISR Sections 6.5 and 6.6: Fluvial Geomorphology and Fluvial Geomorphology Modeling Studies

The objectives of the fluvial geomorphology and geomorphology modeling studies are to understand the current geomorphic conditions of the Susitna River, and to evaluate how dam operations might influence this system in the future. These goals are summarized in ISR 6.5 as follows: "The overall goal of the Geomorphology Study is to characterize the geomorphology of the Susitna River, and to evaluate the effects of the Project on the geomorphology and dynamics of the river by predicting the trend and magnitude of geomorphic response. This will inform the analysis of potential Project-induced impacts to aquatic and riparian habitats." (AEA, 2014, Study 6.5, Part A, p. 2).

To meet these objectives, AEA has completed multiple seasons of field data collection, gathering data on river flows, sediment transport, channel form, and geomorphic change through the Middle and Lower River. AEA is in the process of developing and calibrating one dimensional (1-D) and two dimensional (2-D) open water flow models that will simulate flows and sediment transport in the Susitna River.

3.2.1 Proposed Project Impacts Relevant to Fluvial Geomorphology

The proposed Project would impound water and sediment upstream of the Watana Dam site, and regulate flows on the river downstream of the dam. From a geomorphic perspective, the most important Project impacts on the Susitna River are likely to be:

- Changes in the magnitude and seasonality of flows in the Susitna River. In particular, winter low flows under the OS-1 scenario will increase by a factor of 5–10, and summer high flows will be reduced by a factor of 2 to 3. Peak flow duration would be dramatically reduced.

- Changes in the delivery of sediment to the Susitna River. In particular, bed load supply (sand and gravel) will be completely cut off from upstream of the dam. The majority of the suspended sediment will also be removed by settling in the reservoir behind the dam.
- Changes in the ability of the river to transport sediment. In particular, peak flows will be substantially reduced, limiting the ability of the river to move sediment and rework its bed.
- Altered relative balance of flow and sediment in tributaries and the main channel. This could result in formation of deltas at tributary mouths because the mainstem Susitna may no longer be able to move the delivered load.
- Elimination of large woody debris (LWD) sources from upstream of the dam, and potential reductions in LWD recruitment from channel banks in the Middle River.

Each of these dam-induced changes has implications for salmon habitat. For example, the size and quality of sand and gravel influences the suitability of the channel for establishing redds. As described in Section 2 of this memorandum, these effects will be most pronounced in the Middle River, since significant water and sediment inputs from the Talkeetna and Chulitna rivers make the relative impacts of the dam less significant downstream from the Three Rivers confluence.

3.2.2 Variances and/or Reported Anomalous Environmental Conditions

The ISRs for Studies 6.5 (Fluvial Geomophology) and 6.6 (Fluvial Geomorphology Modeling) suggest that there were few variances from the approved study plans. In general, the variances that did occur were relatively minor. However, there are at least two variances of note, which we describe below along with the implications these variances have for AEA's understanding of the Susitna River system and the impacts of a dam on that system.

Aerial Photography is Incomplete

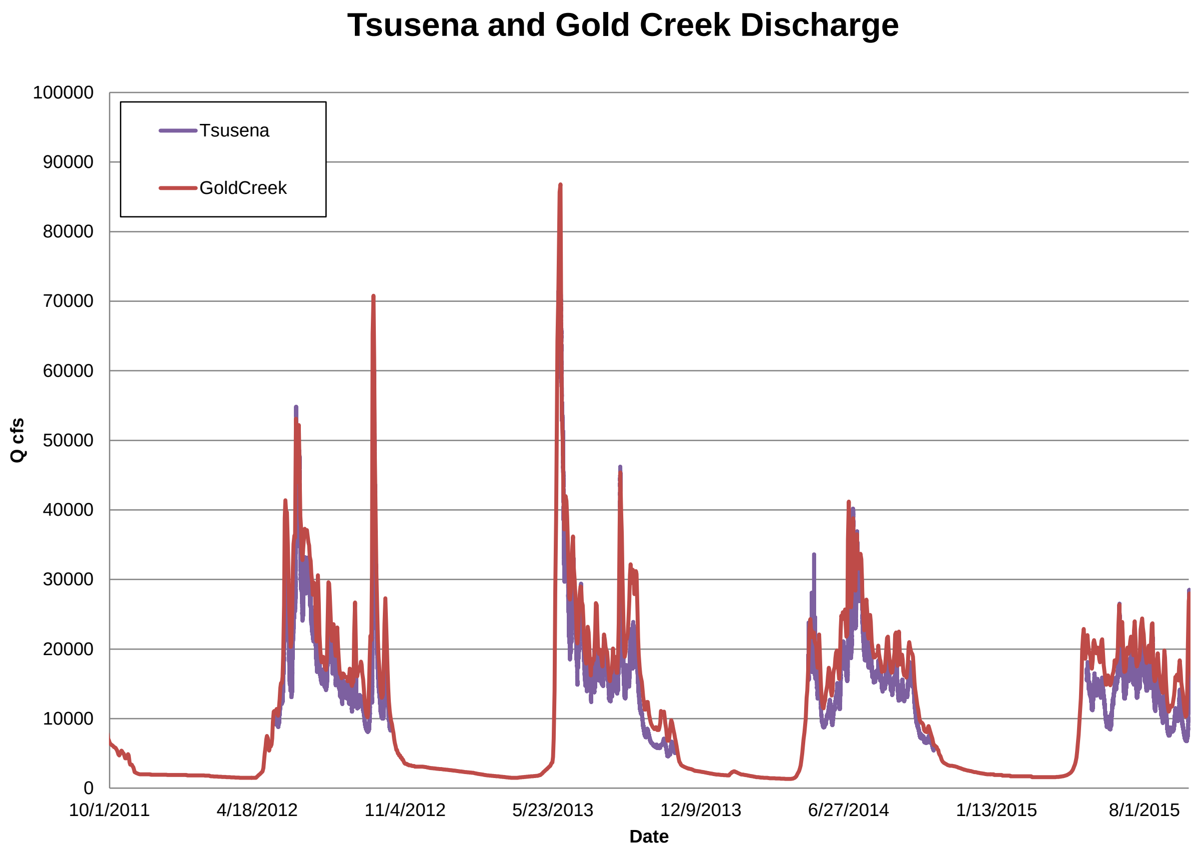
AEA intended to collect three sets of aerial photography in order to estimate habitat areas at a wide range of flow conditions. However, this was not completed as described below.

"It was the intent of the Revised Study Plan Section 6.5.4.5.2.1 to obtain three sets of aerial photography in 2012 at the following approximate discharges: 23,000, 12,500, and 5,100 cfs. Only one set of aerials was actually obtained with the flow for 50 percent of the Middle River at 12,900 cfs and 50 percent of the Middle River at 17,000 cfs. In 2013, it was decided to acquire additional aerial photographs for only the 12,500-cfs target discharge in the Middle River. Aerials were obtained for about 60 percent of the Middle River at 11,300 cfs and 40 percent at 6,200 cfs." (AEA 2014, Study 6.5, Part A, p. 40). Thus, only a portion of the river was photographed at the flows anticipated in the winter.

Because AEA does not have complete aerial photography coverage for the lowest flow proposed in the approved study plan, it is difficult to evaluate how dam-induced changes in flow will influence habitats throughout the Middle River. Under pre-Project conditions, the majority of the winter hydrograph in the Middle River is between ~ 1,000 and 4,000 cfs (see Figure 3), which is substantially lower than 6,200 cfs.

This winter low flow period is when salmon eggs are incubating, primarily in off-channel habitats. Future regulated flows will greatly alter this hydrologic regime, so that winter flows will be closer to 5,000–10,000 cfs (see Figure 1). A key question regarding impacts on salmonids is how off-channel habitats will be affected by these higher winter flows. The lack of baseline aerial imagery for current winter flow conditions may influence AEA's ability to evaluate proposed Project habitat changes from current winter conditions throughout the Middle River.

Figure 3. Baseline flows in the Middle Susitna River, from the U.S. Geological Survey (USGS) data.



Bed Load Sampling is Incomplete

AEA intended to collect bed load samples on the Susitna River at Tsusena Creek, which would help to characterize the size and quantity of sediment passing this site. These samples were not collected:

"Due to logistical and safety issues, the bed load samples at Tsusena Creek were terminated after 2012, were not collected in 2013, and will not be collected in the future. This will not affect the ability to meet study objectives as alternate means are available to determine the bed load passing the dam site for the without Project condition. For with-Project conditions, the bed load passing the dam site will be zero as all bed load will be trapped in the reservoir." (AEA, 2014, Study 6.5 Part A, p. 14).

It is true that bed load passing through the reservoir will be zero. However, this in our opinion does not obviate the need for additional bed load measurements in the reach below the dam. This location approximately 2 miles below the dam will be within the most sediment-starved reach after dam installation, and is likely to be very dynamic in terms of adjustment of sediment load to post-dam conditions. Fully characterizing pre-Project conditions will be critical to evaluating dam impacts to geomorphology along this reach.

3.2.3 Specific Comments

In this section, we summarize our comments on specific sections of ISR Studies 6.5 and 6.6. Where practical, we group these comments into broad thematic areas to facilitate review. In each case, we include specific quotations from ISR Studies 6.5–6.6 and supporting documents, followed by our comments in italics.

1. AEA does not have enough field data to understand the sediment balance in the Middle River

The size, quantity, and quality of sediment being transported through the Middle River helps control channel form, as well as the suitability of the channel substrate for spawning. A dam at the Watana site would completely cut off all bed load sediment and the majority of suspended sediment coming from upstream on the main river. A dam would also reduce the ability of the Susitna River to transport and redeposit sediment through this reach. Thus, it is critical that AEA fully understands all other sources of sediment to the Middle River. As summarized below, there are a number of examples demonstrating that AEA does not have enough data to understand this sediment balance.

"A prerequisite for the 1-D reach-scale morphology models is to determine the sediment supplied by each of the tributaries. Table 2.2 shows 1-D Tributary Sediment Modeling is the first modeling task. This modeling will be conducted for a range of flows to develop sediment rating curves at all tributaries located at Focus Areas, selected tributaries in the Lower Susitna River Segment for sediment supply and limited habitat analyses, and other selected tributaries in the Middle Susitna River Segment for sediment supply only." (Tetra Tech, 2013b, p. 9-10).

"To support the preliminary 1-D bed evolution model simulations (Section 4.5.1.3.1), bed material load sediment rating curves were developed for Indian River and Gold Creek to provide for calculation of tributary sediment supply. At these two tributaries, the sampled bed material gradations were coupled with the reach-averaged hydraulic results from the HEC-RAS models to calculate sediment transport capacity. Sediment transport was measured at both tributaries during water year 1984 (Knott et al., 1986), and these measurements were compared to the calculated sediment rating curve. It was determined that the bed-load transport equation developed by Parker et al. (1982) provided the closest fit to the measurements. This procedure will be applied to the other 22 tributaries to develop bed material load sediment rating curves." (Tetra Tech, 2013b, p. 33).

Comment: Our understanding from these quotations is that AEA has sediment transport data from only two tributaries to the Middle River – Indian Creek and Portage Creek – collected in the 1980s and summarized in Knott et al. (1986). For the other 22 tributaries to the Susitna River, AEA plans to model sediment inputs by assuming that (1) their model of hydraulics for each of these tributaries is accurate, and (2) sediment rating curves from 2 tributaries analyzed over 30 years ago can be used as a proxy for the other 22. Given that one of the major objectives *of these studies is to understand the current geomorphology and projected changes in geomorphology for the Susitna River, it does not appear that AEA has met this objective.*

Re: "Sand is almost certainly supply limited in the Middle River Segment, and likely transitions to capacity limited in the reach upstream of the Yentna River" (AEA, 2014, Section 6.5 Part A, p. 87).

Comment: AEA's discussion of the impacts of the proposed Project on the already limited sand supply are insufficient. The evaluation should describe how trapping of sand by the proposed dam could further reduce sand supply and alter the geomorphic evolution of the Middle River segment post-construction.

Re: "During the initial period after closure of the dam, Project effects on the sand load in the lower part of the Middle River and the Lower River would result primarily from the change in flow regime, because there is currently sand moving through the system and it moves at a much slower rate than the flow. Over time, much of the stored sand will be depleted from the Middle River, and the load just upstream from the Three Rivers Confluence area will be consistent with the supply from the local tributaries." (AEA, 2014, Section 6.5 Part A, p. 106).

Comment: AEA has collected insufficient tributary sediment transport data to evaluate the post-Project impacts on sediment transport and habitat quality. No data are available to evaluate sediment inputs from important tributaries, such as Devil Creek and Portage Creek. Rather, AEA appears to be relying on HEC-RAS modeling to simulate flow in the tributaries, and sediment rating curves from just two tributaries, to model sediment supply. The tributary inputs are a critical component of the sediment balance, and AEA does not have enough data to evaluate tributary sediment supply, or how post-Project flows will transport the sediment delivered from these tributaries.

Re: "Bed-material gradations derived from surface and subsurface samples collected in 2013 in the Lower and Middle Susitna River Segments show that the bed surface is substantially coarser than the subsurface (ISR Study 6.6 Section 5.1.9.1). This condition is typical of gravel-bed streams where a coarse surface layer develops to regulate the transport of the full range of particle sizes. During low to moderate flows, the armor layer is not mobilized, shielding the finer subsurface materials and limiting their transport to the upstream supply." (AEA 2014, Study 6.5 Part A, p. 20).

Comment: The bed of the Susitna River is already armored, such that the bed is mobilized and reworked only during high-flow events. However, the majority of AEA's calculations regarding sediment transport are based on average annual flows. Given that sediment mobilizing flows will be reduced and that a surface armoring layer is already present in the Susitna River, it would seem that the key determinant of sediment mobilization will be daily peak flows, which will be much more muted by reservoir operations than monthly/annual average flows. AEA should consider an evaluation of how reservoir operations will alter peak flows, in order to estimate changes in sediment transport in the Middle River.

2. AEA does not have enough data to understand how the morphology and habitat quality of the Susitna River will change at tributary mouths

A related issue to the overall sediment balance in the Middle River is the capacity of the Susitna River to move the sediment that will be delivered to the river at tributary junctions. Accumulation of fans and bars at tributary mouths could potentially create a significant impact to aquatic habitat downstream of the dam, by changing the accessibility of side-channel habitats or altering the local geomorphology of the mainstem Susitna River near tributary junctions. Because there is very little data related to the quantity and size distribution of tributary sediment inputs, any geomorphic models that AEA develops will be unable to project how the river might adjust to the sediment loads delivered at tributary mouths.

Re: "The armoring size analysis was extended to consider the impacts of with-Project hydrology on sediment delivery from major tributaries. Under pre-Project conditions, the minimum transportable sediment size in the mainstem was considerably larger than the D50 of the bed material for the sampled tributaries. This comparison indicated that long-term accumulation at tributary mouths was not likely to occur under pre-Project conditions. Under with-Project hydrologic conditions, the transportable size in the mainstem was either smaller or only slightly larger than the D50 of the tributary bed materials, so some sediment may accumulate in the tributary mouths and in the mainstem immediately downstream from the tributary confluences." (AEA, 2014, Section 6.5 Part A, p. 16).

Comment: This suggests that the river will change from being able to transport all the sediment supplied at tributary junctions to not being able to transport all this sediment once the Project is built. However, the difference between whether the transportable size in the mainstem is "smaller or only slightly larger than the D50 of the tributary bed materials" could make a significant difference in how geomorphic models behave near these junctions. AEA needs additional data to better understand the quantity and size distribution of sediment being delivered by the tributaries.

"Under post-Project conditions, tributaries are expected to be the primary source of bed-material sediment to the Middle Susitna River Segment. The sediment supply from the tributaries is important not only as input to the bed evolution modeling of the Susitna River, but also to assessing potential Project effects on the ability of fish to access the tributaries and the extent of clear water habitat associated with some tributary confluences. The post-Project flow regime has the potential to change the elevation and location where sediment loads from tributaries are initially deposited because the mainstem may be at a different stage relative to pre-Project hydrology when the tributaries are at peak flow. Potential changes in deposition patterns correspond to potential changes in sediment delivery from the tributaries into the mainstem. Additionally, the ability of the mainstem to mobilize and transport sediment deposited in tributary deltas may also be altered by the post-Project hydrology…As a precursor to modeling geomorphic changes at select tributary deltas, the sediment supply to the deltas must be characterized; a numerical modeling approach is being used for this purpose…Simulated hydraulics will be calibrated where calibration datasets exist; lacking datasets to calibrate the simulated sediment transport, the modeled sediment transport capacities can only be reviewed and adjusted based on professional judgment." (AEA, 2014, Study 6.6, Part A, p. 27-28).

Comment: The first half of this passage summarizes the issue at tributary mouths well. The data collected from these tributary junctions are critical to understanding sediment supply in the mainstem, size distribution of the sediment coming out of these tributaries, ability of the mainstem to transport this sediment, and ability of migrating fish to reach tributary habitats.

AEA apparently has actual sediment transport data from only two tributaries (collected over 30 years ago), which in our opinion is insufficient to model sediment transport at the tributary mouths throughout the Middle River. Instead, AEA must rely on "professional judgement." In order to evaluate potential Project effects on habitat in the mainstem and the tributaries, AEA should have actual sediment transport data on each of the tributaries where fish are present.

"The channel geometry surveys and bed-material samples collected in 2013 from the 11 tributaries appear adequate to quantify the sediment loading delivered to the tributary deltas. These data have been used develop preliminary hydraulic models that will be used to calculate sediment loads. No data were collected at the unnamed tributary (PRM 115.4) based on the lack of an observed delta and the low sediment production potential from the contributing watershed." (AEA, 2014, Study 6.6, Part A, p. 84).

Comment: The document does not provide a description of how AEA determined the adequacy of the data for quantifying sediment loading. AEA should provide information on the validation and calibration of these models using the available channel geometry and bed-material data.

3. AEA's data to characterize habitat vs. flow relationships is incomplete

As summarized above, one of the most important variances we identified in our review relates to the information collected from aerial photography at a range of flows.

"It was the intent of the study plan to obtain three sets of aerial photography in 2012 at the following approximate discharges: 23,000, 12,500, and 5,100 cfs…No aerial photographs were obtained for the lowest flow of 5,100 cfs because ice and snow cover formed prior to the Susitna River dropping to this level in 2012." (AEA, 2014, Study 6.5 Part A, p. 34).

Re: "The intent of acquiring three sets of 2012 aerials was to compare the macrohabitat versus flow relationships from current conditions to 1980s information and determine if there is a difference in the habitat areas for current conditions from those mapped in the 1980s at similar flows. With the aerial photography collected for the limited discharges in 2012, AEA concluded that the macrohabitat areas were appreciably different to those mapped in the 1980s (Tetra Tech, 2013f). AEA also concluded that aerial photography collected at specified discharges to develop macrohabitat versus flow relationships was not necessary for the 2013 study as the combination of the 2-D hydraulic modeling, bathymetry and topography collected in the Focus Areas can provide direct determination of the area of the various macrohabitat types over the range of flows of interest. Therefore, the macrohabitat area versus flow relationships developed from aerial photographs collected at specified discharges are not needed for the current studies." (AEA, 2014, Study 6.5 Part A, p. 40).

Comment: Based on this information, AEA appears to be planning to use their 2-D hydraulic model to simulate habitat areas at low flow, since they do not have aerial photography at low flows. However, precisely because they do not have aerials, these low flows will be well outside the range where they will be able to calibrate their hydraulic model. It is not clear how AEA can make the case that they understand Project effects on salmon habitat, particularly during critical low flows over the winter months, when they lack these data. For example, if flows of 5,000–8,000 cfs (which appear to be the dominant winter flows in the OS-1 scenario) are sufficient to flood side-channel and off-channel habitats, this could dramatically change the conditions under *which salmonids are incubating in those habitats. AEA needs observational rather than modeled data to evaluate whether and where these habitats are flooded under dam operational scenarios.*

4. AEA is not using the proper data to evaluate sediment inflows to the reservoir

Re: "Inflowing sediment loads from the mainstem Susitna River at the Watana Dam were estimated under pre-Project conditions using bed- and suspended-load measurements collected at Gold Creek (Tetra Tech, 2013a). These estimates will be refined by integrating the bed- and suspended-load equations developed for the Susitna River at Tsusena Creek over the extended hydrologic record for the Susitna River. Due to the short record at this station, the information collected at Vee Canyon (Cantwell) and the bed-and suspended-load data collected at Gold Creek will be used to further refine sediment – rating curves at Tsusena Creek." (AEA, 2014, Study 6.5, Part A, p. 55).

Comment: It is unclear why sediment rating curves from Tsusena Creek, at the downstream limit of the dam, are being used to estimate sediment entering the dam. AEA should consider collecting and evaluating bed load and suspended load data from upstream sources near Cantwell, and inputs from the Oshetna River, which may be more representative of sediment entering the reservoir.

5. It appears that AEA is using total annual runoff as a predictor of annual sediment transport. This could substantially under-predict the effects of dam operations on sediment transport, since it does not account for significant changes in peak flow post-Project.

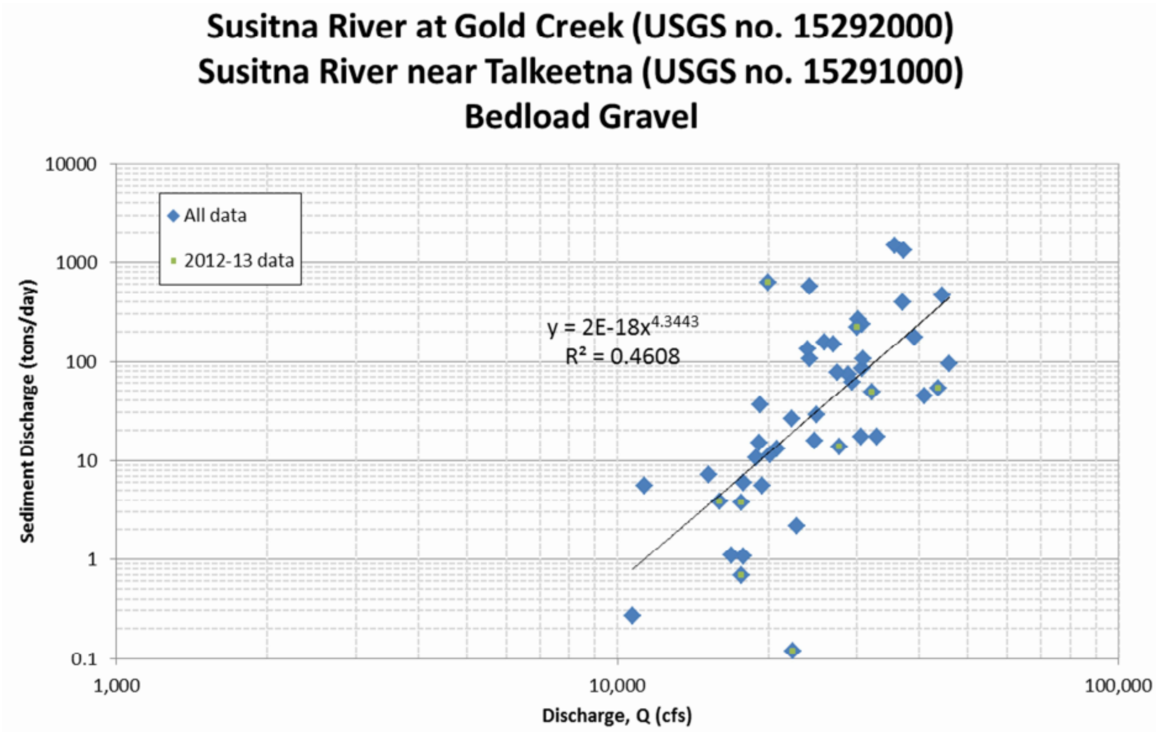
"Results from the analysis indicate that the total sediment load passing the gages varies significantly from year to year, depending primarily on the total runoff. For example, the estimated total annual load passing the Gold Creek gage over the 61-year period ranged from about 0.5 million tons per year to over 10.8 million tons per year (Figure 5.3-1). Similar variation occurs at the other gages (see Tetra Tech, 2013a for details)." (AEA, 2014, Study 6.5 Part A, p. 79).

Comment: Total sediment load will depend much more on peak runoff than on total runoff. Bed load gravel transport in the Middle Susitna River largely occurs between 20,000 and 40,000 cfs (see Figure 4); scenarios based on total annual runoff may not capture this bed load transport efficacy.

6. AEA's discussion of effective discharge and sediment transport is insufficient

"Under pre-Project conditions, the estimated effective discharges along the mainstem ranged from approximately 27,000 cfs at the Gold Creek/near Talkeetna gage to 66,000 and 124,000 cfs, respectively, at the Sunshine and Susitna Station gages…For the Maximum Load Following OS-1 condition, the estimated effective discharges in the mainstem ranged from 9,000 cfs at the Gold Creek/near Talkeetna gage to approximately 46,000 and 108,000 cfs at the Sunshine and Susitna Station gages, respectively…Based on these results, there will be a substantial reduction in effective discharge throughout the mainstem under post-Project conditions, with the relative magnitude of the change decreasing in the downstream direction. These effective discharges are preliminary estimates and will be refined during the next year of study as well as determined for other operational scenarios." (AEA, 2014, Study 6.5 Part A, p. 81).

Figure 4. Sediment rating curve for Susitna River at Gold Creek.



Source: Tetra Tech, 2014, Figure A.4.

Comment: Based on the published bed load gravel rating curve (Figure 5.2.4), the difference in transport between 27,000 and 9,000 cfs (pre vs post-Project flows in the Middle River) is approximately two orders of magnitude. For bed load sand the difference is almost two orders of magnitude, and for suspended load sand the difference is more than two orders of magnitude. This suggests that the ability of the Susitna River to transport sediment will decrease by roughly a factor of 100 across all size classes under post-Project conditions. Because there is a threshold discharge below which there is little to no bed load sediment transport, the total sediment load passing the gages will depend much more on the duration and magnitude of flows above this threshold than it will on "total runoff." AEA needs to evaluate post-Project sediment transport in the context of flows above the threshold for sediment motion, rather than average flows, in order to assess Project effects on habitat quality in the Susitna River.

7. AEA's focused analyses of habitat vs stage relationships are too far downstream

Re: "Tables 5.7-1 through 5.7-3 present example tabular results of the stage-exceedence analyses of the pre-Project hydrologic condition as compared to those for the Maximum Load Following OS-1 hydrologic condition." (AEA 2014, Study 6.5 Part A, p. 88).

Comment: Because AEA is missing aerial photography for the lowest flows, one of the key unknowns under the dam operations scenario is how regulated winter flows will influence off-channel and side-channel winter habitats in the Middle River. Another way to address this *problem is to use stage-exceedence relationships for observed flows, to evaluate which geomorphic features will be overtopped at which flows. AEA has done this for the Lower River where changes in stage will not be nearly as pronounced, but has not to our knowledge done this for the Middle River. Additional information regarding stage-discharge relationships in the Middle River would be illustrative.*

8. AEA's understanding of the LWD budget in the Middle River is insufficient for evaluating Project impacts

Re: "Observations in the channel on August 21, 2013, during the rising limb of a high-flow event suggested that small woody debris began to move between 10 and 11 AM in Focus Area 128, corresponding to a flow of approximately 35,000 cfs at the Gold Creek gage. Large trees were observed to begin moving at approximately 3 PM on the same day, corresponding to a flow of approximately 42,000 cfs at the Gold Creek gage. Boat operators who were on the river the following day (August 22) on the descending limb of the hydrograph (overnight peak of 49,100 cfs) observed little debris in the river between Gold Creek and PRM 115 suggesting that most of the available loose wood/debris had moved on the previous day and overnight." (AEA, 2014, Part A, p. 98).

Comment: Based on these observations, LWD does not start mobilizing until flows reach > 40,000 cfs. Under post-Project conditions, flows of 40,000 cfs will essentially be eliminated in the Middle River. AEA needs to do a more thorough analysis of the sources of LWD to the Middle River (see comment below), and the implications for habitat if LWD is no longer able to be mobilized following Project construction.

"In general, LWD supply from upstream of the dam will be eliminated by the Project, but LWD supplied from tributaries downstream from the dam will be unchanged." (Tetra Tech, 2013b, p. 37).

Comment: It does not appear that the LWD study provided data that will allow AEA to assess the source of the LWD in the main channel, and whether it originates from tributaries downstream of the proposed dam, or from sources upstream of the dam. Thus, with the existing data AEA will not be able to evaluate the effect of the dam on the quantity of LWD below the dam.

"The assessment of the Project effects on the large woody debris processes within the Middle Susitna River will be assisted by the Fluvial Geomorphology Modeling below Watana Dam Study, recognizing that bank erosion is a key process in large woody debris recruitment." (AEA, 2014, Section 6.6 Part A, p. 29).

If LWD from upstream of the dam is eliminated post-Project, and bank erosion is the primary source of LWD post-Project, it is important to understand bank erosion processes. However, AEA's reach-scale hydrodynamic model cannot simulate bank erosion because it is a 1-D model. AEA notes that they are calculating a "bank erosion index," but does not provide sufficient detail in the ISR to critically evaluate how this index is being used. AEA needs to clarify how their 1-D model will be used to simulate bank erosion, and provide calibration and validation data demonstrating that their parameterization of 2-D bank erosion processes in their 1-D model is robust.

9. Ice impacts are not sufficiently integrated into the geomorphology assessment

"The Project will have no impact on the planform of the Upper River segment expect [sic] in the area of delta formation at the upstream end of the reservoir. Depending on the ice-regime the number of low-order channels (sloughs and side channels) could be reduced in the Middle River segment. No impacts on the river planform are expected in the Lower River segment." (AEA, 2015b, Study 6.5, p. 34).

Comment: This comment indicates that an understanding of ice regime is crucial for understanding what will happen to the sloughs and side channels where fish habitat is concentrated. So far, there is no evidence that AEA has sufficient data to make such an assessment. Since AEA has not developed a viable ice processes model for existing conditions, we cannot evaluate AEA's ability to assess changes under with-Project conditions.

10. In some cases, AEA appears to be replacing field data with model parameters

In some cases, AEA has indicated that their field data will either be modified to "fit" their model results, or that models (rather than field data) will be the primary source of information for basic hydraulic parameters.

Re: "Field-based observations and measurements are used to guide model development and data needs and will be used to provide a reality check on model results. In turn, model outputs will be used to modify, refine, quantify and validate field-based observations and key geomorphic processes." (AEA 2014, Study 6.5 Part A, p. 6).

Comment: Based on the second half of this quotation, it appears that model results will, in some cases, be used to "modify" and "refine" field observations. Field data and observations are the foundation of any scientific study. If a numerical model does not properly simulate what can be observed, it is because the model is not properly calibrated, or because the model is not simulating the full range of processes occurring in the natural system. In no case should model outputs be used to "modify" field-based observations.

11. AEA's plans to integrate the different process models are problematic

AEA's choice to use a number of different models for different purposes, rather than a single integrated model, is problematic. Some of the issues related to this choice are highlighted below.

"Local-scale models will be developed at the Focus Areas representing conditions at years-0, -25, and -50. If bed elevations or channel widths change over the 50 year period, the reach-scale model results will not only be used to alter the future (years-25 and -50) geometry, but will provide future downstream stage-discharge and upstream sediment supply rating curves to the local-scale models. The geometry and rating curve information must all be changed to maintain consistency between the models and to maintain internal consistency of the specific local-scale model." (Tetra Tech, 2013b, p. 11).

"With a target channel width determined for the new hydrologic regime, we will need to estimate the rate of width change over the 50-year license period. The rate of width adjustment may be greatest in the initial years after closure, so the time interval for simulating width change may be shorter during the initial periods of the simulation and increase with time during the simulation. The rate of width adjustment may also be limited by the supply of sediment available for deposition in the channel margins…One approach for developing the width versus time relationship is the application of rate law, which is an exponential decay function (Graf, 1977; Wu et al., 2012).” (Tetra Tech, 2013b, p. 34).

Comment: This is a good example of a situation where AEA’s choice of modeling packages may significantly affect their results. Based on the anticipated Project impacts to flow and sediment loads, channel geometry and rating curves will change along the entire Middle River. Currently, AEA has only a 1-D model to simulate the entire Middle River, which by definition cannot accurately simulate changes in channel width. Yet this model must be called upon to set the boundary conditions for the 2-D models in the FAs, so AEA plans to ***prescribe*** *changes in channel width using an uncalibrated and unconstrained exponential function. AEA actually will have no way of knowing how well the 1-D model “width” changes are performing, which in turn means that the boundary conditions for their 2-D models will be unconstrained. These 2-D models will be called upon to simulate changes in key salmon habitat post-Project, but AEA will have no way of knowing whether these projections are realistic because boundary conditions that feed into them will be completely unconstrained.*

“An important aspect of coordination between other studies was to establish which models will be the source for what type of information. There are a number of hydraulic models being applied to various aspects of this study. In order to avoid inconsistencies in reported information such as flows and stage, the model that will take precedence for reporting of information has been established. Table 4.1-4 is an update of the model precedence. In the event that the precedence established in the table changes, a revised table will be provided.” (AEA, 2014, Section 6.6 part A, p. 23).

Comment: A by-product of using multiple models is that in some cases many different models are simulating the same processes, but there may be inconsistencies among the models. Table 4.1-4 lists 6–7 different H&H models that are being used for different purposes in this study (HEC ResSim, HEC-RAS, River 1D, River 2D, EFDC, HEC-6T, and another model that is yet to be determined (either SRH-2D or River 2D). AEA needs to incorporate inconsistencies among these different models into their assessment of model uncertainty.

3.3 ISR Section 7.5: Groundwater

3.3.1 Stated Study Objectives and Summary

As described in ISR Section 7.5, the Groundwater Study, implemented in 2013, was designed to support aquatic and riparian habitat evaluations. “The Groundwater Study uses existing information and data, as well as newly collected data to provide an overall understanding of GW/SW interactions in support of the Aquatic Instream Flow Study, Riparian Instream Flow Study, Water Quality Study, Ice Processes Study and Geomorphology Study.” (AEA, 2014, Study 7.5, Part C, p. 1). “Determine GW/SW relationships of upwelling/downwelling in relation to spawning, incubation, and rearing habitat (particularly in the winter) within selected Focus Areas as part of the Fish and Aquatics Instream Flow Study.” (AEA, 2014, Study 7.5, Part A, p. 2).

To meet this objective, AEA collected groundwater and surface water data using telemetered wells, self-logging temperature and water level recorders, and remote cameras in 2013–2015. These data were collected in several FAs, but particularly FA-128. The data were then used to develop a preliminary groundwater flow model in FA-128 using MODFLOW. In addition, the

Groundwater Study relies on work completed in the 1980s, which are summarized in Appendix C to the Groundwater SIR (AEA, 2015b, Study 7.5).

3.3.2 Study Status

The current status of the Groundwater Study is that groundwater data were collected in 2013–2015 to supplement the data from the 1980s. A preliminary groundwater flow model has been developed for one FA, FA-128, using MODFLOW, but it has not been finalized. We are not aware of any other groundwater flow models developed for other FAs, although they are planned for FA-104, FA-115, and FA-138. There does not appear to be any regional groundwater modeling planned.

3.3.3 Proposed Project Impacts Relevant to Groundwater

The proposed Project would alter the flow on the Susitna River downstream of the dam (Section 2). The flow changes will depend on the operation of the dam. In a load following scenario, flows during the peak winter months will be increased and will alternate between approximately 5,000 and 10,000 cfs at the dam. In addition, flows during the spring and summer will be reduced as the reservoir fills, and there will be a dampened and reduced period of high flow in the late summer. These flow changes will alter the interaction between groundwater and surface water, and may have significant impacts on off-channel (i.e., side channels and sloughs) habitats and habitats that are important for egg incubation and rearing of fish. In particular, the flow changes may:

- Modify the existing flow regime in off-channel habitats, resulting in changes to surface water and groundwater relationships
- Reduce or alter groundwater upwelling in off-channel habitats, resulting in changes in water temperature that may affect fish spawning success, egg incubation, fry emergence timing and success, and juvenile fish growth and survival
- Alter river and off-channel water quality, which may influence water quality in sediments affected by groundwater upwelling and downwelling.

In addition, higher river flows in the winter and the higher river stage may result in cold river water entering off-channel habitats. It may also create areas of downwelling of river water rather than upwelling of groundwater.

The Groundwater Study is designed to collect data and conduct modeling to evaluate these potential Project impacts.

3.3.4 Variances and/or Reported Anomalous Environmental Conditions

The Groundwater Study ISR describes a few variances from the AEA-approved study plan for the collection of groundwater data. In general, the variances that did occur were relatively minor. However, the primary Groundwater Study variances that impact the study are those related to delays in the schedule, which affect our ability to review and comment on any completed models.

As of June 2014, the proposed dates were:

- Literature review and bibliography would not be completed until 2014
- Schedule for completing groundwater flow models, model input and calibration datasets, and files and model documentation was rescheduled for 2015 (AEA 2014, Study 7.5, Part C).

The November 2015 ISR updates these variances, stating that:

"The schedule for completion of the GW flow models, including model input and calibration data sets, files and model documentation will commence in 2015 for FA-128 (Slough 8A) and will occur sequentially for FA-104 (Whiskers Slough), FA-115 (Slough 6A), and FA-138 (Gold Creek) once all necessary information has been assembled and reviewed. A preliminary MODFLOW model has been prepared for FA-128 (Slough 8A) and is included as SIR Study 7.5, Appendix B." (AEA, 2015a, Study 7.5, Part D, p. 10).

Importantly, although a preliminary model for FA-128 (Slough 8A) has been prepared, a final groundwater flow model is not ready, nor are models for FA-104 (Whiskers Slough), FA-115 (Slough 6A), and FA-138 (Gold Creek). Thus, although we can provide comments on the preliminary FA-128 model, we cannot evaluate models for the other FAs, as they are not yet available.

Furthermore, the steps still required to complete the Groundwater Study are substantial and include:

- Compiling, reviewing, and analyzing the empirical data
- Running multiple other models, including OWFRM, SRH-2D, River 1D, and River 2D ice processes models, followed by running different reservoir operational scenarios through the MODFLOW models to simulate changes in groundwater/surface water interactions
- Providing MODFLOW outputs to assist the Riparian IFS, and then evaluating operational effects of the dam on floodplain vegetation
- Linking MODFLOW outputs with 2-D Physical Habitat Simulation (PHABSIM) fish habitat models.

At this point, a calibrated final MODFLOW model is not completed, and to the extent other models and evaluations depend on MODFLOW output, they also cannot be completed.

3.3.5 Specific Comments

Specific Groundwater Study comments are listed below, by topic area.

1. Linkages or couplings between models are not described in the reports

The ISR states

"Where applicable, GW models (MODFLOW) will be developed and linked with other resource models (e.g., Open-water Flow Routing Model [OWFRM] [Study 8.5], SRH-2D hydraulic model [Study 6.6], River1D and River2D Ice Processes models [Study 7.6], 2D Fish Habitat models [Study 8.5], and Riparian Floodplain Vegetation modeling [Study 8.6]) to evaluate different Project operational scenarios on GW/SW interactions and the resulting effects on riparian vegetation and fish and aquatics habitats." (AEA, 2015a, Study 7.5, Part D, p. 2).

A similar statement was included in the Fish and Aquatics IFS (AEA, 2015b, Study 8.5, p. 6).

"Since the June 2014 ISR, work has continued on the development and refinement of these models as described in SIR for Studies 5.6, 6.6, 7.5, 7.6, 8.5 and 8.6. Of particular note is the development of a preliminary three dimensional MODFLOW GW model for FA-128 (Slough 8A) (SIR Study 7.5; Appendix B). When fully calibrated, this model will utilize inputs from the OWFRM (SIR Study 8.5), SRH-2D hydraulic models (SIR Study 6.6), and the River1D and River2D (SIR Study 7.6) Ice Processes models for evaluating Project operational effects on GW/SW interactions. Output from the MODFLOW can then be linked with the 2-D Physical Habitat Simulation (PHABSIM) Fish Habitat Models for assessing Project effects on fish habitats dependent on/influenced by GW (e.g., spawning, egg incubation, juvenile overwintering). Similar MODFLOW models can be developed and utilized for FA-104 (Whiskers Slough), FA-115 (Slough 6A), and FA-138 (Gold Creek) (SIR Study 7.5)."

Comment: We were unable to find a description of how the Groundwater Model will be linked, spatially and temporally, with these six other models. These linkages will be critical to the success of the modeling studies. It does not appear that the linkages will be bi-directional, in the sense that the output from the hydraulic models will feed into the groundwater model, and the groundwater model will feed back into the hydraulic model. Particularly in the off-channel habitats, the surface water and groundwater will interact in space and time. The surface water and groundwater processes should be coupled in space and time, rather than using the output from one model to feed into another separate model, which is then run separately.

Additional comment: It is unclear how MODFLOW will be used in PHABSIM to project effects on fish habitats (spawning, incubation habitats, overwintering rearing habitats, and overwinter egg incubation and embryo survival), because MODFLOW does not have the capability to simulate temperature.

2. **The preliminary MODFLOW model for FA-128 has several shortcomings that need to be addressed before it could be used for any predictive modeling work**

Re: "However, use of the model to evaluate effects of different Project operational scenarios will require further model refinement and model calibration." (AEA, 2015b, Study 7.5, App B, p. 19).

Comment: We agree with this statement. Much more work is needed, even to use the preliminary MODFLOW model in one FA, FA-128. We have the following additional comments:

Re: "No previous studies are available documenting the storage coefficient for the alluvial aquifer." (AEA, 2015b, Study 7.5, Appendix B, p. 7). The storage coefficient was adjusted from a confined to an unconfined value during calibration. "The storage coefficient was initially set to 0.2, but was eventually reduced to a value of 0.001 to achieve a better match to the observed GW elevation response. This value is somewhat low for an unconfined aquifer and may suggest the aquifer is semi-confined." (AEA, 2015b, Study 7.5, Appendix B, p. 17).

Comment: The storage coefficient value used in the model to improve calibration is a confined aquifer value, which is inconsistent with the representation of the alluvial aquifer as an unconfined (water table) aquifer that interacts with the surface water. For example, the groundwater level maps prepared for the area are labeled "water table" maps, suggesting an unconfined water table aquifer. AEA's choice to change this model parameter is inconsistent *with a conceptual model of a water table aquifer. Because many combinations of model parameters can result in a model that matches observed conditions, other parameters could have been adjusted instead during model calibration. Despite adjustment of the storage coefficient, the transient model calibration still was not a good match for many of the wells (see next comment).*

Re: "Despite the poor match to groundwater elevation changes at some stations, the calibration statistics for the transient model were relatively good (Table 5-1)" (AEA, 2015b, Study 7.5, Appendix B, p. 18).

Comment: The model's ability to represent observed conditions is a consideration in establishing the credibility and reliability of the model. The preliminary model does a poor job representing water levels in several wells, particularly those located away from the river, side channels, and sloughs [e.g., FA128-4, FA128-5, FA128-21, FA128-25, FA128-26, FA128-27 (see Figure 3-3, Figures B1-1 through B1-15, (AEA, 2015b, Study 7.5, and Appendix B). The ability of the model to simulate observed conditions informs the confidence that can be placed in the predictive capabilities of the model and its ability to represent Project conditions/dam operations.

Re: "Note that simulated differences between groundwater and surface water elevation can be as little as 0.1 feet, which is much less than the calibrated target residuals of the model. Consequently, the current MODFLOW model requires further calibration before simulation of small vertical gradients (both in magnitude and direction). Also, the transient river stages are currently based on estimates of an equivalent open water stage during the spring melt flooding event (see Section 4.2.4.2.2). Calibration to observed responses may therefore be difficult to achieve." (AEA, 2015b, Study 7.5, Appendix B, p. 19).

Comment: Small head differences in groundwater and surface water elevation will drive changes in upwelling and downwelling. Although the primary objective of the model is to understand how Project operations might change these patterns of upwelling and downwelling, at this point, the current model does not appear to have the ability to simulate these small differences effectively. This could become a particular problem when simulating operational conditions, since the transient river stages could oscillate by multiple feet over sub-daily timescales (see Figure 2).

The preliminary MODFLOW model currently contains simplified parameters based on 1980s studies. Most of these aquifer parameters were obtained from locations that are not in the modeled area (FA-128), and values ranged widely. No additional aquifer testing was done during the 2013–2015 timeframe. The simplified parameters include application of a single groundwater recharge value per season, and a single value for hydraulic conductivity, storage coefficient, riverbed conductance, and regional groundwater influx to the alluvial aquifer boundaries.

Comment: The simplified model does not do a good job of simulating water levels within the model domain and will need to be refined.

Re: One of the most important parameters in a groundwater model is the hydraulic conductivity assumed for the aquifer. "The hydraulic conductivity of the alluvial aquifer in the Susitna River floodplain is estimated to range from about 1 to 100 ft/day. These ranges are based on the following studies: a pumping test conducted on the water supply well at the Talkeetna Fire Hall (HESJV, 1984a); specific capacity data from several Talkeetna Wells (HESJV, 1984b); falling head borehole tests conducted at Slough 9 in the 1980s (R&M Consultants, 1985); and values reported for the lower Susitna River (USGS, 2013). An initial value of 66 ft/day was assigned to the alluvial aquifer and later adjusted during the steady state calibration." (AEA 2015b, Study 7.5, Appendix B, p. 6).

Comment: No aquifer testing has been done to estimate the hydraulic conductivity in FA-128 (Slough 8A); this parameter was estimated from testing done in other areas that may or may not represent conditions in Slough 8A.

Re: We could find no evidence that a sensitivity analysis has been performed for the preliminary model. (AEA, 2015b, Study 7.5, Appendix B, p. 21).

Comment: A sensitivity analysis should be completed for the MODFLOW models.

3. Water temperature in the Groundwater Model is not currently modeled, nor is it possible to model temperature using MODFLOW

Re: "Vining et al. (1985) suggested that upwelling was the single most important feature in maintaining the integrity of incubation in slough habitats of the Susitna River as well as localized areas in side channel habitats. The importance of groundwater on fish habitat was noted as being especially important during the winter time owing to its' warming effects and benefits associated with temperature constancy and egg development and survival." (GWS and R2, 2014, p. 30).

Re: "Impacts to water temperatures can also be evaluated with model output but this will require additional model refinement." (AEA, 2015b, Study 7.5, Appendix B, p. 20).

Re: "Changes in surface/groundwater temperatures can also be evaluated, but will first require an assessment of the effects of current hydrograph changes on vertical gradients and temperatures" (AEA, 2015b, Study 7.5, Appendix B, p. 21).

Comment: The documents do not describe how this would be accomplished with MODFLOW model output. Although there are models that simulate groundwater flow and water temperature, this is not a capability of MODFLOW. It is unclear how the Groundwater Model will be refined to evaluate impacts to water temperature.

4. The methods that will be used to look at groundwater/surface water changes during the Project are not described or defined

Re: The notes from the December 2014 groundwater meetings (GWS, 2015) state, "Chris Holmquist-Johnson asked how the GW versus riverine effect will be evaluated when the Project hydrograph is flip flopped. Dudley Reiser responded that the short answer is that it will be pieced together from data and professional judgement. Not sure how it will come together yet but the first step is to get the models developed and look at existing conditions for certain flow conditions and timescales/seasonality, then Project operations will be brought in. How GW flows are expected to change will be evaluated using the contour maps. The contour maps are a powerful way to evaluate potential Project effects."

Comment: To ensure that the data that have been collected to date will be adequate to evaluate groundwater and surface water interaction changes within the river, one needs to know how these data will be used in the evaluation. "Pieced together from data and professional judgment" is not a sufficient plan for how groundwater and surface water changes will be *evaluated. The contour maps provide information about water levels at a point in time, but do not provide information about how groundwater fluxes (upwelling and downwelling) will change in response to changes in river stage on a daily or seasonal basis with the Project.*

5. The methods that will be used to extrapolate from the FAs to the rest of the Susitna River are not described or defined

The documents contain several statements that suggest that the results from the MODFLOW model in the FAs will be extrapolated to other areas. Re: "However, as part of addressing GW Study (Study 7.5) Component 2 (Geohydrologic Domains), the differentiating characteristics of sloughs (such as the presence of tributaries, upland soil/geology type, apparent influence from mainstem flows, influence from overtopped-berm flows, etc.) will be reviewed along with their hydrologic responses to see if sloughs with similar characteristics show similar responses. If this is the case, the simulated results from the representative Focus Area sloughs that are being modeled, could be extrapolated to other sloughs that are expected to have similar response." (AEA, 2015b, Study 7.5, p. 14).

Comment: The consultants working on the groundwater/surface water studies in the 1980s concluded, "Detailed projections cannot be made of the slough discharge or temperature variations which might result from changes in mainstem conditions as a result of project operation. Because of the substantial differences among the sloughs in their hydraulic and thermal behavior, it would be necessary to construct mathematical models of each individual slough in order to make detailed predictions of the effects on the sloughs of changes in mainstem conditions." (R & M Consultants and Woodward-Clyde, 1985, p. 4-17).

Since that time, extensive surface water and groundwater data have been collected in detail in one FA, FA-128, and some data have been collected in a few other FAs. It is difficult to evaluate whether these data are sufficient to develop an assessment of the impacts on FA-128, to say nothing of all individual off-channel habitats, many of which have no data.

The documents do not describe how extrapolation of data and models from FAs to the rest of the river system will be accomplished. MODFLOW models will be developed for four FAs. No regional groundwater model is planned. The study plans should describe how data and model results from these four FAs will be used to assess Project impacts for the groundwater/surface water interactions within the Susitna River. In addition, the methods that will be used to determine the representativeness of results from these four FAs for application to the rest of the river should be detailed.

6. Sources of data-related and modeled uncertainty are not addressed/described

The documents do not adequately describe the sources of uncertainty and how they will be addressed. Uncertainties include those resulting from evaluating groundwater/surface water relationships outside of FAs, in conditions that are beyond those used to calibrate the model, and under Project operations.

Comment: Methods that will be used to evaluate uncertainty are not presented. There are multiple sources of uncertainty: uncertainty in evaluating groundwater/surface water relationships outside of FAs, in conditions that are beyond those used to calibrate the model, and under Project operations.

7. Conceptual model for groundwater/surface water interactions has not been adequately presented

The Final Groundwater Study plan states that a conceptual model of the groundwater/surface water system will be developed. Re: "Based on the information, a description of the pre-Project groundwater conditions will be developed in the vicinity of the Watana Dam and Reservoir. This will include a characterization of known permafrost and bedrock hydrogeology in the Watana Dam vicinity. From this, conceptual GW/SW models will be developed that describe pre-Project conditions and post- Project conditions." (AEA, 2013, FSP, p. 7.5-7).

In addition, the RSP (AEA, 2012) states that conceptual models of groundwater/surface water interactions, flow conditions, and riparian plant community interactions will be developed. "Developing conceptual model and numerical representations of the GW/SW interactions, coupled with important processes in the unsaturated zone, will help evaluate natural variability in the Susitna River riparian floodplain plant communities, and assesses how various Project operations may potentially result in alterations of floodplain plant community types, as well as improve the understanding of what controlled fluctuations of flow conditions would result in minimal riparian changes." (AEA, 2012, p. 8-188).

"The results of floodplain vegetation and soils mapping, forest succession models, seed dispersal study, seedling establishment studies, ice processes study, floodplain erosion and sediment transport study, and groundwater and surface water interaction study will be integrated into a conceptual ecological model of Susitna River floodplain vegetation and physical processes, including flow, sediment and ice process regimes." (AEA, 2012, p. 8-191).

Comment: Although the development of conceptual models was planned, we have been unable to find detailed conceptual models incorporating the data that have been collected to date. A conceptual framework for the models that are under development should be prepared and expressed to ensure that the modeling is consistent with the conceptual site model.

3.4 ISR Section 7.6: Ice Processes

As described by AEA, the objectives of ISR Section 7.6 are to understand the processes driving ice formation and breakup in the Susitna River, and to predict the impacts of dam operations on these processes:

"The overall goals of the Ice Processes in the Susitna River Study (Study 7.6) are to understand existing ice processes in the Susitna River and to predict post-Project ice processes." (AEA, 2014, Study 7.6 Part A, p. 2).

To meet these objectives, AEA has to date collected observational data describing the timing of ice formation and breakup in the Susitna River, as well as additional observational data such as ice thickness measurements and time-lapse photography to help inform process-based models of ice formation and breakup. From the documents we reviewed, we have not seen evidence that AEA has developed an initial model of ice formation and breakup in the Susitna River. Appendices A and B in the October 2015 SIR (AEA, 2015b) suggest that AEA has developed an initial open-water flow model and has begun to calibrate their thermal model. However, the ice processes component of this model has not been completed (HDR, 2016).

3.4.1 Proposed Project Impacts Relevant to Ice Processes

Based on the documents we have reviewed, winter ice is an important element of the hydrology and geomorphology of the Susitna River system. In particular, ice jams that occur during breakup in the spring contribute to the flooding of off-channel and side-channel habitats, and may play an important role in both the geomorphic evolution of those habitats and the outmigration of salmonids.

Under existing conditions, freeze-up in the Middle River consistently occurs when wintertime flows are approximately 2,000–3,000 cfs (AEA, 2014, Study 7.6, Part A, Figure 4.1-3). Under a load-following (OS-1) scenario, wintertime flows would instead cycle daily between approximately 5,000 and 10,000 cfs. Because AEA's ice processes studies are far from complete, it is difficult at this stage to evaluate what effect this higher, oscillating winter discharge would have on ice formation and breakup. However, it is likely that daily oscillations in winter water levels and flows would slow ice formation in the early winter, would result in ice forming at a higher stage along the river bank, and would result in an overall thinner ice by the time of spring breakup.

3.4.2 Variances and/or Reported Anomalous Environmental Conditions

Based on our review of ISR Study 7.6, there were very few variances of note in this study component. In general, the variances that did occur related to minor discrepancies in the location of time-lapse cameras due to specific field conditions, destruction of time-lapse cameras during ice breakup, or modifications from the approved methods for measuring ice thickness.

3.4.3 Specific Comments

In this section we summarize our comments on specific sections of ISR Study 7.6. Because the ice modeling is not yet complete, we comment here only on the data and information collected to date and reported in Study 7.6, and the relevance of information reported by AEA to salmon habitat under current and future conditions. In each case, we include specific quotations from ISR Section 7.6 and supporting documents, followed by our comments in italics.

1. Interactions among ice, and main-channel and side-channel habitats are incompletely understood

Side channels and side sloughs represent critical habitats for salmonids in the Middle River. The importance of these habitats is stressed throughout the ice processes modeling studies, yet AEA currently does not have sufficient data to understand the basic relationships among winter mainstem flows, ice breakup, and the flooding of side-channel and side-slough habitats.

Re: "The following locations were subject to ice jam activity and flooding in the 1980s, 2012, and 2013:

- Slough 11 (PRM 137.5-139.4 [RM 134-136]): Major ice jams and ice jam flooding were documented near Slough 11 (PRM 139.4 [RM 136]) in 1983 and 1985 (LaBelle, 1984; R&M, 1985). Previous observers documented that Slough 11 was in fact created by an extensive ice jam breakout in May of 1976 (R&M, 1983).
- Slough 8 and Slough 9 (PRM 130-133.4 [RM 126.4-130.2]): Historically, PRM 132.4 (RM 129) (Slough 9 area) was a very active break-up location with many observations of ice

jams and side channel and slough ice-induced flooding (LaBelle 1984) (R&M 1983). In 1985, a break-up jam released from the same location and caused ice to flow through and possibly scour Slough 8A (R&M, 1986)." (AEA 2014, Study 7.6 Part A, p. 22).

Comment: Based on these observations, the side sloughs in the Middle River are very active during breakup, and are in some cases actually formed during breakup. Given the apparent importance of ice jams in generating and/or inundating side-channel habitat, there is currently little discussion of how changes in ice formation and breakup during proposed Project operations might influence these events. When AEA has completed the ice modeling, they need to demonstrate that their model can simulate the inundation of side channels during breakup under baseline conditions, and include discussion of how any changes in ice thickness or elevation might alter this periodic flooding under operational scenarios.

"Studies conducted by the Alaska Department of Fish and Game (ADF&G) (Vining et al., 1985) showed that river stage and discharge during the winter period can directly affect both spawning and egg incubation habitat. They found that the typical pattern of decreased discharge in the winter resulted in the off-channel spawning and rearing habitat to warm due to the decreased input of cold river water and the increased contribution of relatively warm upwelling ground water… During the time of stable ice cover, some slough habitats may remain ice-covered and thus become insulated from extremely cold air temperatures, while in others open thermal leads may develop resulting from upwelling groundwater (Figure 3-1). Warmer water associated with the groundwater upwelling increases the rate of embryo development and decreases the overall hatching time. If the river discharge and thus stage drops too low, however, the slough can completely dewater, leading to freezing of the substrate and mortality of the eggs and hatchlings. In contrast, if the river discharge and stage increases to a point where the slough entrances can be overtopped/breached, this can cause a decrease in water temperature due to the sudden addition of colder river water which can slow development and delay hatching." (AEA, 2014, Study 7.6, Part C, Appendix C, p. 10).

Comment: This is critically important, but is not fully discussed in the ice processes report. How does a change from approximately 2,000 cfs flow to approximately 5,000–10,000 cfs flow during the winter affect flooding/ice formation/habitat in the side sloughs? It seems clear that flow in winter needs to be "just right" so that there is neither significant overtopping of side sloughs from the main channel, nor is there too little flow to keep the side sloughs from dewatering and freezing completely. The amount of flow in the side sloughs will depend on whether the discharge created by the dam is sufficient to flood the side sloughs, and by how much. This is why it is important to have documentation of habitat areas from aerial photographs under the actual range of flows that will occur during the winter, and to collect field data on stage-discharge relationships at each side slough where salmon habitat is important. AEA currently does not have full coverage of the Middle River from aerial photography, and appears to be missing basic data describing stage-discharge relationships adjacent to many side channels and side sloughs. It is not clear how the data that have been collected will be used to simulate and inform changes in these processes during Project operations. This is an important data gap that AEA needs to fill in order to have sufficient calibration data for their hydrodynamic models.

"Increased discharge throughout the winter will lead to the ice cover being formed at a higher elevation than natural conditions. Some entrance berms of sloughs may be overtopped continuously all winter by this increased stage of the river. The stage and ice elevation, however, will also be stable over the winter without the typical reduction seen during natural conditions. For the Susitna River in particular, the more stable discharge levels throughout the winter will result in constant stage and ice elevations in the lower river over the winter. For the middle river, there will be some variations in the maximum upstream extent on the ice cover and the leading edge may move up or downstream based on air temperatures over the winter." (AEA, 2014, Study 7.6, Part C, Appendix C, p. 15).

Comment: AEA's conceptual model of ice formation in the winter appears to be that ice will form at a higher elevation than natural conditions due to a higher "stable" water level. However, the available information would indicate that operational conditions will not result in "more stable discharge levels throughout the winter," but that discharge will oscillate and create changes in river stage of 1–2 feet each day (see Figure 2). Since oscillating flows of this sort do not occur under baseline conditions, AEA will need to describe the uncertainties introduced by modeling something far outside of their model calibration conditions.

"A better understanding of breaching flows (i.e., flows at which surface flows from the main channel Susitna River begin to enter side channel and off-channel habitats) and relationships between under-ice stage and main channel flows within each of the Focus Areas will be possible once the open water and under ice 2-D hydraulic models are fully developed (AEA, 2012, Sections 6.6 and 7.6)." (AEA, 2014, Study 8.5, Part C, Appendix L, p. 11).

Comment: It is not clear why open water flow and 2-D hydraulics models are necessary to understand breaching flows. This could easily be characterized without a hydrodynamic model if AEA had a sufficient understanding of stage-discharge relationships at each of the side channels and off–channel areas of interest. This needs to be characterized through careful data collection, using measured cross-sections and water level gages in the vicinity of each side-channel and off-channel habitat area of importance. Relying on hydrodynamic models to provide this answer may be misguided, since without these field data the hydrodynamic models will be untestable. AEA should be collecting the data they need to understand stage-discharge relationships adjacent to important side-channel and off-channel habitats.

3.5 SIR Sections 8.5 and 8.6: Fish and Aquatics IFS and Riparian IFS

3.5.1 Stated Study Objectives and Summary

The overall goal of the Aquatic IFS (Study 8.5) and its component study efforts is to provide quantitative indices of existing aquatic habitats that enable a determination of the effects of alternative Project operational scenarios. Eight study objectives were established and listed in RSP Section 8.5.1.2 (AEA, 2012) and include:

1. Map the current aquatic habitat in the main-channel and off-channel habitats of the Susitna River affected by Project operations.
2. Select study areas and sampling procedures to collect data and information that can be used to characterize, quantify, and model mainstem and lateral Susitna River habitat types at different scales.
3. Develop a mainstem OWFRM that estimates water surface elevations and average water velocity along modeled transects on an hourly basis under alternative operational scenarios.

4. Develop site-specific Habitat Suitability Curves (HSCs) and Habitat Suitability Indices (HSIs) for various species and life stages of fish for biologically relevant time periods selected in consultation with the Technical Work Group (TWG).
5. Develop integrated aquatic habitat models that produce a time series of data for a variety of biological metrics under existing conditions and alternative operational scenarios.
6. Evaluate existing conditions and alternative operational scenarios using a hydrologic database that includes specific years or portions of annual hydrographs for wet, average, and dry hydrologic conditions and warm and cool Pacific Decadal Oscillation (PDO) phases.
7. Coordinate instream flow modeling and evaluation procedures with complementary study efforts, including the Riparian Instream Flow (Study 8.6), Geomorphology (Studies 6.5 and 6.6), Groundwater (Study 7.5), Baseline Water Quality (Study 5.5), Fish Passage Barriers (Study 9.12), and Ice Processes (Study 7.6) (RSP Section 8.5.4.8).
8. Develop a DSS-type framework to conduct a variety of post-processing comparative analyses derived from the output metrics estimated under aquatic habitat models (RSP Section 8.5.4.8).

3.5.2 Status

Although some components of the IFS are nearing completion, it is largely ongoing.

Models of baseline conditions (i.e., flow, stream temperature, water quality, and sediment) are still largely being developed. The range of predicted changes in baseline conditions due to alternative operational scenarios has not been evaluated and incorporated into the Habitat-Specific model within a DSS framework. As such, estimates of Project impacts to habitat or fish cannot be evaluated at this time.

3.5.3 Proposed Project Impacts Relevant to Fish and Aquatics Instream Flow

The major impacts of the proposed Project on fish and aquatic habitats relate to changes in the magnitude, timing, and variability of Susitna River discharge that would occur under Project operational scenarios. For example, under a load-following operational scenario, winter flows will be substantially higher and more variable than they are under pre-Project conditions, whereas summer peak flows will be substantially lower (Figure 1). These changes in river discharge and associated river stage will result in changes in the depth and timing of inundation on side-channel and side-slough habitats, changes in the degree of groundwater/surface water exchange, changes in the ability of the system to transport sediment, and changes in stream temperatures and water quality. All of these instream flow changes will have impacts on fish and aquatic habitats.

3.5.4 Variances and/or Reported Anomalous Environmental Conditions

As with many of the other studies that are a part of this review, AEA lists a number of variances to approved study plans in Study 8.5. In general, these variances from approved study plans are minor. In this section we discuss only those variances that we consider important to AEA's understanding of the Susitna River system and fish and aquatic instream flows.

Gaging of Tributaries to the Susitna River

Re: "Tributary inputs in the OWFRM were estimated based on drainage area and then adjusted using available tributary gaging data as described in SIR Study 8.5, Appendix B. Adjustments for Fog Creek were based on spot measurement data collected in three different years (1982, 2014, and 2015). Data gaps associated with the lack of continuous gage data on Fog Creek will not appreciably affect accretion calculations used in the OWFRM."(AEA 2015b, Study 8.5, p. 10).

Comment: Along with estimations of tributary inputs to the OWFRM based on drainage area, AEA should also evaluate/provide details and implications of uncertainty of drainage area flow estimations on final predictions in the DSS.

Development of HSCs

Re: "Substrate composition was simplified to include only two gravel size classes (small and large). Using two size classifications to describe gravel is consistent with substrate classifications used on numerous other HSC/HSI curve development studies and is not anticipated to impact HSC/HSI curve development." (AEA, 2015b Study 8.5, p. 20).

Comment: While using two substrate classifications may be more feasible in the field in turbid water conditions, AEA should describe why using two classifications instead of the planned three will not impact the HSC/HSI curves or, more importantly, what effect this may have on the final DSS framework results for different reservoir operation scenarios.

Re: The Study Plan indicated that "field surveys will be conducted at potential stranding and trapping areas on an opportunistic basis following up to three flow reduction events during 2013. During a May 17, 2013 TT meeting, participants indicated that site-specific stranding and trapping studies should be a low priority. Because the Project does not yet exist, the effects of Project-induced flow fluctuations cannot be directly studied in the Susitna River. Some opportunistic observations of potential stranding and trapping areas were recorded during substrate classification surveys conducted during falling river stage conditions in September 2013, but the observations did not follow robust survey protocols." (AEA, 2015b Study 8.5, p. 20).

Comment: It is unclear why the priority for potential stranding/trapping was downgraded by participants of the May 17, 2013 TWG, and why September 2013 observations have been omitted because robust survey protocols were not followed. While it may not be possible to replicate the dramatic changes in flow that would occur each day under operational scenarios, an effort should be made to collect this information to the extent possible, so that AEA will have an understanding of this important impact to salmonids.

Habitat-Specific Model Development

Only one variance is noted: "Surveying of 1-D PHABSIM sites in LR-2 was not conducted in 2014; however, flow data were collected in Sheep and Caswell creeks and the Deshka River (Section 4.3) and HSC data were collected in LR-2 between PRM 65 to PRM 70. Surveying, hydraulic model calibration and habitat modeling of LR-2 sites is needed to complete this study component; this change in schedule will not have a substantive effect on meeting study objectives." (AEA, 2015b Study 8.5, p. 7).

Comment: Although the authors suggest this schedule variance will not have a substantive effect on meeting study objectives, this is highly vague and no effort is made to demonstrate this is the case, especially if this limits the effective model calibration of a full 1-D PHABSIM model to specific areas/times.

Temporal and Spatial Habitat Analysis

A primary objective of the spatial habitat analysis is to develop a method for extrapolating habitat-flow relationships from measured locations to other non-modeled locations. It does not appear that this objective has been met. "The final approaches for both the temporal and spatial analysis were to be provided in the ISR (RSP Section 8.5.4.7.1.3); and while discussion occurred during implementation of the Study Plan in 2013 and early 2014, decisions on the final approaches were deferred to 2015." (AEA, 2014 Study 8.5 Part C, p. 23).

Comment: As with many other components of the ISR, it is difficult to evaluate the adequacy of AEA's data collection efforts when they have not yet articulated their approach to using their field data to inform their models.

3.5.5 Specific Comments

In this section, we summarize our comments on specific sections of ISR Sections 8.5 and 8.6. Where practical, we group these comments into broad thematic areas to facilitate review. In most cases, we include specific quotations from SIR (and ISR) Sections 8.5 and 8.6 and supporting documents, followed by our comments in italics.

AEA Does Not Present Well-Defined Conceptual Models for Study 8.5

Comment: Based on our review, AEA has not defined, nor described in detail, a well-defined, integrated conceptualization of flow, sediment transport, ice modeling, water quality, and habitat modeling. This conceptual model should be the foundation of all subsequent modeling and data collection efforts. This is standard procedure for any sort of modeling, as summarized by American Society for Testing and Materials (ASTM) standard ASTM D5979-96 (ASTM, 2014) and Kolm (1993).

For example, AEA should carefully describe and define how all processes (e.g., flow, sediment transport, aqueous geochemistry, ice formation and degradation, surface water-groundwater interactions) interact with each physical domain (e.g., reservoir, mainstem Susitna River, side channels, fans, overland flow, unsaturated and saturated groundwater) through different times of the year. Alternative conceptualizations of how these processes and systems interact should then be developed and considered across all of AEA's modeling studies. Currently, the flow framework is not adequately described and the parameters that feed AEA's models all have very high uncertainties. These uncertainties are compounded by uncertainties related to the model conceptualization.

Calibration of OWFRM Does Not Follow Standard Practice

Comment: The presentation of the calibration for the Steady State and Transient State OWFRM is non-standard. Key calibration statistics of model performance against observations do not appear to have been presented for either steady state or transient models, as is standard practice (see ASTM D5981, 2002; Moriasi et al, 2007; Bennett et al, 2010). The same issues apply to *development and calibration of other models (e.g., habitat-specific models; see Pearce et al., 2000, for predictive performance evaluations).*

Two Different Flow Models Have Been Developed, but Linkages between Models and Steps to Ensure Consistency Are Not Described

Re: "Two different flow routing models have been developed: an open-water model (HEC-RAS) described in this section of the SIR and a winter model to route flows under ice-covered conditions (Study 7.6)." (AEA 2015b, Study 8.5, p. 11).

Comment: The development of separate 1-D hydraulic models by different study groups makes little sense and unnecessarily introduces potential inconsistencies between models, errors within individual studies, and confusion among different modelers and studies. A single model should be developed for routing 1-D hydraulic response to different reservoir operations so that each study group is using the best available model.

More generally, AEA should provide a clear and concise modeling flow chart that illustrates how all of their process models relate to one another. Here and elsewhere, it is unclear how the specific data, assumptions, parameters, boundary conditions, and outputs are transferred between models. It is much too confusing for any stakeholder/reviewer to get a clear idea of inputs, assumptions, modeling approaches, etc., when critical modeling details are divided up into so many different reports. This in itself is an important limitation of the existing studies. It also makes it extremely difficult to see how AEA will combine all of their models in a DSS framework to make meaningful decisions, or how AEA will assess uncertainty in their model outputs.

Diagrams in ISR and SIR Study 8.5 Documents Relating Models Are Confusing and Do Not Adequately Describe Integration Of Models

Re: "The overall goal of the IFS (Study 8.5) and its component study efforts is to provide quantitative indices of existing aquatic habitats that enable a determination of the effects of alternative Project operational scenarios" (AEA 2015b, Study 8.5, p. 4).

Comment: The flow diagrams in the ISR and SIR 8.5 IFS documents that attempt to show how the various studies and models relate to each other are highly confusing. This information is critical to demonstrate to FERC and stakeholders that all proposed modeling efforts are correctly integrated, consider uncertainty, and fully meet the stated objectives of the aquatic instream flow study (IFS) and riparian instream flow study (RIFS). To clearly and transparently show how the main goal of the IFS and RIFS efforts will be met by these modeling efforts, AEA must make a much more concerted effort to provide better roadmaps showing how all models are integrated, across multiple, representative, and complete years. Below we provide a few examples that are illustrative of this problem.

Figures 4.1-1a and 4.1-1b (AEA, 2015b, Section 8.5, pp. 96–97)

Comment: These diagrams are the primary modeling flow charts, which guide all studies, modeling, and evaluations. These flow charts are poorly conceived and conceptualized. SIR Figures 4.1-1a (Figure 5) and 4.1-1b (Figure 6) are confusing and their meaning is not well-described in the text. Specific comments are as follows:

1. *In Figure 4.1-1a, it is unclear why the dam operational scenarios do not feed directly into the open-water flow model. For example, AEA needs to clarify how the geomorphic reach (6.5) habitat mapping (9.9) and hydrology models (8.5.4.4) modulate the transition between reservoir operations and open-water flow modeling.*

2. *As depicted in Figure 4.1-1a, open-water flow influences groundwater, but there is no feedback between groundwater and open-water flow modeling. Clearly, river stage will influence groundwater flow, as demonstrated by the one-way arrow from open-water flow to the riverine processes box, but groundwater flow will also influence river stage. AEA needs to clarify how this feedback is being modeled or characterized in the overall modeling framework.*

3. *As depicted in Figure 4.1-1a, there is no feedback between ice processes and open-water flow. Ice formation will influence flow, as will ice breakup. AEA needs to clarify how these feedbacks are being considered in the modeling of flow in the river.*

4. *It is not clear how the flow chart in Figure 4.1-1b relates to the flow chart in Figure 4.1-1a. For example, the white box at the top right of Figure 4.1-1b shows mainstem, open-water flow routing feeding into the green habitat specific model box – yet Figure 4.1-1a shows no such interaction. AEA needs to clarify how and if these modeling components are actually being coupled.*

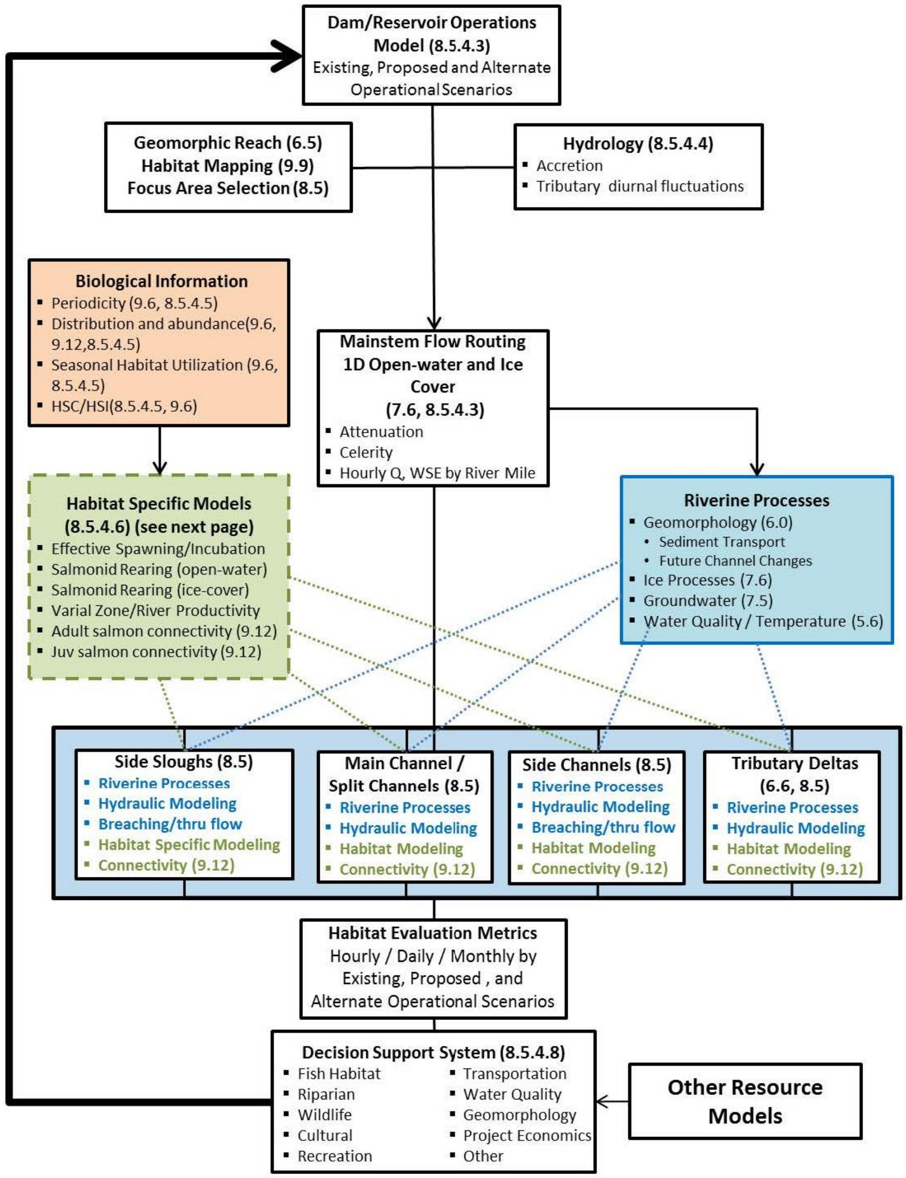
5. *It is not clear from the flow chart in Figure 4.1-1b which of the parameters listed in the blue boxes are being passed back to the Habitat-Specific Models at the top of Figure 4.1-1b (green box). AEA needs to clarify which parameters are being used, and how each of those parameters is being considered in the habitat models.*

6. *Comment: Figure 5.6-13 from 8.5 IFS ISR, Part A (Figure 7), shows a flow chart of data/models that appear to start with "Flow and Dam Operations" (purple boxes) and end up predicting "Effective Spawning/Incubation Surface Area at the End of the Incubation Period" (a purple ellipse at the bottom). At a minimum, this flow chart should clarify key decisions to be made at every step, clearly describe the inputs/outputs that are being transferred between the various modeling steps, and show how it relates to other important flow charts summarized above. Specific comments on this figure include the following:*

   - *It is not clear whether the results of this analysis feed back into dam operations, to evaluate a range of impacts or to optimize operations in order to minimize negative impacts.*

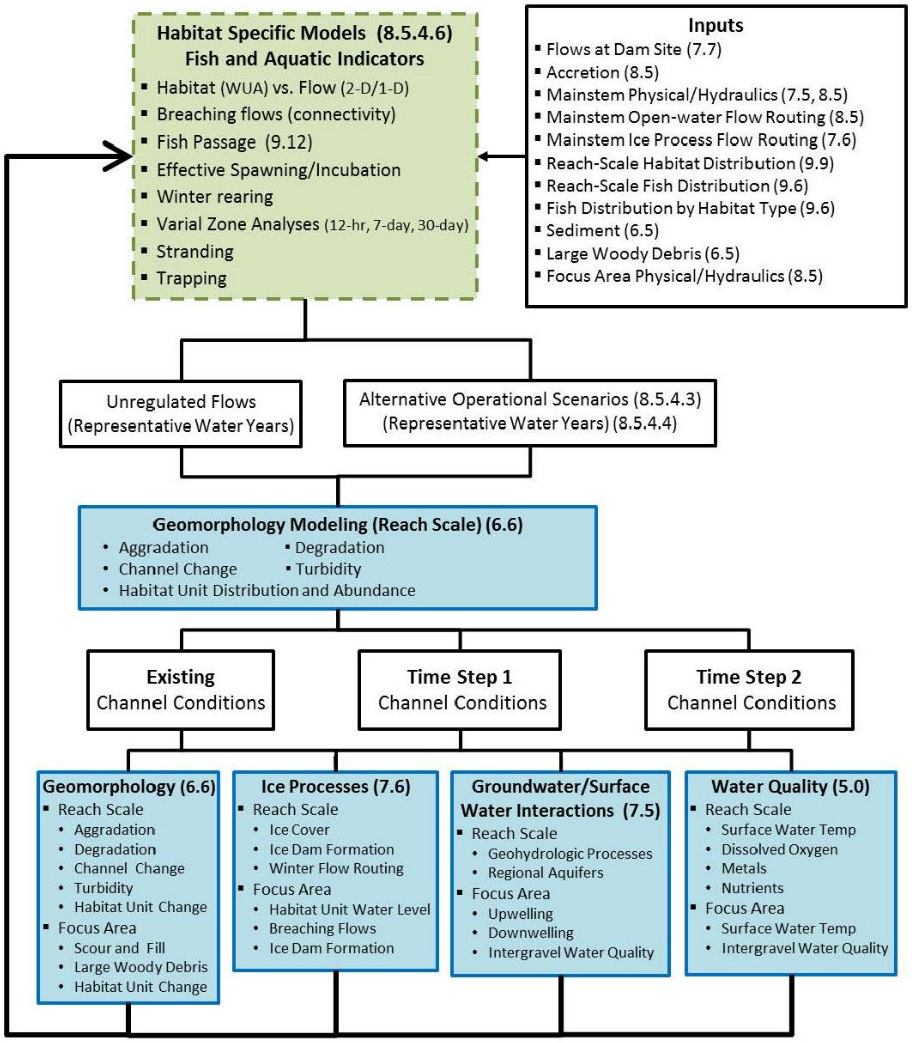
   - *Based on Figure 5.6-13, the OWFRM 1-D hydraulic model feeds into the 2-D Sediment Model and 2-D Hydraulic Model, but the 2-D Hydraulic Model does not feed into the 2-D Sediment Model. AEA needs to clarify the interactions between 2-D hydraulics and 2-D sediment transport in their modeling.*

Figure 5. AEA's conceptual framework for integration of habitat-specific models and riverine processes, presented in ISR Study 8.5.



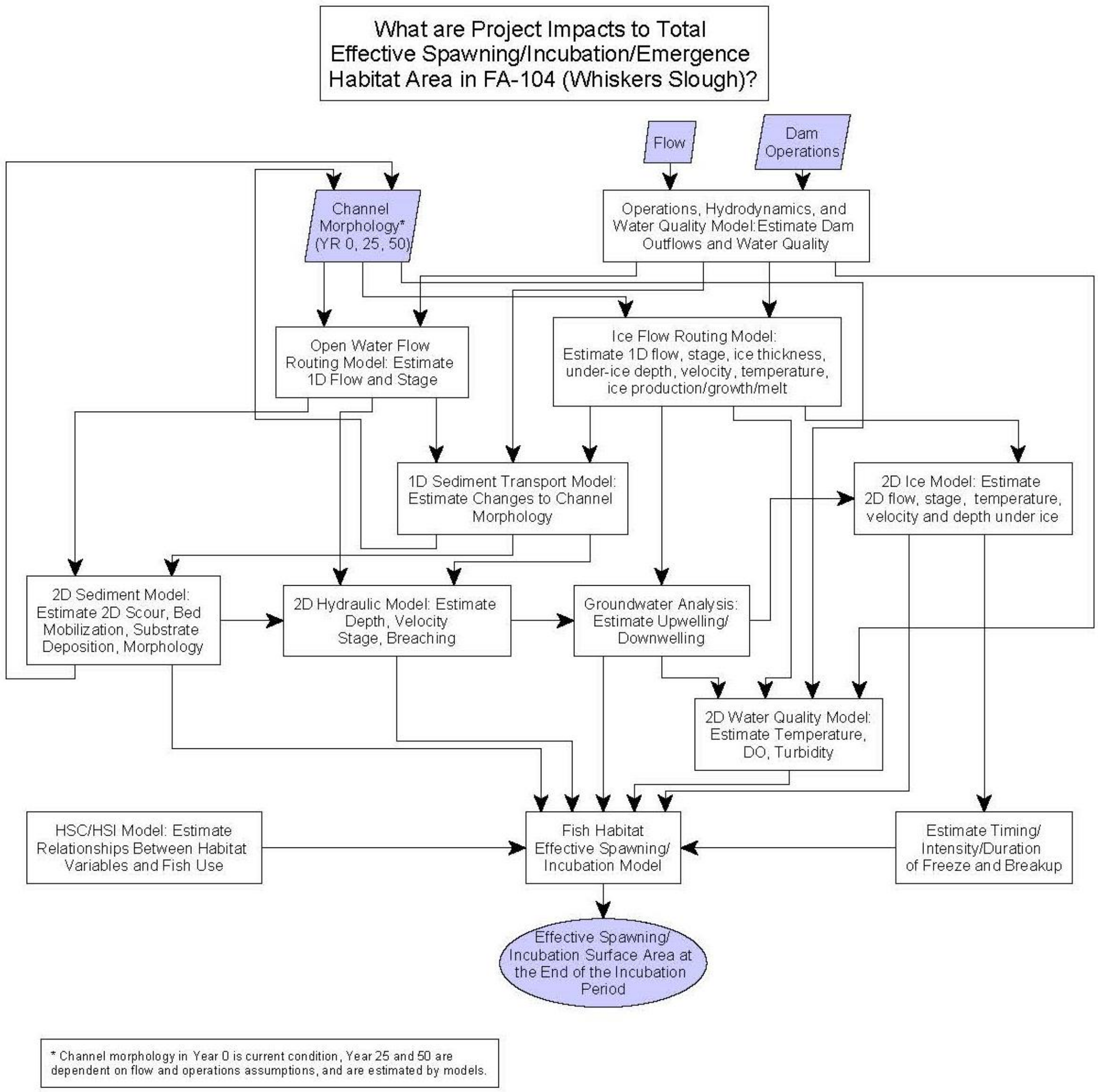
Source: AEA, 2015b, Study 8.5, p. 96.

Figure 6. AEA's conceptual framework depicting integration of riverine processes to develop fish and aquatic habitat specific models, presented in ISR Study 8.5.



Source: AEA, 2015b, Study 8.5, p. 97.

Figure 7. Example presented in ISR for Study 8.5 showing data dependencies and data flow for effective spawning/incubation analysis in the Middle River FAs



Source: AEA 2014, Study 8.5, Part A, Figure 5.6-13.

- *It is not clear from the figure or the text how this local FA-104 modeling evaluation is translated to the entire Middle River and Lower River. AEA needs to articulate how the FAs will be used to develop an understanding of the entire river system.*
- *Since groundwater is a key component of heat input to rivers, AEA needs to clarify how they are modeling heat transport and temperature in the stream when they do not appear to be simulating 3-D subsurface heat transport in groundwater (see specific comments on Study 7.5 above).*

DSS Methodology to Optimize Decisions

Re: The December 2012 RSP for IFS (Section 8.5.4.8.1) describes a methodology for integration of the IFS, which is essential to developing a DSS.

Comment: What appears to be missing from the methodology discussed in the RSP and the very limited discussion presented in IFS ISR Part A (Section 4.8) and IFS SIR (Section 4.8.1) is how the optimization of results from DSS scenarios will be accomplished. In particular, AEA needs to describe how weighted performance results for all scenarios will be collectively assessed to yield scores for each objective (i.e., fish habitat, recreation, flooding, power generation), and how appropriate operational strategies will be developed and adopted in order to minimize damage to fish habitat. To date, AEA has not articulated how optimization strategies for multi-objective scenario evaluations will be developed and considered.

This limited discussion raises two concerns about the development of a DSS scenario:

- *Many "Resource Indicators" in the December 2012 RSP (AEA, 2012; Table 8.5-21) are missing, including sediment and water quality indicators (i.e., stream temperature), which could be used in the DSS evaluations.*
- *As described above, it is unclear how AEA plans to integrate multiple models within a DSS scenario. Developing a DSS scenario for this system will be a very large undertaking, and may require substantial simplification of model processes and couplings in order to be accomplished. This would in turn limit the usefulness of such a DSS scenario.*

We recommend that AEA consider using a proven and advanced DSS tool for this purpose (i.e., DHI's DSS: DHI, Undated).

3.6 ISR Section 8.6: Riparian IFS

3.6.1 Stated Study Objectives and Summary

As stated in ISR Study 8.6, the goal of the RIFS is to provide a quantitative, spatially explicit model to predict potential impacts to downstream floodplain vegetation from Project operational flow modification of the natural Susitna River flow, sediment, and ice regimes. Specific objectives include:

1. Synthesize the historical physical and biological data for Susitna River floodplain vegetation
2. Delineate sections of the Susitna River with similar environments, vegetation, and riparian processes, termed riparian process domains (RPDs) and select FAs
3. Characterize the seed dispersal and seedling establishment groundwater and surface water hydroregime requirements
4. Characterize the role of river ice in the establishment and recruitment of dominant floodplain vegetation
5. Characterize the role of erosion and sediment deposition in the formation of floodplain surfaces, soils, and vegetation

6. Characterize the natural floodplain vegetation groundwater and surface water maintenance hydroregime

7. Synthesize floodplain vegetation studies, scale FAs to RPDs and model effects of Project operations.

3.6.2 Status

To meet these objectives, AEA has surveyed seed dispersal and developed models at 4 study sites; implemented a study of balsam/willow seedling establishment on multiple transects and plots in 5 FAs; surveyed tree ice scars along the riverbank between PRM 102.2 and PRM 145.8; measured tree/shrub composition and abundance at 80 island plots in the Middle River and Lower River; and conducted riparian groundwater/surface water studies, including collecting plant, soil, and water samples and measuring transpiration in trees at 2 FAs.

Although the fieldwork appears to have been largely completed, the final laboratory isotope analysis has not been completed. The majority of modeling analysis has yet to be initiated. Internal discussions appear to have only addressed the conceptual model for how spatially explicit floodplain models will respond to Project operations.

3.6.3 Proposed Project Impacts Relevant to Riparian Instream Flow

Winter river stage will be substantially higher under operational scenarios than under baseline conditions, whereas summer river stage will in general be lower under operational scenarios than under baseline conditions. The increase in winter-time flow (and stage) will likely increase ice damage to adjacent vegetation, and the establishment of a new average stage and ice configuration will also likely increase average groundwater levels in the winter. Lower river stage in the summer may also decrease groundwater levels in the summer. AEA also states that the exact nature of the impacts will be determined via the DSS scenario.

3.6.4 Variances and/or Reported Anomalous Environmental Conditions

AEA does not note any variances to the approved study plans.

3.6.5 Specific Comments

It is currently unclear how ice processes and floodplain vegetation will be integrated.

Re: “The objectives of the ice processes floodplain vegetation interaction and modeling study are as follows:

1. Develop an integrated model of ice process interactions with floodplain vegetation.

2. Conduct primary research to identify the effects of ice on floodplain vegetation within mapped Susitna River ice floodplain impact zones.

3. Provide Project operational guidance on potential effects” (AEA, 2014, Study 8.6 Part A, p. 16).

Comment: It is unclear how the ice-process modeling study will incorporate dynamic changes in bed evolution and vegetation with time. AEA needs to clarify how trees and other vegetation influence ice development and breakup and whether these are considered in the current ice *modeling work. In addition, AEA needs to clarify how calibration error, predictive uncertainty, and limitations on simulating the correct physics of ice modeling (e.g., water flow over ice, breakup dynamics, anchor ice) will be tracked and fully considered in their DSS. Finally, AEA needs to clarify how local-scale (FA) ice process modeling will be up-scaled to the entire Middle River and Lower River.*

Re: Section 7.5 Floodplain Stratigraphy and Floodplain Development, RIFS 8.6, page 15.

Comment: Although fieldwork appears to have been completed, the majority of modeling analysis has yet to be started. As a result, it is difficult to comment on how Project operations will influence sediment transport and soil development, or plant community succession on floodplains. It is clear that a major impediment to making more progress on both the IFS and RIFS studies is lack of the projected range of hydraulic responses to reservoir operations. We recommend AEA use the recently developed hydraulic models (i.e., OWFRM version 2.8) to provide all studies with an initial possible range of hydraulic responses to Project operations. Important conceptualizations for individual studies would greatly benefit from knowing what the maximum hydraulic impacts might look like. Stakeholders are likely most interested in knowing what the maximum or worst-case impacts might be for any given operational scenario. This should be a critical component of individual studies.

Use of MODFLOW to Evaluate Groundwater/Surface Water Interactions, Evapotranspiration, and Thermal Regimes

Section 7.6 Riparian Floodplain Vegetation Groundwater and Surface Water Hydroregime Study, RIFS 8.6, page 15.

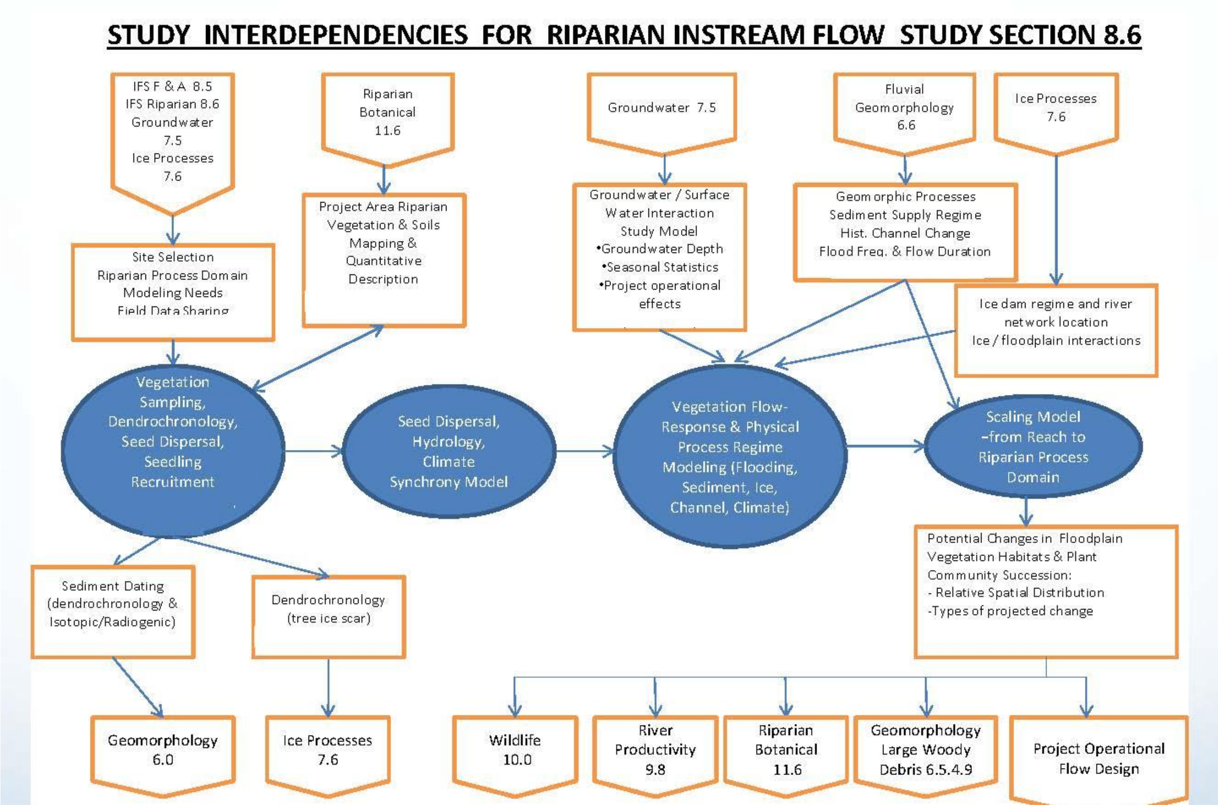
Comment: We question the use of MODFLOW for groundwater-surface water evaluations. It is well known that MODFLOW only simulates saturated flow conditions, and oversimplifies plant transpiration processes. Better tools exist to model the subsurface variable saturation conditions and associated recharge/evapotranspiration dynamics. As described in Section 4 of this memorandum, we recommend that AEA consider using more sophisticated, physically-based, and fully integrated tools that can much more readily incorporate surface water dynamics into this evaluation. As indicated above, MODFLOW also lacks the ability to simulate 3-D heat flow in groundwater, which is an important factor associated with the upwelling/downwelling associated with the salmon lifecycle. AEA should consider using a more appropriate code such as the Integrated Hydrology Model (InHM), Hydrogeosphere, or a similar code to evaluate the 3-D heat balance in groundwater. As described in the comments on Study 7.5, above, more work also needs to be done to consider how to upscale the FA groundwater/surface water coupling/modeling to the Project area.

Diagrams in ISR and SIR Study 8.6 Documents Relating Models Are Confusing and Do Not Adequately Describe Integration of Models

Comment: Details associated with the flow chart (Figure 8) associated with the April 29–30, 2014 TWG meeting (R2, 2014) below should be significantly revised to more clearly show how data, models, and critical decisions actually feed into each other. It should also be made consistent with other primary flow charts presented above (i.e., Figures 4.1-1a and 4.1-1b in the 8.5 IFS study). These flow charts are critically important for showing all stakeholders how data are used/transferred between studies, and how the various model inputs and outputs are shared. More importantly, these flow charts provide the basis for showing how the most important *modeling, the scenarios linking all models in the DSS scenario, will be used to (1) assess impacts of Project operations on all resources, (2) summarize how Project operations may be optimized to minimize damage to these resources, and (3) characterize the considerable number of sources of uncertainties and their magnitudes. As in AEA's other attempts to show model interdependencies, these diagrams become confusing and contain inconsistencies. For example, in Figure 8, AEA needs to clarify which model(s) each of the blue ellipses actually depends on, and whether the blue ellipses are meant to indicate key decision points, or analyses. AEA also needs to articulate how this flow chart will fit into the larger, more important task of evaluating, via the DSS scenario, the various Project operational scenarios and their impacts on habitat. For example, in a DSS framework this figure should be reframed as loop system that clearly shows decision points and key outputs.*

The diagrams and descriptions in the ISRs and SIRs do not provide a clear understanding of how the complex studies/models will be integrated over space and time. Thus, we are concerned that there is not a clear plan to evaluate how the DSS scenario will integrate all of these different studies/models to assess the full impacts to all resources, over the entire system, resulting from the installation of the dam and Project operations.

Figure 8. AEA's presentation of study interdependencies for riparian IFS, presented at the May 29, 2014, TWG meeting.



Source: R2, 2014.

4. Proposed Modifications to Studies

The sections above provided specific examples of areas where we believe that AEA's baseline riverine studies are lacking. In this section, we propose a series of potential modifications to the riverine modeling studies that might help AEA come closer to meeting their overall objective of assessing the impacts of the proposed Project on downstream river conditions and habitats. The majority of these proposed modifications are closely related, and are centered on AEA's conceptual site model, the interactions among relevant processes, and modeling uncertainties.

In the most general terms, we believe that AEA should improve upon and more clearly articulate their conceptual model for how the relevant hydrologic, geomorphic, and ecological processes in the Susitna River system interact. This conceptual model should be depicted in a clear, concise diagram that illustrates each of the relevant processes and the interactions between them. This figure would replace the series of figures currently depicted as Figures 5-8 in this memorandum, which we believe are too complicated for stakeholders to understand exactly how different physical processes interact in the Susitna system, or how the current models simulate these interactions in space and time. This conceptual model should then be used to guide and develop a fully integrated groundwater and surface water model of the entire system, which can accurately track and simulate the exchanges of water, heat, and other relevant parameters that occur between surface water and groundwater systems. Although the data collected in the focus areas would still provide key data for calibrating this revised model, an integrated modeling framework would more broadly inform AEA's understanding of surface water-groundwater interactions, heat exchange, and sediment transport throughout the Susitna system, rather than just within these focus areas.

In the remainder of this section we provide more details on these key modifications, in addition to some more specific proposed study modifications.

4.1 Provide a Detailed Framework for Integrating Process Models

As described in Section 2 and in specific comments in Section 3, AEA has not provided detailed descriptions of their conceptual site model of the system, or how the multiple models they are developing will be integrated. Linking and integrating models with different spatial and temporal scales can be quite challenging. The available documents do not describe the methods that AEA plans to use to link these models. At a minimum, more work is needed to develop and vet methods that will be used to create an integrated tool to evaluate proposed Project impacts on multiple resources, and to support operational decisions for the Project.

We recommend that AEA consider developing a fully integrated groundwater and surface water model. The benefits of an integrated model include:

1. Avoiding complicated linkages of separate models in space and time. Instead of attempting to manually couple groundwater flow code MODFLOW with the OWFRM 1-D hydraulic model, EFDC, the 2-D SRH-2D and River 2D models, or Bed Evolution models, AEA could consider using readily available, fully coupled, hydrologic/hydraulic codes. Many codes are available, such as MIKESHE/MIKE11, or GSFLOW, Hydrogeosphere, Parflow, Coupled HEC-RAS-MODFLOW using OpenMI, or MODHMS. Many of these codes can simulate processes relevant to the Susitna Watana modeling efforts, including snowmelt, ice, sediment transport, and fully integrated advective/dispersive fate/transport and water quality. Codes

such as this would directly incorporate upstream inflows from the 1-D HEC-RAS OWFRM model as model boundary conditions. Fully integrated models are driven by event-based external climate conditions, which would allow easier simulation of climate change impacts, based directly on output from general circulation models (GCMs). Translation of 2-D hydraulic model results to MIKESHE is also possible via OpenMI, or simply done using dynamic boundary arrays for topography, vegetation, and flows.

2. Avoiding over-simplification of tributary inflows. An integrated hydrologic/hydraulic model avoids over-simplification of tributary inflows and distributed lateral "accretions" by calculating these based on physically-based inputs instead of basing them on highly-uncertain estimates, which are based on discharge relations with the basin area. This becomes important when modeling must evaluate future operational scenarios under the influence of climate change (i.e., glaciers melt out and the surface water/groundwater flow conditions change current tributary inflows).

3. Integrating water quality modeling capabilities**.** Integrated tools allow simulation of integrated fate/transport and water quality modeling, including more robust heat balance tools that simulate a more realistic heat balance, not just in the stream, but also in the subsurface. The current modeling tools only consider heat transport within the stream itself, because MODFLOW does not simulate heat transport. Moreover, groundwater modeling appears to only be planned in FAs and the MODFLOW model is not dynamically coupled to surface hydraulic models. This coupling is a complex process, involving flows through the unsaturated zone. No plan appears to have been offered in the studies reviewed, which attempt to model how either groundwater or heat flow within the subsurface changes due to changes in surface water flows, which respond to operational changes. This defect in the existing approach will not be easily addressed in the DSS scenario.

4. Avoiding oversimplification of baseflows. An integrated model calculates distributed baseflow and lateral tributary inflows based on differences in physical characteristics of each contributing subcatchment. It would incorporate important changes due to major changes in subsurface hydrogeology, or surface drainage complexity in each subcatchment. Baseflows (and associated stream temperatures) are critical to correctly assessing habitat-specific models and impacts to changes due to different operational scenarios. The current 1-D hydraulic models (i.e., OWFRM) appear to lump distributed overland flows and baseflows into "accretions," which do not realistically simulate these processes.

4.2 Expand Consideration of Uncertainty

It is clear in reviewing reports that a minimal effort has been made to (1) clearly identify all sources of uncertainty (e.g., in data, model parameters, model boundary conditions, conceptualizations), and (2) to clearly show a methodology for tracking and accounting for all of these sources of uncertainty. Although AEA indicates that they will develop an example of how uncertainty will be handled in the DSS scenario, we are concerned that AEA will not be able to assess uncertainty in data and models (e.g., hydraulics, groundwater flow, water quality, sediment, dam operations), or address cumulative uncertainty in predictions of effects of different operational schemes on aquatic habitats.

Industry standard methods for developing/implementing a formal uncertainty analysis should be used to consider cumulative uncertainties from all sources (i.e., see Goodarzi et al., 2013, Ch. 2).

Given the large sources and magnitudes of collective uncertainty that will be present in the DSS integrated model predictions, a much clearer approach and flow chart for dealing with uncertainty at all levels should also be developed. A major challenge for the existing set of tools in the DSS scenarios will be developing methods to incorporate all the sources of uncertainty into the various separate models and linking these to each other, and estimating a cumulative uncertainty in final predicted impacts to habitats/aquatic species. If integrated models are developed, this would provide an easier method to account for uncertainty.

4.3 Develop and Describe Methods for Extrapolating from FAs to the Entire River System to Evaluate Project Impacts

Methods for extrapolating from areas where data have been collected to areas without data should be articulated, and this should be part of the considerations for data collection and model development. In particular, AEA needs to address the issue raised by R&M and Woodward Clyde (1980) and described in Section 3.3.5 of this memorandum, that "it would be necessary to construct mathematical models of each individual slough in order to make detailed predictions of the effects on the sloughs of changes in mainstem conditions." (R & M Consultants and Woodward-Clyde, 1985, p. 4-17). Even if AEA had completed a simulation that accurately described baseline conditions throughout side sloughs, plans to move from current conditions to simulation of Project operations would need to be developed and described. To fully assess the sufficiency of the collected data and preliminary models, it is important to understand how these data will be used to assess Project operations. Despite an extensive, multiyear data collection effort, for many of these studies, the methods that will be used to evaluate the full extent of Project impacts on the river system have not been articulated.

4.4 Incorporate Climate Change Projections into the Modeling Framework

As described in Section 2, we recommend that AEA include climate change projections for the life of the proposed Project. A range of emissions scenarios and GCM output should be included in evaluations and simulations of Project impacts.

If an integrated model is developed, driven by actual variations in climate conditions, it could be used to assess climate change effects. It is difficult to imagine how the current 1-D hydraulic models could be used to simulate changes to the existing, natural hydrologic flow conditions due to climate change because all of the boundary flows are dependent on historical mainstem and tributary boundary inflows. For example, the loss of glaciers would strongly influence catchment hydrology, to the point that current estimates of tributary inflows based on catchment size would not be valid. Simulating flow conditions with a fully integrated flow model, with an appropriate snowmelt model component (i.e., MIKESHE), would permit evaluation of such conditions, driven by expected external climate changes. A number of studies have already been conducted using these advanced tools, including studies in Alaska (e.g., Prucha et al., 2012).

4.5 Begin DSS Scenario Evaluations As Soon As Possible

We recommend AEA consider using DSS software with a proven track record and capabilities rather than attempting to revise a simple USGS Excel file used in the Black Canyon of the Gunnison (i.e., Auble, 2009) to meet the much more complicated and unique Susitna system. For example, DHI has a DSS tool that could be applied (DHI, Undated). We recommended that AEA initiate DSS scenario evaluations as soon as possible, perhaps just with the major hydraulic indicators, to learn about the sensitivity of DSS results and associated decisions. This would allow AEA to convey information to various study groups, so that they can take the appropriate actions needed in data collection and final modeling efforts that are consistent with the final DSS simulations/needs.

4.6 Simulate Reservoir Operation/Releases under a Full Range of Scenarios and Consider this Range across the Various Studies

We recommend that AEA simulate a range of reservoir operations/releases, and provide these results to the different studies as soon as possible, even if these values are available for only part of the year, and with the knowledge that these will be refined as the study progresses. With this information, different studies could consider an initial range of impacts that will need to be evaluated with the data and models. Each study appears to rely heavily on projected operational scenarios, which have not been fully assessed beyond proof of concept.

AEA should promote development and simulation of a more complete range of possible discharges from the dam, so that each group can fully appreciate/understand and assess their respective study areas within the maximum impacted areas. At present, the study groups do not know what the maximum impacted areas will be, and therefore cannot ensure that they are collecting adequate data or developing models that adequately capture the maximum range of impacts. For example, more progress could be made on both the IFS and RIFS studies with a projected range of hydraulic responses to reservoir operations. An initial possible range of hydraulic responses to Project operations could be estimated using initial 1-D hydraulic models that have been developed (i.e., OWFRM version 2.8). In addition, it would provide stakeholders with an understanding of what the maximum or worst-case impacts might be for any given operational scenario.

4.7 Collect More Primary Data for Some Studies

For some studies, data collected to date are inadequate to assess current baseline conditions. A primary example of this is the lack of data describing sediment transport in tributaries entering the Susitna mainstem (Section 3). Without these data, a sediment balance for the river can only be developed with model-estimated sediment loads, and cannot be compared or calibrated with field data. This greatly increases uncertainty, and reduces the confidence that can be placed in the modeling. In cases where we have noted data gaps in our specific comments, we recommend that AEA consider collecting additional primary data prior to continuing with modeling.

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List of Acronyms

1-D	one dimensional
2-D	two dimensional
3-D	three dimensional
Abt	Abt Associates
AEA	Alaska Energy Authority
ASTM	American Society for Testing and Materials
DSS	Decision Support System
EFDC	Environmental Fluid Dynamics Code
EPA	U.S. Environmental Protection Agency
FA	focus area

FERC	Federal Energy Regulatory Commission
GCM	general circulation model
HSI	Habitat Suitability Index
HSC	Habitat Suitability Curve
IFS	Instream Flow Study
InHM	Integrated Hydrology Model
ISR	initial study report
LWD	large woody debris
OWFRM	Open Water Flow River Model
PDO	Pacific Decadal Oscillation
PHABSIM	Physical Habitat Simulation
PRM	Project River Mile
Project	Susitna-Watana Hydro Project
RIFS	Riparian Instream Flow Study
RPD	riparian process domain
RSP	Revised Study Plan
SIR	study implementation report
TIR	thermal infrared imagery
TWG	Technical Work Group
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey