Susitna-Watana Hydroelectric Project Document
ARLIS Uniform Cover Page

Title: Instream flow study (IFS)	**SuWa 146**
Author(s) – Personal:	
Author(s) – Corporate: Alaska Energy Authority	
AEA-identified category, if specified: Aquatic and fish resources study requests	
AEA-identified series, if specified:	

Series (ARLIS-assigned report number): Susitna-Watana Hydroelectric Project document number 146	**Existing numbers on document:**
Published by: [Anchorage] : Susitna-Watana Hydroelectric Project, [2012]	**Date published:** 5/15/12
Published for:	**Date or date range of report:**
Volume and/or Part numbers:	**Final or Draft status, as indicated:**
Document type:	**Pagination:** 13 p.
Related work(s):	**Pages added/changed by ARLIS:**
Notes:	

All reports in the Susitna-Watana Hydroelectric Project Document series include an ARLIS-produced cover page and an ARLIS-assigned number for uniformity and citability. All reports are posted online at http://www.arlis.org/resources/susitna-watana/

1.1. Title of proposed study

Instream Flow Study (IFS)

1.2. Requestor of proposed study

AEA anticipates resource agencies will request this study.

1.3. Responses to study request criteria (18 CFR 5.9(b))

The following sections provide the necessary context and justification for the proposed study.

1.3.1. Describe the goals and objectives of each study proposal and the information to be obtained.

The objectives of the Instream Flow studies are as follows:

1. Develop modeling approaches to quantify the seasonal habitat versus flow and other parameter relationships for aquatic species, life stages and/or guilds, within the different habitat types of the Susitna River.

2. Use the habitat versus flow/other parameter relationships to develop time series and effective habitat analysis appropriate for quantifying existing conditions and a range of with-Project conditions; the time scale for this analysis will be based on proposed Project operations and may include hourly, daily, weekly, or seasonal time steps.

3. Select surface-water transects for 1-D modeling and/or segments for 2-D modeling to measure and model mainstem Susitna River habitat types.

4. Identify the time periods, flow/other parameter conditions and life stages when habitat may be a limiting factor for aquatic species.

5. Develop new, or modify existing, habitat suitability criteria (HSC) curves for selected target species and life stages.

6. Develop a set of integrated habitat-specific aquatic habitat models (i.e., mainstem, side channel, side slough, upland slough, tributary mouth, etc.) that can be linked with riverine process models that produces a time series of data for a variety of biologically relevant metrics under alternative operational scenarios. These metrics include (but are not necessarily limited to):

     o water surface elevations at selected river locations;
     o water velocities within transect subdivisions (cells) over a range of flows;
     o groundwater (upwelling/downwelling);
     o varial zone areas;
     o frequency and duration of exposure/inundation of the varial zone at selected locations;
     o habitat quantities by species and life stage within respective habitat types;
     o water temperature characteristics; etc.

7. Conduct a variety of post-processing comparative analyses derived from the output metrics estimated under the habitat specific aquatic habitat models. These include (but are not necessarily limited to):

  o comparisons of habitat quantity and quality (e.g., habitat exceedance plots)
  o ramping rates (e.g., changes in flow versus time);
  o juvenile fish stranding/trapping;
  o habitat sustainability (effective habitat analysis);
  o distribution and abundance of benthic macroinvertebrates under alternative operational scenarios.

8. Develop hydraulic routing models that estimate water surface elevations and average water velocity along modeled transects (with and without ice conditions) on an hourly basis under alternative operational scenarios.

9. Map the current aquatic habitats in the Susitna River both above and below the Watana Dam.

1.3.2. If applicable, explain the relevant resource management goals of the agencies and/or Alaska Native entities with jurisdiction over the resource to be studied. [Please include any regulatory citations and references that will assist in understanding the management goals.]

To be completed by requesting organization.

1.3.3. If the requester is not resource agency, explain any relevant public interest considerations in regard to the proposed study.

Fisheries resources are owned by the State of Alaska and the Project could potentially affect these public interest resources by affecting aquatic habitat.

1.3.4. Describe existing information concerning the subject of the study proposal, and the need for additional information.

Substantial information exists for the Susitna River that was collected and analyzed as part of the 1980s studies. The extent and details of many of those studies were provided in the Draft Environmental Impact Statement (DEIS 1984) for the previous project (FERC No. 7114) along with companion appendices and attachments in the way of ADFG reports. Some of that information was cited and summarized in the HDR (2011) gap analysis report; however, there has not been a thorough review of the studies and underlying data. The gap analysis did provide for an initial listing of salient reports and data that warrant more detailed evaluations. The References section of this plan contains some of the more relevant documents that were identified. As noted by HDR (2011), instream flow studies of the Susitna River were conducted by the then Alaska Power Authority (APA) for the previous hydroelectric project (FERC No. 7114) that was proposed in the early 1980s. Those study efforts focused on establishing the

relationships between physical variables, fluvial processes and fish resources in the middle Susitna River. Faced with the complexity of the number of environmental variables involved and the number of species of fish which inhabit the middle Susitna River, it was deemed necessary to focus only on the most important physical variables and carefully identified fish resources which were most sensitive to project-related changes (Trihey & Associates and Entrix 1985b). Inspection of the 1980s report confirms that the majority of efforts were focused on the Middle River portion of the Susitna River.

The gap analysis presented in HDR (2011) outlines the major elements required in an instream flow study. Although substantial data and information were collected in the 1980s, those data are approximately 30 years old and therefore additional information needs to be collected to provide a contemporary understanding of the baseline conditions existing in the Susitna River. In addition, the configuration and proposed operations of the Project have changed and must be evaluated within the context of the existing environmental setting. This includes consideration of potential load following effects on important fish and aquatic habitats both downstream and upstream of the Watana Dam. This evaluation needs to extend for the entire length of the Susitna River below the Watana Dam that is affected by the Project, including the reach of river below the confluence of the Chulitna and Talkeetna rivers, as appropriate. Potential effects of proposed Project operations on aquatic habitats and biota and potential benefits and impacts of alternative operational scenarios have not been quantitatively analyzed. The aquatic habitat specific models will provide an integrated assessment of the effects of Project operations on biological resources and riverine processes. These models will provide an analytical framework for assessing alternative operational scenarios and quantitative metrics that will aid in comparing alternatives that may lead to refinements in proposed Project operations. Project effects will be quantified using indices of potential habitat rather than estimates of the number of fish produced or lost under alternative operational scenarios.

1.3.5. Explain any nexus between project operations and effects (direct, indirect, and/or cumulative) on the resource to be studied, and how the study results would inform the development of license requirements.

Project construction and operation, ~~as described in the Pre-application Document (PAD, AEA 2011),~~ would have an effect on the flows downstream of the dam, the degree of which will ultimately depend on its final design and operating characteristics. ~~With a proposed elevation of 700 ft resulting in the creation of a 39 mi. long reservoir (20,000 acre) and a nominal generating capacity of 600 MW (PAD AEA 2011), the project would change the timing and magnitude of flows in the river below the powerhouse~~ The alteration in the timing and magnitude of flows in a river can influence downstream resources/processes, including fish and aquatic biota and their habitats, channel form and function including sediment transport, water quality, ice dynamics and riparian and wildlife communities. The license may include conditions pertaining to any or all of these matters. ~~, all of which have been alluded to in the PAD (AEA 2011).~~

~~The potential operational flow induced effects of the Project will need to be carefully evaluated as part of the licensing process. This study plan describes the Instream Flow Study (IFS) for the Susitna-Watana Project that will be conducted to characterize and evaluate these effects.~~

1.3.6. Explain how any proposed study methodology (including any preferred data collection and analysis techniques, or objectively quantified information, and a schedule including appropriate field season(s) and the duration) is consistent with generally accepted practice in the scientific community or, as appropriate, considers relevant tribal values and knowledge.

The IFS plan is specifically directed toward establishing a contemporary understanding of important biological communities and associated habitats, and the hydrologic, physical, and chemical processes that are currently operating in the Susitna River that directly influence those resources. The focus of much of this work will be on establishing a set of analytical tools/models based on the best available information and data that can be used for defining both baseline conditions; i.e., how these resources are currently functioning under existing flow conditions, and how these resources and processes will respond to various alternative Project operations.

The foundation of the IFS analyses rests with the development of the Susitna Mainstem Flow Routing Models (HEC-RAS, CRISSP1D and/or other routing models) (MFRM) that will provide hourly flow and water surface elevation data at numerous locations longitudinally distributed throughout the length of the river extending from RM 184 downstream to RM 75 (about 23 miles downstream from the confluence with the Chulitna River). Two different flow routing models will be developed: a summer ice-free model (HEC-RAS); and a winter model to route flows under ice-covered conditions (CRISSP1D or equivalent).

The routing models will initially be developed based on approximately 100 transects and on gaging stations at approximately 9 locations on the Susitna River that will be established and measured in 2012 as part the IFS program. The hourly flow records from USGS gaging stations on the Susitna River will also be utilized to help develop the routing models. Depending on the initial results of the flow routing models, it may be necessary to add additional transects to improve the performance of the models between RM 75 and RM 184, and to possibly extend the models further downstream past RM 75.

The gaging stations initially installed in 2012 will be maintained through 2013 and 2014 to help calibrate and validate the flow routing models and provide data supporting other studies. The gaging stations will be used to monitor stage and flow under summer ice-free conditions and to

monitor water pressure under winter ice-covered conditions. Continuous measurement of water pressures during the 2012/2013 and the 2013/14 winter periods under ice-covered conditions will be produce information different from open-water conditions. During partial ice cover, the pressure levels measured by the pressure transducers is affected by flow velocities, ice-cover roughness characteristics and other factors such as entrained ice in the water column. The pressure-head data is important for understanding groundwater/surface-water interactions.

Periodic winter discharge measurements will be completed at selected gaging stations in the winter, in coordination with USGS winter measurement programs, and will provide valuable information for understanding hydraulic conditions in the river during a season when groundwater plays a more prominent role in aquatic habitat functions. Winter flow measurements will also be used to help develop the CRISSP1D model (or equivalent).

Output from the flow routing models will provide the fundamental input data to a suite of habitat specific and riverine process specific models that will be used to describe how the existing flow regime relates to and has influenced various resource elements (e.g., salmonid spawning and rearing habitats, invertebrate habitat, sediment transport processes, ice dynamics, large woody debris (LWD), the health and composition of the riparian zone). These same models will likewise be used to evaluate resource responses to different Project operational scenarios, again via output from the routing models, including various baseload and load following alternatives, as appropriate. As an unsteady flow model, the routing models will be capable of providing flow and water surface elevation information at each location on an hourly basis and therefore Project effects on flow can be evaluated on multiple time steps (hourly, daily, and monthly) as necessary to evaluate different resource elements.

The consistency of various elements of the program to generally accepted practices is described below:

- **Habitat Mapping.** Studies regarding habitat mapping are commonly conducted at many hydroelectric projects as part of FERC licensing (e.g., Watershed GeoDynamics 2005, R2 Resource Consultants 2003, R2 Resource Consultants 2004). Mapping surveys will utilize protocols similar to those performed at other hydroelectric projects.

- **Hydraulic Unsteady Flow Routing.** One-dimensional unsteady flow hydraulic models are commonly used to route flow and stage fluctuations through rivers and reservoirs. Examples of public-domain computer models used to perform these types of processes include FEQ (USGS 1997), FLDWAV (U.S. National Weather Service 1998), UNET (U.S. Army Corps of Engineers 2001), and HEC-RAS (U.S. Army Corps of Engineers 2010a, 2010b, and 2010c). The HEC-RAS (Hydrologic Engineering Center – River Analysis System) model has proven to be very robust under mixed flow conditions (subcritical and supercritical), as will be expected in the Susitna River. The HEC-RAS model also has the capability of automatically varying Manning's "n" with stage through the use of the equivalent roughness option. Another feature of HEC-RAS is the capability of varying Manning's "n" on a seasonal basis. The robust performance and

flexibility of HEC-RAS make this model an appropriate choice for routing stage fluctuations downstream from the proposed Project dam under summer ice-free conditions. Under winter ice-covered conditions, the CRISSP1D model (or equivalent) can be used to route unsteady flows downstream through the Susitna River. CRISSP1D is a one-dimensional unsteady flow model that can be used to analyze water temperature, thermal ice transport processes, and ice cover breakup (Chen et al 2006). The seasonal timing of the transition from the HEC-RAS model to the CRISSP1D model (or equivalent) and vice versa will vary from year-to-year and will depend on meteorological conditions.

- **Mainstem, Side channel, and Slough Habitat Models.** Physical habitat models are often used to evaluate alternative instream flow regimes in rivers (e.g., the Physical Habitat Simulation [PHABSIM] modeling approach developed by the U.S. Geological Survey; Bovee 1998, Waddle 2001). Methods available for assessing instream flow needs vary greatly in the issues addressed, their intended use, their underlying assumptions, and the intensity (and cost) of the effort required for the application. Many techniques, ranging from those designed for localized site or specific applications to those with more general utility have been used. The summary review reports of Wesche and Rechard (1980), Stalnaker and Arnette (1976), EA Engineering, Science and Technology (1986), the proceedings of the Symposium on Instream Flow Needs (Orsborn and Allman eds. 1976), Electric Power Research Institute (2000), and more recently the Instream Flow Council (Annear et al. 2004) provide more detailed information on specific methods. The methods proposed in the IFS will likely include a combination of approaches depending on habitat types (e.g., mainstem, side channel, slough, etc.) and the biological importance of those types. During the 1980s studies, methods were designed to focus on both mainstem and off-channel habitats, although mainstem analysis was generally limited to near-shore areas. Both PHABSIM based models and juvenile salmon rearing habitat models were employed and will be considered as part of the IFS plan. It is likely that more rigorous approaches and intensive analysis will be applied to habitats determined as representing especially important habitats for salmonid production. It is also likely this will include both 1-D and, in some cases, 2-D surface-water hydraulic modeling that can be linked to habitat based models. Incorporation of a groundwater component into the habitat models will provide the basis for evaluating how Project operations may alter the surface-water/groundwater interactions that could influence habitat utilization of sloughs and other groundwater influenced habitat types. The proposed modeling approach is consistent with the use of physical habitat models used at other hydroelectric projects to assess the effects of alternative operational scenarios on aquatic habitat.

- **HSC and HSI Development.** HSI curves have been utilized by natural resources scientists for over two decades to assess the effects of habitat changes on biota. HSI curves were developed by the USFWS for use with fish and wildlife (see http://www.nwrc.usgs.gov/wdb/pub/hsi), but their usage has also included periphyton and wetland tree habitats (e.g., Tarboton et al. 2004). The proposed method for the

development and verification of HSI curves is analogous to the methods described in Bovee (1982; 1986) and USFWS (1981). The proposed fish sampling and observation methods will be consistent with those described in Murphy and Willis (1996) and will consider methods previously used in the 1980s (e.g., Suchanek et al. 1984). The proposed use of an expert panel to develop and verify fish HSI curves is modified from that described by Crance (1987) and has been applied in FERC licensing/relicensing studies of other projects.

A tentative schedule that includes field season(s) and the duration of the study is provided in Table 1.

Table 1.   Schedule for development of all components of the Mainstem Aquatic Habitat Model.

Activity	2012				2013				2014			
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4Q
Technical Consultant Selection	▲											
Refine and Finalize Study Plan		----▲	--▲---	-------								
Agency Stakeholder Site Visit			--▲									
Study Site Selection (mainstem, slough, side channels, etc.)			--▲									
Review of 1980s Data and Information			--------	------●								
Model Selection by habitat type (1-D, 2-D, mapping, etc.)			--------	----●								
Hydraulic Routing: data collection and reporting		--------	--------	------●	-------	-------	-------	-------	-------	-------	-------	-------
Hydraulic Routing: develop executable model				-------	-------	-------	-------	-------	-------	-------	-------	-------
HSC/Periodicity Fish: Review literature and 1980s reports			--------	------●	-------	-------	-------	-------	-------	-------	-------	-------
HSC Fish: Field data collection (summer, fall, winter) (both years)			▲	▲	------	--▲---	-▲-----	--▲---	------	-▲-----	--▲--	▲
Habitat Mapping (GIS, aerial videography, aerial photography)		--------	--------	-------	-------	-------	-------					
Habitat Surveys (side channels, sloughs, mainstem)					--------	-------	-------	-------	-------	-------	-------	-------
Collect Velocities and depths at transects selected for habitat analysis (3 flows)						▲	▲					
Re-establish old cross-sections and establish new cross-sections for flow routing model		------	-------			-------	-------					
Maintain gaging station for stage and flow measurement		------	-------			-------	-------			-------	-------	
Maintain gaging station for stage measurement				-------	-------			-------	-------			
Winter measurement programs				------	-------			-------	-------			
Develop groundwater/surface flow models				------	-------	------	-------	-------				
Hydraulic Model Integration and Calibration							------	------				
Varial Zone Model and Downramping Analysis								--------	-------	-------		
Habitat Modeling								--------	-------	-------		
Alternate Scenario Post-Processing								--------	-------	-------		
Reporting				●				●●				●●

1.3.7. Describe considerations of level of effort and cost, as applicable, and why any proposed alternative studies would not be sufficient to meet the stated information needs.

Based on a review of study costs associated with similar efforts conducted at other hydropower projects, and in recognition of the size of the Project and logistical challenges associated with the remoteness of the site, study costs associated with the IFS plan are expected to range from $5,000,000 to $6,000,000. Study costs include office-based tasks such as development of draft and final study plans, compilation and review of the extensive instream flow data developed during the 1980s, analysis and processing of data collected in 2013 and 2014, hydraulic and habitat model development and testing, and draft and final study reports.

Field efforts include habitat survey and mapping, collection of physical and hydraulic data to support instream flow modeling, validation of salmonid habitat suitability curves, and monitoring of the groundwater/surface interface. To obtain efficiencies in the overall relicensing work effort, portions of this study will be conducted in conjunction with Water Resource, Geomorphology, Water Quality, Operational Modeling, and other Aquatic Resource Studies; however, costs of those studies are reflected in those individual study requests. Estimated study costs are subject to review and revision as additional details are developed.

1.3.8. Literature Cited

[ADF&G] Alaska Department of Fish and Game. 1981a. Aquatic studies procedures manual: Phase I. Su-Hydro Aquatic Studies Program. Anchorage, Alaska. Susitna Hydro document no. 3506.

—. 1981b. Subtask 7.10 Phase 1 Final Draft Report Resident Fish Investigation on the Upper Susitna River. Alaska Department of Fish and Game, Anchorage, Alaska.

—. 1982. Upper Susitna River Impoundment Studies 1982. ADF&G. Anchorage, Alaska.

—. 1983a. Susitna Hydro aquatic studies phase II final report. Adult anadromous fish studies, 1982, volume 2. Susitna Hydro Document No. 588, Anchorage, Alaska.

—. 1983b. Aquatic Habitats and Instream Flow Studies Parts I and II. Susitna Hydro Aquatic Studies Phase II Basic Data Report volume 4, Susitna Hydro Document No. 585. Anchorage, Alaska.

—. 1984a. Susitna Hydro aquatic studies report no. 1. ADF&G, Susitna Hydro Aquatic Studies Report Series, Susitna Hydro Document No. 1450, Anchorage, Alaska.

—. 1984b. Population Dynamics of Arctic Grayling in the Upper Susitna Basin, Report 4, Part II. Schmidt, D.C., C. Estes, D. Crawford, and D. Vincent-Lang, editor. Access and Transmission Corridor Aquatic Investigations (July–October 1983). Susitna Hydro Document No. 2049. ADF&G, Anchorage.

—. 1984c. Susitna Hydro Aquatic Studies Report No. 2. Resident and juvenile anadromous fish investigations (May–October 1983). D.C. Schmidt, S.S. Hale, D. L. Crawford, and P.M. Suchanek, editors. Prepared for the Alaska Power Authority, Susitna Hydro Document No. 1784, ADF&G, Anchorage, Alaska.

—. 1984d. Aquatic Habitat and Instream Flow Investigations (May–October, 1983). Chapter 1. Stage and Discharge Investigations – 1984. Susitna Hydro Document No. 1930. ADF&G, Anchorage, Alaska.

—. 1984e. Aquatic Habitat and Instream Flow Investigations (May–October, 1983). Chapter 2. Channel Geometry Investigations. Susitna Hydro Document No. 1931. ADF&G, Anchorage, Alaska.

—. 1984f. Aquatic Habitat and Instream Flow Investigations (May–October, 1983). Chapter 3. Continuous Water Temperature Investigations. Susitna Hydro Document No. 1932. ADF&G, Anchorage, Alaska.

—. 1984g. Aquatic Habitat and Instream Flow Investigations (May–October, 1983). Chapter 5. Eulachon Spawning Habitat – 1984. Susitna Hydro Document No. 1934. ADF&G, Anchorage, Alaska.

—. 1984h. Aquatic Habitat and Instream Flow Investigations (May–October, 1983). Chapter 6. An evaluation of passage conditions for adult salmon in sloughs and side channels of the Middle Susitna River. Susitna Hydro Document No. 1935. ADF&G, Anchorage, Alaska.

—. 1984i. Aquatic Habitat and Instream Flow Investigations, (May–October, 1983). Chapter 7. An evaluation of chum and sockeye salmon spawning habitat in sloughs and side channels of the Middle Susitna River. Susitna Hydro Document No. 1936. ADF&G, Anchorage, Alaska.

—. 1984j. Aquatic Habitat and Instream Flow Investigations, (May–October, 1983). Chapter 8. Evaluation of chum salmon spawning habitat. Susitna Hydro Document No. 1937. ADF&G, Anchorage, Alaska.

—. 1984k. Aquatic Habitat and Instream Flow Investigations, (May–October, 1983). Chapter 9. Habitat suitability criteria for Chinook, coho and pink salmon spawning in tributaries of the Middle Susitna River. Susitna Hydro Document No. 1938. ADF&G, Anchorage, Alaska.

—. 1984k. Aquatic Habitat and Instream Flow Investigations, (May–October, 1983). Modeling of juvenile salmon and resident fish habitat. Susitna Hydro Development Part 7. ADF&G, Anchorage, Alaska.

Addley, C. 2006. Habitat modeling of river ecosystems: Multidimensional spatially explicit and dynamic habitat templates at scales relevant to fish. Ph.D. dissertation. Utah State University, Logan, Utah.

Annear, T., I. Chisholm, H. Beecher, A. Locke and 12 other authors. 2004. Instream flows for riverine resource stewardship, revised edition. Instream Flow Council, Cheyenne, WY. 268 pp

Bovee, K. D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Paper No. 12. Washington, DC: U.S. Fish and Wildlife Service (FWS/OBS-82/26).

Bovee, K. D. 1986. Development and evaluation of habitat suitability criteria for use in the instream flow incremental methodology. Washington, DC: U.S. Fish and Wildlife Service (Biological Report 86[7]). 235pp.

Chen, Fanghui, Hung Tao Shen, and Nimal C. Jayasundara. 2006. A one-dimensional comprehensive river ice model, Proceedings of the 18th IAHR International Symposium on Ice.

Crance, J. 1987. Guidelines for Using the Delphi Technique to Develop Habitat Suitability Index Curves. US Fish and Wildlife Service Biological Report 82(10.134). Fort Collins, CO. 22 pp.

DeVries, P., B. Kvam, S. Beck, D. Reiser, M. Ramey, C. Huang, and C. Eakin. 2001. Kerr Hydroelectric Project, Lower Flathead River ramping rate study. Prepared by R2 Resource Consultants, for Confederated Salish and Kootenai Tribes of the Flathead Nation, Montana.

Dugan, L.J., D. A. Sterritt, and M.E. Stratton. 1984. The distribution and relative abundance of juvenile salmon in the Susitna River drainage above the Chulitna River confluence. Alaska Department of Fish and Game. Completion Report. Susitna Hydroelectric Studies. Anchorage, Alaska.

EA Engineering, Science, and Technology, Inc. 1986. Instream flow methodologies. Electric Power Research Institute (EPRI). EPRI EA-4819, Project 2194-2, Final Report.

Electric Power Research Institute (EPRI). 2000. Instream flow assessment methods: guidance for evaluating instream flow needs in hydropower licensing. Electric Power Research Institute (EPRI). Report number 1000554.

Hardy Thomas B., and Tarbet Karl, 1996. Evaluation of one-dimensional and two-dimensional hydraulic modeling in a natural river and implications in instream flow assessment methods. Proceedings of Second International Symposium on Habitat Hydraulics Ecohydraulics 2000, Quebec, Canada, June 1996, Volume B, 395-406.

HDR Alaska. 2011. Susitna-Watana Hydroelectric Project; Railbelt Large Hydro; Aquatic Resources Data Gap Analysis. Prepared for Alaska Energy Authority, Anchorage, Alaska.

Klemm, D.J., P.A. Lewis, F. Fulk, and J.M. Lazorchak. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. EPA/600/4-90/030, Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio.

Leclerc, M., Boudreault A., Bechara, J. A., and Corfa, G., 1995. Two-dimensional hydrodynamic modeling-a neglected tool in the instream flow incremental methodology. Transactions of the American Fisheries Society 124(5), 645-662.

Marshall, R. P., P. M. Suchanek, and D.C. Schmidt. 1984. Juvenile salmon rearing habitat models. Report No. 2, Part 4. Susitna Hydro Aquatic Studies, Alaska Department of Fish and Game, Anchorage, Alaska.

Murphy, B. R. and D. W. Willis. 1996. Fisheries Techniques, Second Edition. American Fisheries Society, Bethesda Maryland. 732 pp.

National Oceanic and Atmospheric Administration/National Marine Fisheries Service (NOAA/NMFS). 2012. Letter from J.W. Balsiger to W. Dyok (AEA) regarding: Susitna-Watana Hydroelectric Project (P-14241) 2012 Study Meetings. February 29, 2012.

Orsborn, J.F. and C.H. Allman (editors). 1976. Proceedings of the symposium and specialty conference on instream flow needs. American Fisheries Society, Bethesda, Maryland 20014. Volume I & II.

Perry, S.A. and W.B. Perry. 1986. Effects of experimental flow regulation on invertebrate drift and stranding in the Flathead and Kootenai rivers, Montana, USA. Hydrobiologia. 134: 171 182.

R2 Resource Consultants, Inc. 2003. Baker River Project Relicensing (FERC No. 2150), Large Woody Debris Budget, Aquatic Resource Study A-20. Prepared by R2 Resource Consultants, Redmond, WA, prepared for Puget Sound Energy, Inc., Bellevue, WA. 105 pp.

R2 Resource Consultants, Inc. 2004. Baker River Project Relicensing (FERC No. 2150), Lower Baker Physical Habitat Mapping, Aquatic Resource Study A-02. Prepared by R2 Resource Consultants, Redmond, WA, prepared for Puget Sound Energy, Inc., Bellevue, WA. 105 pp.

Rabeni, C. F. 1996. Invertebrates. Chapter 11 in Murphy, B. R. and D. W. Willis. (eds) Fisheries Techniques, Second Edition. American Fisheries Society, Bethesda Maryland.

Reice, S.R. and M. Wohlenberg. 1993. Monitoring freshwater benthic invertebrates and benthic processes: Measures for assessment of ecosystem health. Pages 287-305 in D.M. Rosenberg and V.H. Resh, editors. Freshwater biomonitoring and benthic macroinvertebrates. Routledge, Chapman and Hall, Inc., New York, New York.

Reiser, D.W, T. Nightengale, N. Hendrix, and S. Beck. 2005. Effects of pulse-type flows on benthic macroinvertebrates and fish: a review and synthesis of information. Report prepared by R2 Resource Consultants for Pacific Gas and Electric Company, San Ramon, California.

Stalnaker, C. and J. Arnette (eds). 1976. Methodologies for the determination of stream resource maintenance flow requirements: an assessment. U.S. Fish and Wildlife Service, Western Water Allocation.

Stalnaker, C., B.L. Lamb, J. Henriksen, K. Bovee, and J. Bartholow. 1995. The instream flow incremental methodology, a primer for IFIM. National Biological Service, U.S. Department of the Interior. Biological Report 29.

Tarboton, K. C., Irizarry-Ortiz, M. M., Loucks, D. P., Davis, S. M., and Obeysekera, J. T. 2004. Habitat Suitability Indices for Evaluating Water Management Alternatives. Office of Modeling Technical Report. South Florida Water Management District, West Palm Beach, Florida. December, 2004.

Thorp, J.H. and A.P. Covich. 2001. An overview of freshwater habitats. Pages 19-41 in J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, San Diego, California.

Troelstrup, N.H., Jr. and G.L. Hergenrader. 1990. Effect of hydropower peaking flow fluctuations on community structure and feeding guilds of invertebrates colonizing artificial substrates in a large impounded river. Hydrobiologia 199: 217 228.

U.S. Army Corps of Engineers. 2001. UNET One-dimensional unsteady flow through a full network of open channels, User's manual, CPD-66.

U.S. Army Corps of Engineers. 2010a. HEC-RAS River Analysis System User's Manual, CPD-68.

U.S. Army Corps of Engineers. 2010b. HEC-RAS River Analysis System Hydraulic Reference Manual, CPD-69.

U.S. Army Corps of Engineers. 2010c. HEC-RAS River Analysis System Applications Guide, CPD-70.

USFWS (U.S. Fish and Wildlife Service). 1980. Habitat evaluation procedures (HEP). ESM 102. U.S. Fish and Wildlife Service, Division of Ecological Services, Washington, D.C. March 31, 1980.

USFWS (U.S. Fish and Wildlife Service). 1981. Standards for the development of habitat suitability index models for use in the Habitat Evaluation Procedures, USDI Fish and Wildlife Service. Division of Ecological Services. ESM 103.

U.S. Fish and Wildlife Service (USFWS). 2011. Letter from A.G. Rappoport to S. Fisher-Goad (AEA) regarding: Proposed 2012 pre-licensing studies for the Susitna-Watana Hydroelectric Project, FERC Project No. 14241-0000. December 30, 2011.

U.S. Fish and Wildlife Service (USFWS). 2012. Letter from A.G. Rappoport to S. Fisher-Goad (AEA) regarding: 2012 pre-licensing draft study plans for the Susitna-Watana Hydroelectric Project, FERC Project No. 14241-0000. February 10, 2012.

U.S. Fish and Wildlife Service (USFWS). 2012. Letter from A.G. Rappoport to S. Fisher-Goad (AEA) regarding: Comments on an additional 2012 draft study plan for the Susitna-Watana Hydroelectric Project, FERC Project No. 14241-0000. February 21, 2012.

U.S. Department of the Interior. 2012. Letter from P. Bergmann to K.D. Bose (FERC) regarding: COMMENTS on the Notice of Application for Preliminary Permit: Susitna-Watana Hydroelectric Project, FERC Project No. 14241-0000. January 12, 2012.

Wesche, T. A., and P. A. Rechard. 1980. A summary of instream flow methods for fisheries and related research needs. Eisenhower Consortium Bulletin 9. Water Resources Research Institute, University of Wyoming, Laramie, Wyoming. 122 p.