7. HYDROLOGY-RELATED RESOURCES

7.1. Introduction

Operation of the Susitna-Watana Project (Project) is expected to change the water quality characteristics of the riverine portion of the drainage and the mainstem Susitna River reach inundated by the Project reservoir. This will affect flow, water depth, surface water elevation, channel characteristics, and sediment regimes. The potential effects of the Project on ice formation, surface and groundwater temperature and quality, mercury bioaccumulation, and geomorphology need to be carefully evaluated as part of the licensing process because changes to these parameters can affect aquatic and riparian habitat quality, which can in turn affect fish populations, riparian-dependent species, and roads, bridges, structures, and recreation opportunities along the river corridor.

This section of the RSP describes the water resource studies that will be conducted to characterize and evaluate these effects. These studies will be subject to revision and refinements in consultation with licensing participants as part of the continuing study planning process identified in the Integrated Licensing Process (ILP). The impact assessments will inform development of any necessary protection, mitigation, and enhancement measures to be presented in the draft and final License Applications.

An additional study is being proposed on glacial and runoff changes in the upper Susitna basin, in response to written requests from the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), as well as other licensing participants. This study will research, describe, and quantify glacial retreat and runoff changes in the upper Susitna basin, and assess reasonably foreseeable impacts to the Project.

7.2. Nexus Between Project Construction / Existence / Operations and Effects on Resources to be Studied

Construction and operation of the Project have the potential to alter water chemistry, temperature, river flow, sedimentation, and ice processes in the Susitna River. Changes to these processes may affect channel morphology and aquatic habitat downstream of the Project site. Understanding existing conditions provides baseline information needed for predicting the likely extent and nature of potential changes to the river that may occur due to Project construction and operations.

For any hydropower project it is important to understand the variability of the discharge. On-going retreat of the glaciers feeding the upper Susitna drainage, along with the anticipated long-life of the project, means that glacial retreat could have significant impacts to the ecosystem, economics of the Project, and proposed mitigation measures. These impacts from natural changes to the environment may be additive to impacts from the proposed dam. The effects will be varied and could include the following:

- Glacial retreat can affect runoff contribution from glaciers that could result in reduced summertime stream flows.

- Decreased snowpack and glacial runoff combined with increased air temperatures could change the thermal regime of the Susitna River and affect fish and aquatic invertebrates.
- Sedimentation changes could affect Project longevity and thus cost-benefit calculations for the reservoir. The rate of sedimentation is strongly tied to erosion processes, which may change as glacial ice becomes a smaller contribution to the total run-off.
- An understanding of changes in the hydrologic regime (water timing, quantity, and quality) in combination with Project operations will inform post-construction monitoring needs. This could include stream temperature measurements, assessment of fish habitat conditions under changing conditions, instream flow throughout the system to assess changes in flow contribution from tributaries, and stream temperature monitoring in the reservoir and downstream.

7.3. Resource Management Goals and Objectives

Water quality in the state is regulated by a number of state and federal regulations. This includes the federal Clean Water Act (CWA), and the State of Alaska Title 18, Chapter 70, of the Alaska Administrative Code (18 AAC 70). Aquatic resources including fish and their habitats, and wildlife resources, are generally protected by a variety of state and federal mandates. In addition, various land management agencies, local jurisdictions, and non-governmental interest groups have specific goals related to their land management responsibilities or special interests. These goals are expressed in various statutes, plans, and directives.

In addition to providing information needed to characterize the potential Project effects, these water resources studies will inform the evaluation of possible conditions for inclusion in the Project license. These studies are designed to meet FERC licensing requirements and also to be relevant to recent, ongoing, and/or planned resource management activities by other agencies.

7.4. Summary of Consultation with Agencies, Alaska Native Entities, and Other Licensing Participants

These study plans have been modified in response to comments from various agency reviewers, including NMFS, the Alaska Department of Environmental Conservation, and USFWS. Consultation on the study plan occurred during licensing participant meetings held on April 6, 2012, and during the June 14, 2012 Water Resources Technical Work Group (TWG) meeting. At the June 2012 TWG meeting, study requests and comments from the various licensing participants were presented and discussed, and refinements were determined to address agreed-upon modifications to the draft study plans.

A summary of consultations relevant to water quality resources is provided in Table 7.4-1.

Table 7.4-1. Summary of consultation on Hydrology Related Resources study plans.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
Ice Processes In the Susitna River Study (Section 7.6)					
Email to Dudley Reiser	09/12/2012	Eric Rothwell	NOAA	I have a concern with winter flow routing and ice processes, and how they will inform site selection. Site selection for analyzing winter instream flow effects to fish and their habitat will depend on an understanding of operational effects downstream (to flow timing and quantity, hydraulics, and water quality). Also the extension of the studies downstream will depend on these results. The winter hydraulic flow routing model will rely on ice process modeling to determine the downstream extent and magnitude of operational flow effects. The ice process modeling will need several years of data, in addition to the ice thickness measurements and discharge measurements at each of the cross-sections for the winter routing model. I see a lack of time to collect data for the models (winter flow routing and ice process) calibrate the models and then selection sites and methods to conduct ISF studies to assess project effects on fish during winter operations under the currently proposed study period.	See Ice Study Interdependencies (Figure 7.6-1 and 7.6-2) and Schedule (Table 7.6-1) for a description of how ice processes model input and output are scheduled. Final winter flow routing/ice model results for project conditions will not be available prior to selection of focus areas. The selection of candidate focus area sites will use prior information (80s and other), current 2012 studies and professional judgment to select sites that would be affected by changes to winter flow. Preliminary results from a steady-flow HEC-RAS model with ice cover can be used to estimate the potential for stage changes in the lower river. For instance, if the HEC-RAS model indicates that winter discharges will be higher than the natural range of variability in the Lower River, marginal habitats that would be susceptible to under-ice inundation may be selected. The proposed model development and simulation goals will continue to inform the study teams during the 2013-14 study period so that information can be used to help refine studies, as technical and scientific analysis warrants. This adaptive approach will help the concurrent studies each run in parallel, helping address both the concerns of study timeframes and adaptive approaches to modifying study designs as additional knowledge is gained.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
Email to Dudley Reiser	09/12/2012	Eric Rothwell	NOAA	• What can be determined from each of the study components, a description of deliverables (not results) this will help us understand if our requests have been met. • How will uncertainty be determined for each of the study components? (ice processes -> hydraulic flow routing -> winter fish and habitat effects)	AEA has included in the Ice RSP Section 7.6.4 description of study components and deliverables (including field data collected and model output). 7.6.4.4 describes how the ice processes model uncertainty will be assessed by comparing the results of the existing conditions model to known conditions.

7.6. Ice Processes in the Susitna River Study

7.6.1. General Description of the Proposed Study

The Ice Processes Study will further the understanding of natural ice processes in the Susitna River and provide a method to model/predict pre-Project and post-Project ice processes in the Susitna River. The study will provide a basis for impact assessment, which will inform the development of any necessary protection, mitigation, and enhancement measures. The study also will provide ice processes input data for other resource studies with winter components (e.g., fluvial geomorphology modeling, instream flow, instream flow riparian, and groundwater).

7.6.1.1. Study Goals and Objectives

The overall goal of the Ice Processes Study is to understand existing ice processes in the Susitna River and to predict post-Project ice processes. The specific objectives are as follows:

- Document the timing, progression, and physical processes of freeze-up and breakup during 2012–2014 between the Oshetna River confluence (river mile [RM] 233.4) and tidewater (RM 0), using historical data, aerial reconnaissance, stationary time-lapse cameras, and physical evidence.
- Develop a modeling approach for quantitatively assessing ice processes in the Susitna River.
- Calibrate the model based on existing conditions.
- Determine the potential effect of various Project operational scenarios on ice processes downstream of Watana Dam using modeling and analytical methods.
- Use the model to determine the extent of the open water reach downstream of Watana Dam during project operations.
- Use the model to determine the changes in timing and ice-cover progression and ice thickness and extent during project operations.
- Provide observational data of existing ice processes and modeling results of post-Project ice processes to the fisheries, instream flow, instream flow riparian, fluvial geomorphology, groundwater, recreation, and socio-economic studies.
- Summarize known effects of existing hydropower operations in cold climates.

Thermal and ice modeling for the reservoir and the general thermal modeling for the river during the 5 months when ice is not present will be accomplished under the Water Quality Modeling Studies (Section 5.6). The output from this work will be used in the river ice processes studies.

7.6.2. Existing Information and Need for Additional Information

7.6.2.1. Existing Information

Ice affects the Susitna River for approximately 7 months of the year, between October and May. When air and water temperatures drop below freezing in September and October, shelf ice grows along the banks of the river, and frazil ice begins accumulating in the water column and flowing downstream, eventually accumulating against ice bridges and solidifying into a solid cover. By January, much of the river is under a stable ice cover, with the exception of persistent open leads corresponding with warm upwelling water or turbulent, high-velocity flows. Flows generally drop slowly throughout the winter until snowmelt commences in April. During April and May, river stages rise and the ice cover weakens, eventually breaking into pieces and flushing downstream (R&M 1982b). Ice jams are recurrent events in some reaches of the river. If severe, jams can flood upstream and adjacent areas, drive ice overbank onto gravel bars and into sloughs and side channels, shear off or scar riparian vegetation, and threaten infrastructure, such as the Alaska Railroad and riverbank property (R&M 1982b).

Ice processes were documented between the mouth of the Susitna River (RM 0) and the proposed dam site (RM 184) between 1980 and 1985 (R&M 1981, 1982a, 1983, 1984, 1985). Both freeze-up and breakup progression were monitored using aerial reconnaissance. Locations of ice bridges during freeze-up and ice jams during breakup were recorded each season. One winter, a time-lapse camera was installed in Devils Canyon to observe ice processes through the narrow, turbulent rapids. Additional ice data were collected to calibrate a model. These included ice thicknesses at selected river transects, top of ice elevations, air and water temperatures at meteorological stations and Gold Creek, slush ice porosity at selected transects in the middle and lower river, and frazil density at Gold Creek.

Of particular interest was the influence of freeze-up and ice cover on salmon habitat areas. Water levels at certain sloughs in the middle river and lower river were monitored during the winter to determine whether staging during freeze-up and ice cover diverted water into side channels and sloughs (R&M 1984).

Other entities (National Weather Service, U.S. Geological Survey [USGS], and U.S. Army Corps of Engineers [USACE]) also have collected and compiled ice thickness, breakup, and freeze-up data for various locations on the river. Although these data were not collected for the purpose of understanding the potential effects of the Project, they are relevant for furthering our understanding of winter hydrology along the Susitna River.

Freeze-up and melt-out processes in the middle river (between Gold Creek and Talkeetna) were modeled using ICECAL, a numerical model developed by the USACE Cold Regions Research and Engineering Laboratory (CRREL) (Harza-Ebasco 1984). The model utilized the outputs from a temperature model developed for the river (SNTEMP) and empirical data on frazil production and ice-cover progression derived from observations. Both the Watana-only and Watana-Devils Canyon operations, as proposed in the 1980s, were modeled for a range of meteorological conditions that had been encountered, including a cold winter (1971–1972) a very warm winter (1976–1977), a warm winter (1982–1983), and an average winter (1981–1982). The results of the model included predictions of the extent of ice cover, the timing of ice cover progression, ice surface elevations, and the inundated area beneath the ice cover for selected cross-sections. The elevation of water flowing beneath the ice was compared to the elevation necessary to overtop slough berms at selected fish habitat study areas in the middle river in order to assess the impacts of project operation on winter flow in these sloughs. Empirical data on frazil production and ice cover progression was used to estimate changes in ice cover progression between tidewater and Talkeetna. Reservoir ice was simulated using DYRESM and calibrated to conditions at Eklutna Lake (Harza-Ebasco 1986).

R&M undertook a survey of ice-affected hydropower projects in other northern regions (Harza-Ebasco 1985). The results of the survey indicated that other hydroelectric projects generally relied on observations and operator experience to limit adverse effects of flow regulation on winter conditions. Ice jamming during the freeze-up and subsequent flooding of infrastructure and communities were the primary concerns.

7.6.2.2. Additional Information Needs

The need for additional information beyond what was gathered and analyzed during the 1980s is driven by three factors: (1) the new proposed configuration of the Project and project operational scenarios; (2) advances in predictive models of winter flow regimes beyond what was available in the 1980s; and (3) the need to supplement previously documented observations of natural ice processes.

The proposed Project consists of one dam that will be at a lower height and have a different configuration than the originally proposed project in the 1980s. The Pre-Application Document (PAD) describes an operational scenario that would release more water in the winter, with a potential for day-to-day fluctuations. The ICECAL model did not simulate flow fluctuations with a time period shorter than one week. The ICECAL model was largely an empirical data-driven model, rather than a dynamic predictive model, as is available today. A dynamic model will be able to simultaneously predict flow and temperature fluctuations downstream of the dam, as well as ice cover progression. Finally, the ICECAL model only simulated flows between Talkeetna and Gold Creek. There are several important fish habitat areas upstream of Gold Creek where knowledge of winter conditions is necessary to predict post-Project habitat changes.

Freeze-up and breakup processes depend on a complex suite of variables, some of which currently are outside the realm of predictive modeling, usually because the process depends on very local conditions, or sequence of events. Ice bridging locations are an example of a process that cannot currently be predicted by a model; thus, analytical methods to predict ice cover progression depend on multiple years of observations. The presence of open thermal leads are another phenomenon that is not captured by ice processes models because it depends on local hyporheic flow conditions or groundwater contributions. Additional documentation is needed to determine whether locations of these features and timing of ice cover progression are similar to conditions observed in the 1980s. In addition, in the 1980s, the location of frazil production early in the freeze-up period varied significantly between study years. An assessment is needed to determine the importance of the Susitna River upstream and downstream of the proposed dam in frazil production for a range of meteorological conditions.

7.6.3. Study Area

7.6.3.1. **Observations**

The ice processes observation study area includes the 234-mile segment of river between tidewater and the Oshetna River confluence (from RM 0 to RM 233.4). Observations of open leads, breakup progression, and freeze-up progression will be made in this area. In addition, ice thickness, top-of-ice elevations, and under-ice water stages will be surveyed in the middle river to calibrate and verify a predictive ice model.

7.6.3.2. Middle River River1D Modeling

Predictive ice, hydrodynamic, and thermal modeling using River1D is planned for the middle river between the proposed dam and the Three-Rivers Confluence near Talkeetna (from RM 184 to RM 100).

7.6.3.3. Middle River Detailed Modeling (Focus Areas)

Several focus areas determined in conjunction with the instream flow habitat and riparian studies in the middle river will receive more detailed ice modeling and observation attention. Depending on the local channel geometry, either detailed River1D or River2D models will be developed, and observations of ice cover progression, ice thickness, and open leads will be more detailed in order to calibrate these models. See the Instream Flow Study plan for criteria and potential sites.

7.6.3.4. Lower River

There are currently no accepted models for predicting dynamic ice processes on complex braided channels, such as those found in the lower Susitna River downstream of the Talkeetna; therefore, no hydrodynamic modeling is planned for the 100-mile reach between tidewater and the Talkeetna River (from RM 0 to RM 100). However, there is a need to assess the potential for change to ice cover on the lower river both for fish habitat studies and to understand the potential effects of the project on winter transportation access and recreation, which depend on ice cover on the lower Susitna River. Project effects to the lower river will be determined based on the magnitude of change seen at the downstream boundary of the River1D model, the estimated contributions of frazil ice to the lower river from the middle river from observations and modeling, and with simpler steady flow models (HEC-RAS) for short sections of interest in the lower river.

7.6.4. Study Methods

7.6.4.1. Aerial Reconnaissance

Aerial reconnaissance and global positioning system (GPS) mapping of ice features, including ice jams, ice bridges, frazil accumulations, and open leads during the breakup and freeze-up periods will be performed from tidewater to the Oshetna River confluence (from RM 0 to RM 233.4). The number of observations will vary depending on ice process conditions, but it is anticipated that approximately 10 reconnaissance trips per spring will occur during breakup and 10 reconnaissance trips per winter will occur during freeze-up in 2012, 2013, and 2014. The data collected will include locations of ice features and open leads, georeferenced photographs, and videos of ice processes. Ice processes field observation standards follow those of EM-1110-2-1612, Ice Engineering, developed by USACE (2002).

7.6.4.2. Time-Lapse Camera Monitoring

Time-lapse camera monitoring of breakup and freeze-up will be done at locations corresponding to flow routing model instrumentation, key ice processes, and fish habitat locations. Time-lapse cameras are set to take photos of the main channel or a side slough at 1-hour intervals, and the results are compiled into a video. The selection of camera locations may be refined when the final determination of focus areas is made for the Instream Flow Study. The current locations of the time-lapse cameras for 2012 are as follows:

- RM 9.5 – Near Upper Tidal Influence
- RM 25.6 – Susitna Station
- RM 59 – Rustic Wilderness Side Channel
- RM 88 – Birch Creek Slough
- RM 99 – Slough 1 (2012 breakup only)
- RM 101.5 Whiskers Slough (2012 Freeze-up)
- RM 103 – Talkeetna Station
- RM 121 – Curry Slough
- RM 129 – Slough 9
- RM 141 – Slough 21
- RM 149 – Mouth of Portage Creek
- RM 184 – Dam Site

Planned camera locations for 2013–2014 include the following:

- RM 9.5 – Near Upper Tidal Influence
- RM 25.6 – Susitna Station
- RM 101 – Whiskers Slough
- RM 112 – Slough 6A
- RM 124 – Slough 8A
- RM 135 – Slough 11
- RM 138 – Indian River
- RM 141 – Slough 21
- RM 149 – Mouth of Portage Creek
- RM 171 – MR2-wide
- RM 184 – Dam Site

Additional telemetered time-lapse cameras are located at the following sites by the Flow Transect Study:

- RM 11 – Susitna River near Flathorn Lake (ESS10)
- RM 13 – Susitna River near Dinglishna Hill (ESS15)
- RM 26 – Susitna River at Susitna Station (ESS20)
- RM 96 – Susitna River near Twister Creek (ESS30)
- RM 98 – Susitna River near Chulitna River (ESS35)
- RM 103 – Susitna River Above Whiskers Creek (ESS40)
- RM 113 – Susitna River Below Lane Creek (ESS45)
- RM 121 – Susitna River At Curry (ESS50)
- RM 149 – Susitna River Below Portage Creek (ESS55)
- RM 165 – Susitna River Near Devil Creek (ESS60)
- RM 176.5 – Susitna River Near Fog Creek (ESS65)

- RM 184 – Susitna River Below Deadman Creek (ESS70)
- RM 223 – Susitna Gage near Cantwell (now ESS80)

And by the USGS at the following stations:

- RM 137 – Susitna River at Gold Creek
- RM 84 – Susitna River at Sunshine Station

7.6.4.3. Transect Data

Winter field data will be collected at the 13 transects identified above for the flow routing model study (ESS80-ESS10). The following data will be collected in conjunction with the Flow Routing Study:

- Ice thickness
- Top of ice elevation
- Air temperature
- Water temperature
- Water stage
- Discharge
- Thickness of snow cover
- Slush-ice thickness (where applicable)
- Slush-ice porosity (where applicable)
- Frazil-ice density (when present)

7.6.4.4. **Other Field Data**

The Riparian Instream Flow Study will be collecting field data on ice interactions with floodplains and vegetation, including tree scars and floodplain disturbance by ice. These data indicate locations where ice events have been significant. The results of the Riparian Instream Flow Study will be used to delineate reaches of the river where ice processes, primarily breakup jams, have occurred in the past. The Riparian Instream Flow Study will use these data to develop a model of riparian-floodplain interactions, while the ice study will use these data to supplement historical observations of ice jams..

7.6.4.5. River Ice Processes Model Development for Existing Conditions

A River1D model will be developed and applied to the Susitna River between the proposed dam site and Talkeetna. River1D is a hydrodynamic flow routing and thermal model that also models frazil generation, ice cover progression, and decay (Hicks and Steffler 1992; Andrishak and Hicks 2005a and 2005b; She and Hicks 2006; She et al. 2009; She et al. 2012). The model has the ability to route reservoir releases downstream at small time-steps (hourly or less) and was designed to be able to predict when fluctuating flows can destabilize a winter ice cover (She et al. 2012). The model has been developed by the University of Alberta River Ice Engineering Program (Hicks 2005; Andrishak and Hicks 2005a). Updated code is due to be released to the public domain on January 1, 2013.

The Susitna River Ice Processes Model will be used to simulate time-variable flow routing, heat-flux processes, seasonal water temperature variation, frazil ice development, ice transport processes, and ice-cover growth and decay. The first step is to calibrate an open-water model using known discharge events. The second step is to simulate pre-Project ice processes to verify that the model is correctly working on the Susitna River. Inputs to the existing condition model include the following:

- River geometry from the Instream Flow Routing Study
- Discharge as measured by gages along the modeled reach
- Air temperature and solar radiation from meteorological stations
- Water temperature along the river and tributaries from the Water Quality Study
- Boundary conditions for ice-cover progression (bridging locations)

The model will be verified using ice thickness and elevation measurements at Flow Routing Transects, and observed timing of ice cover progression and decay. The accuracy of the model will be evaluated by comparing the measured values with the modeled values, and by testing the sensitivity of the model to assumed values (Manning's n), and any other input data for which values are estimated (i.e., geometry between measured cross-sections).

7.6.4.6. River Ice Processes Model Projections for Proposed Conditions

For the middle river, the calibrated River1D model will be used to model the proposed Project operational scenarios. The model will predict water temperature, ice cover formation and extent, and flow hydrograph between the proposed dam site and Talkeetna.

Additional inputs to the proposed conditions model include the following:

- Flow releases from Watana Dam provided by the Reservoir Operations Model
- Temperature of released flow provided by the Water Quality Model
- Range of meteorological conditions (warm, cold, wet, and dry winters) as developed in coordination with the Water Quality Study

7.6.4.7. Focus Areas Ice Processes Model

Up to six focus areas (0.5- to 2-mile long reaches) will be chosen for detailed modeling as part of the Instream Flow Habitat Study. Winter conditions at these sites will be modeled using either more detailed River1D models or River2D models, depending on channel geometry.

7.6.4.8. Review and Compilation of Existing Cold Regions Hydropower Project Operations and Effects

Hydropower projects in northern North America, especially Canada, and in other northern countries have operated on ice-covered rivers for many decades (National Research Council of Canada 1990). Other river systems where ice modeling has been completed include the following:

- Peace River, Canada (Andrishak and Hicks 2005b; Andrishak and Hicks 2008; Hicks and Steffler 1992; She et al. 2012)
- Athabasca River, Canada (Katopodis and Ghamry 2005)
- Ohio River, USA (Shen et al. 1991)

- St. Clair River, USA (Kolerski and Shen 2010)
- Romaine River, Canada (Thériault et al. 2010)

References to the effects of these hydropower operations on ice cover will be summarized, and, where relevant, study authors contacted to obtain additional information that may be relevant to the Susitna River. The product of this portion of the study will be a memorandum summarizing these references.

7.6.5. Consistency with Generally Accepted Scientific Practice

This study'smethodologies for data collection, analysis, modeling, field schedules, and study durations are consistent with generally accepted practice in the scientific community. The study plans were developed with the input of technical experts including USACE CRREL and the University of Alberta Ice Engineering Group.

7.6.6. Schedule

Field data will be collected as follows:

- Continuous time-lapse camera data will be collected during the breakup and freeze-up periods 2012–2014.
- Freeze-up reconnaissance observations will be conducted between October 1 and January 15, 2012, 2013, and 2014.
- Ice thickness and elevation data along transects will be collected between March 1 and April 1, 2013, and again between March 1 and April 1, 2014.
- Open lead locations will be documented at the same time that ice thickness and elevation data are collected.
- Breakup reconnaissance observations will be conducted between April 10 and May 15, 2012, 2013, and 2014.

Model development and calibration will occur continuously during 2013 and 2014 (see Table 7.6-1). Preliminary modeling runs for existing conditions will be calibrated to 2012 and 2013 conditions by the end of 2013, and proposed operations scenarios will be run primarily in 2014. AEA will issue Initial and Updated Study Reports documenting actions taken to date within 1 and 2 years, respectively, of FERC's Study Plan Determination (i.e., February 1, 2013). The interdependency of the ice studies with other studies is illustrated in Figures 7.6-1 and 7.6-2.

Table 7.6-1. Schedule for implementation of the Ice Processes Study.

Activity	2012				2013				2014				2015
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1Q
Open Lead Surveys, ice thickness and elevation	——				——				——				
Breakup Reconnaissance		——				——				——			
Freezeup Reconnaissance				——	——			——	——				
Initial Study Report									Δ				
Existing Condition 1D Model Development					——	——	——	——					
Proposed Condition 1D Model Development								——	——	——	——	——	
Intensive Site Models									——	——	——	——	
Updated Study Report											——	——	▲

Legend:

—— Planned Activity
----- Follow up activity (as needed)
Δ Initial Study Report
▲ Updated Study Report

7.6.7. Level of Effort and Cost

Below is an estimate of costs associated with field documentation and model development in 2013–2014, which are the major components of the ice study.

7.6.7.1. Costs of Field Observation Effort

The 2013–2014 field components include the following, and are anticipated to roughly total about $1.1M (including helicopter hours):

- Ice thickness and elevation measurements
- Open lead reconnaissance, mapping, and video processing
- Breakup reconnaissance, mapping, and video processing
- Time-lapse camera setup, maintenance, and processing
- Freeze-up reconnaissance, mapping, and video processing

The 2013–2014 modeling components include the following, and are anticipated to roughly total about $750,000:

- Geometric and meteorological data compilation and input
- Open-water flow routing model development and calibration
- Existing condition ice-covered model development and calibration
- Intensive study site geometry input
- Existing condition intensive study site model development
- Proposed condition hydrologic and meteorological data compilation and input
- Project alternative River1D model development
- Project alternative focus study area model development

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7.6.9. Figures

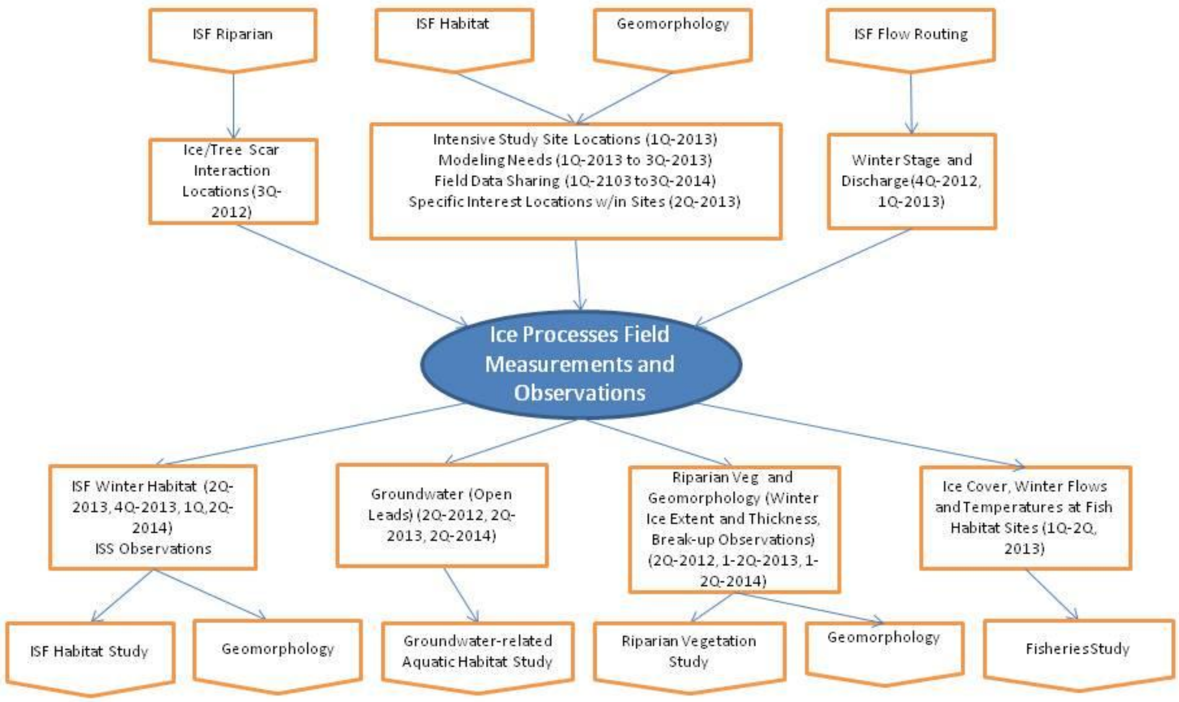

Figure 7.6-1. Relationship of ice observations to other studies

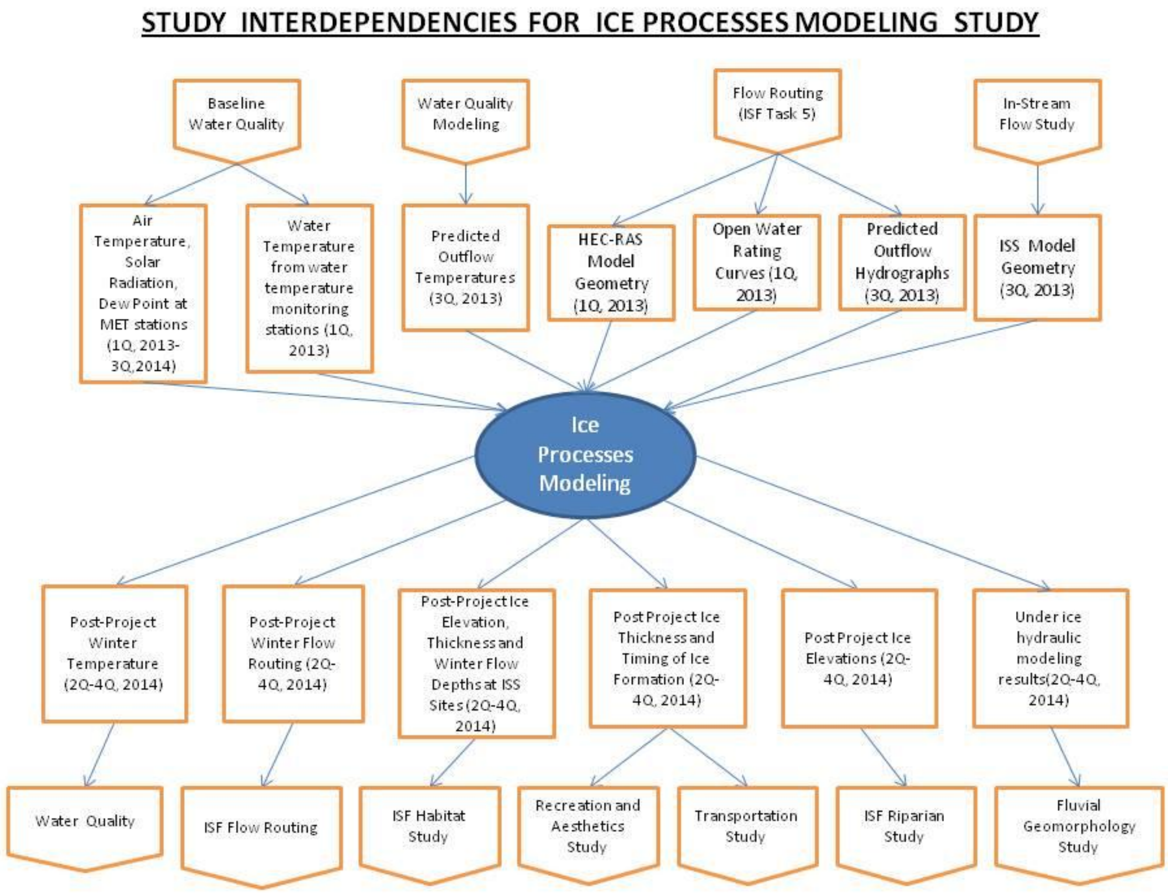

Figure 7.6-2. Relationship of ice modeling to other studies.