

## **APPENDIX 5-1**

# **CHAKACHAMNA LAKE HYDROELECTRIC PROJECT STUDY PLANNING APPROACH**

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## CHAKACHAMNA LAKE HYDROELECTRIC PROJECT STUDY PLANNING APPROACH

### 1 PREFACE

The overall study program for the Chakachamna Project consists of 1) engineering and operations studies and 2) environmental studies. The purpose of this appendix is to present an approach to those studies that are environmental in nature and will therefore be part of the Phase 1 and Phase 2 Proposed Study Plans (PSPs) as part of the formal licensing process described in Sections 2 and 5 of this PAD. TDX developed this appendix in response to stakeholder requests for a vision for how the overall study program will be approached and how key questions will be framed and answered. The following sections present the conceptual framework for study planning; outlines the study components and objectives for each of the 43 studies identified to date; and describes in general terms the timeframe TDX is anticipating for the completion of the study and for answering the identified Key questions

#### 1.1. Introduction

The proposed Chakachamna Hydroelectric Project (“Project”) is a major development, potentially affecting the environment within a large, remote area containing two complex watersheds. As such, the study requirements are likewise complex. The ultimate goal of an environmental study program is to collect adequate information so that the licensing and permitting processes can proceed to a conclusion, regardless of what that conclusion might be. When developing a new project, time and financial resources are always limited to some extent; consequently, it is important that study efforts emphasize the collection of information that specifically informs the licensing process and minimizes the expenditure of effort on studies that do not inform the process.

The purpose of the engineering and operations studies is to arrive at fully optimized project layout, to develop an adequate cost estimate, and to properly evaluate the feasibility of the project. The ensuing further project management and design activities will then be able to address adequately various aspects of project development such as; stakeholder’s requirements, environmental regulations, hazardous issues mitigation, and overall project risk management.

The Project is somewhat unique in that there is little resource information currently available for the project area. It is desirable for studies to be carefully designed to answer specific overarching impact-related questions that could affect project design, operation, or overall viability. However, for some resource considerations, especially in relation to fish and aquatic habitat values, it is difficult to know which questions to ask without an adequate knowledge of the resource base. Additionally, there has been debate in recent years among the Alaskan resource agencies regarding appropriate study emphasis when assessing large development projects and making permit decisions. Some agencies feel strongly that a careful description, including the use of statistically supportable quantifications, of the existing environment (baseline condition) is most important so that existing conditions can be compared with future conditions and, thus, allow an assessment of post-project effects. Other agencies are of the

opinion that it may be more important to place emphasis on addressing specific impact issues and answering questions that have a direct bearing on project viability, design, and mitigation needs. In actuality, all resource information adds to the baseline data base. The important consideration then becomes one of balancing the study program to address issues and, at the same time, collect sufficient quantitative baseline information to satisfy stakeholders.

## 1.2. Overarching Issues and Related Questions

Stakeholder outreach and input from project scientists has resulted in a long list of potential impact issues that will need to be addressed during the licensing process as presented in Section 5 of the Pre-Application Document (PAD). Some issues are relatively routine and common to most large Alaskan development projects. Other issues are specific to the Project and highly significant in the sense that they may affect Project viability, Project design, and/or Project operations. TDX has identified 43 discreet study titles that attempt to respond to the identified impact issues and related questions. The most important study programs are those that specifically address the questions raised by these overarching issues. The following list is not comprehensive, but describes the most important questions by impact category and itemizes those that must be answered to gain a full understanding of the issue, determine specific project impacts, and/or design mitigation measures to minimize potential impacts.

- **Issues Associated with potential impacts to aquatic resources within Chakachamna and Kenibuna Lakes and Lake Tributaries resulting from reservoir management and outflow of water into the power tunnel**
  - Will salmon spawners be able to enter Chakachamna Lake and points beyond?
  - Will salmon spawners be able to reach spawning areas in lake tributary streams?
  - Will salmon and lake trout eggs incubating in lakeshore spawning areas be affected by lake draw-down?
  - Will juvenile salmon rearing in Chakachamna Lake be able to outmigrate into the Chakachatna River?
  - Will fish be entrained into the power inlet?
  - Will habitats for rearing salmon and resident fish be harmed by the changing conditions?
  
- **Issues associated with transfer of water from the Chakachatna River into the McArthur River**
  - Will fish habitat (spawning, rearing, over wintering) be maintained in the presence of reduced flow and altered water quality in the mainstem of the Chakachatna River and increased flow in the mainstem of the McArthur River
  - Will fish habitat (spawning, rearing, over wintering) be maintained in the presence of reduced or increased surface and/or groundwater flow in side channels, sloughs, wetlands, and tributaries to the rivers
  - Will spawning salmon be attracted to the tailrace discharge rather than to their normal spawning areas

- Will transfer of water change the nature of wetland habitats within and adjacent to the Trading Bay State Game Refuge with consequent effects on the plants and animals supported by the refuge

### 1.3. Study Approaches

The basic approach in designing an overall study program for the Project has been to first look at the most important questions and determine the kinds of information that will be needed to address the questions. In some cases, additional baseline resource information is needed to assess the existence or significance of an issue. For example, it is currently unknown whether sockeye salmon spawn along the Chakachamna Lake shoreline in significant number. Consequently, one task is to determine whether and to what extent spawning occurs. If spawning occurs, then extended information gathering will target the depth and timing of spawning which can be related to proposed reservoir operating characteristics to assess the likelihood of impact of draw-down on incubating eggs. On the other hand, it is known that substantial numbers of juvenile sockeye salmon outmigrate from Chakachamna Lake to the ocean each year. Consequently, studies can target the timing and duration of outmigration which is of particular interest relative to planning for the provision of downstream passage for juvenile fish. At the same time, it may be appropriate to include an aspect of juvenile salmon study that also incorporates the establishment of a quantitative measure of smolt outmigration as a convenient measure of lake productivity. This kind of approach balances the collection of baseline information with targeted studies directed toward addressing issues.

Some complex sets of impacts require special multidisciplinary studies to integrate resource information and assist in the prediction of impacts or optimization of mitigation. The proposed Aquatic Habitat Modeling/Instream Flow study program is one such specialized study with multidisciplinary applications. A proposed 3-dimensional fluid dynamics study of Chakachamna Lake is another such study intended to help address numerous lake issues. In planning for the Proposed Study Plan (PSP), TDX will endeavor to make the inter-relationship between studies and key questions or issue areas apparent.

## 2 PROPOSED STUDIES AND THEIR COMPONENTS

Attached below is a matrix which itemizes all of the study programs that are currently proposed, describes basic study components, describes the issues and/or questions that they address, and indicates a proposed general timeline for each study. The matrix list is intended to be fairly complete, but, it is expected that some changes will occur in response to stakeholder suggestion and as detailed study plans are reviewed during the licensing process. The timelines reflect the phased study planning approach with the selected Phase 1 (PSP-1) studies beginning in 2010 and, in some cases, continuing in future years. Phase 2 (PSP-2) studies will be primarily be conducted during the 2011-2013 period with some monitoring studies continuing beyond 2013. As with any large study program, the initial studies inform the later studies, and study plans will evolve as required by the needs of the project.

### 3 STUDY APPROACHES TO SELECTED ISSUE CATEGORIES

In order to further illustrate the reasoning that has gone into the study planning process, three important issue areas have been selected for more detailed discussion. These discussions provide some indication of the complexity of impact issues and the kinds of inter-related multidisciplinary study programs that will be needed to completely address the issues.

#### 3.1. Chakachamna Lake Aquatic Resource Issues

The changes that might occur to Chakachamna Lake resulting from the proposed Project appear to be straight forward, consisting of increased lake level fluctuations, a new deep water outlet for water at the power intake, and an additional outlet structure to replace the Chakachamna Stream channel when water levels are low. However, the effects of these changes on lake physical characteristics and fish resources that depend on the lake are potentially complex and, in some cases, subtle. A list of general impact questions is presented below:

- Issues Related to Increased Lake Level Fluctuations
  - Will fish access to lake tributary spawning streams be blocked?
  - Will lakeshore spawning by lake trout and salmon be affected?
  - Will lake rearing habitats be adversely affected?
- Issues Related to Blockage of Upstream Fish Passage into Chakachamna Lake
  - Will adult sockeye salmon be prevented from reaching the lake or lake tributaries?
  - Will resident fish species be prevented from entering the lake?
- Issues Related to Interference with Downstream Fish Passage (Out Of Chakachamna Lake)
  - Will juvenile sockeye salmon be able to freely outmigrate from Chakachamna Lake?
  - Will resident fish species be able to move downstream into the Chakachamna River?
- Issues Related to the Presence of the Power Intake Structure
  - Will fish of any species be entrained into the intake and forced through the power generating equipment?
  - Will juvenile salmon be falsely attracted to the intake rather than the fish passage outlet structure?
  - Will the presence of the deep water outlet affect the physical characteristics (limnology) of Chakachamna Lake in such a way that fish resources are affected?

The above list is probably not complete and some of the issues could be further subdivided. Figure A5.1-1 displays the above list, indicates the kinds of studies that have been proposed to answer these questions, and shows the complex interactions between studies and issues. The kinds of information required to answer any one of the questions is variable and, often, multidisciplinary. For example, getting at the question of whether fish might be blocked from

entering tributaries during low lake levels requires a sequence of information acquisition that might look like the following:

- Determine from operations models the likely seasonal post-project lake level regime
- Examine lakeshore topography at tributary outlets – determine stream gradients at stream mouths at varying lake levels – determine whether gradients might prevent fish from stream entry
- Investigate the life history of anadromous and resident fish species – determine which species and/or life history stages would likely need to gain entry to the stream during periods when lake levels are sufficiently low to block access
- Estimate impacts to fish populations and/or plan mitigation measures

Another set of potential impacts relates to changes in the physical characteristics of Chakachamna Lake, some of which may be subtle. For example, water temperatures; wind driven currents and mixing; and volume and turbidity of input streams all contribute to the formation of moving layers of water of different densities and turbidities within Chakachamna Lake. Distribution of fish food organisms and, consequently, distribution of pelagic juvenile sockeye salmon is likely related to the distribution of water layers (supported by evidence from the APA study program). The vulnerability of juvenile salmon to entrainment in the power intake and/or false attraction to the intake during outmigration is related to their depth distribution and seasonal proximity to the intake structure. The sequence of information required to assess impacts to juvenile salmon resulting from the intake structure might look like the following:

- Collect basic seasonal limnological data to determine key physical characteristics of the Chakachamna Lake water mass (temperature and turbidity profiles, currents, water quality)
- Determine seasonal depth and areal distribution of juvenile salmon
- Determine timing and behavior of outmigrating salmon smolts
- Construct 3-dimensional fluid dynamics model to indicate lake water mass conditions at various times of the year
- Predict locations of salmon and vulnerability to entrainment at various times of the year
- Predict location of salmon during the outmigration period and likelihood of false attraction

### **3.2. Chakachatna and McArthur River Aquatic Resource Issues**

Water departing Chakachamna Lake via the power tunnel will be removed from the Chakachatna River system and transferred to the upper McArthur River. At the same time, some water will be allowed to flow out of Chakachamna Lake into the Chakachatna River, either via the natural channel of the river at high lake levels or diverted into the Chakachatna River via a bypass structure to allow maintenance of instream flow when lake levels are low. The end result is that mean annual flow will be greatly reduced in the Chakachatna River and greatly increased in the McArthur River. Aquatic habitats will be significantly altered, but the overall changes to habitat

value to the various species and life stages are complex. A list of general impact questions is presented below:

- **Issues related to flow reduction in the Chakachatna River**
  - Will changes to flow adversely affect fish habitat in the mainstem of the river
  - Will changes to flow adversely affect fish habitat in side channels, sloughs, and clear tributaries
  - Will changes to flow affect groundwater input to critical habitats
  - Will changes to flow adversely affect fish habitat in Noaukta Slough
  - Will changes to flow cause long term changes to stream geomorphology that might affect fish resources
  - Will changes in flow strand fish
- **Issues related to flow increase in the McArthur River**
  - Will changes to flow adversely affect fish habitat in the mainstem of the river
  - Will changes to flow adversely affect fish habitat in side channels, sloughs, and clear tributaries
  - Will changes to flow affect groundwater input to critical habitats
  - Will changes to flow cause long term changes to stream geomorphology that might affect fish resources
  - Will changes to flow adversely affect wetland and intertidal fish habitats
  - Will changes in flow strand fish
- **Issues related to changes in water temperature and water quality**
  - Will water transfer cause changes to water temperature regimes within various habitat areas
  - Will temperature alterations affect salmon spawning success
  - Will temperature alterations affect the timing and success for rainbow trout spawning
- **Issues related to tailrace outflow**
  - Will sockeye salmon en route to Chakachamna Lake be falsely attracted to the tailrace outflow
  - Will Chakachatna River salmon be falsely attracted to the tailrace outflow
  - What might be the consequences of false attraction
  - Will the outflow conditions create nitrogen gas saturation and consequent harm to fish

The above list is probably not complete and some of the issues could be further subdivided. Figure A5.1-2 displays the above list, indicates the kinds of studies that have been proposed to answer these questions, and shows the complex interactions between studies and issues. Analysis of impacts to aquatic habitats requires a multidisciplinary approach to determine how the stream areas might be physically changed under different flow regimes. Then the data need to be combined with information regarding fish abundance, seasonal habitat utilization, and habitat requirements. One of the challenges of this analysis is presented by the wide variety of habitats in the study area and the presence of special habitat types, like side channels and clear tributaries, that likely account for a disproportionate amount of the highest value habitat. The planned Aquatic Habitat Modeling and Instream Flow study program is the most important study

tool that will be utilized to provide the link between altered stream physical characteristics and fish habitat values. Instream flow studies also provide the ability to predict habitat values at varying flows so that design flow regimes can be optimized and/or negotiated to achieve best results for stakeholders.

As an example of the complex issues involved, one of the specific questions relates to possible impacts of reduced flow on side channel spawning and rearing habitats that are known to depend in part on groundwater input. The sequence of information required to assess these kinds of impacts might look like the following:

- Determine source of groundwater to area
- Determine link (if any) between surface water volume and volume of groundwater in upwelling areas
- Model changes in surface area, depth, and upwelling that might occur under altered river flows
- Determine fish distribution, abundance, and habitat requirements relative to the specific area
- Model the changes in surface areas of suitable habitats for key species and life stages that might occur under a range of flow conditions
- Optimize selected flow regime to retain habitat values

### **3.3. Low-elevation Wetland Issues**

It has been evident from the beginning of discussions about Project area environmental resources, that one of the key resource impact concerns was how changes in Project area hydrology would affect downstream/downgradient wetlands. This concern has been reiterated in comments from agencies and stakeholders.

Wetlands and riparian areas are the main features of the low-elevation landscape between the mountains and Cook Inlet. The importance of some of these areas that lie adjacent to Trading Bay on Cook Inlet has been recognized by the creation of the Trading Bay State Game Refuge. Therefore, one focus of our study program has been developing a suite of studies that would provide information to allow us to evaluate accurately the potential impacts of Project operations on these low-elevation wetlands and the resource values that they provide.

Despite recognition of the importance of wetlands in the Project area there is little or no baseline information available on many biotic and abiotic wetland habitat factors. Because much information on environmental factors in the Project area is either non-existent or old, a number of the studies planned are for the purpose of gathering basic baseline data on Project area conditions.

The ecology of the low-elevation wetlands and riparian areas is supported by the interrelationships of numerous biotic and abiotic factors. A group of sub-issues has evolved from consideration of these interrelationships:

- The contribution of water to the wetlands and associated clear water tributaries from the Chakachatna River and Noaukta Slough
- The influence of the McArthur River
- The amount and source of surface and sub-surface flow into the wetlands
- The effect of natural variability of channel migration of the Chakachamna River and distributaries
- The effects of climate
- The effect and extent of upstream glacial melt
- The effects of volcanic ash on soils
- The types of vegetation within the area of low-elevation wetlands and riparian areas
- The species of birds that breed, stage, or are resident in the wetlands
- The species of wildlife that are either residents or seasonal inhabitants of the wetlands
- The dependence of fish on special habitats provided by off-channel wetland areas.
- The interdependence of stream flow and fish habitat value on wetland function.
- The various types of wetlands and their functions

Figure A5.1-3 displays the above list, indicates the kinds of studies that have been proposed to answer these questions, and shows the complex interactions between studies and issues. In addition to the list above, there are also potential secondary effects on subsistence and cultural resources, recreation use, and the aesthetic/visual resources values of the wetlands.

The need to attempt to describe some of these interrelationships has driven the choice of studies. The interdisciplinary group of studies that will provide information to apply to wetlands issues questions includes surface and near surface hydrology; stream sediment transport and geomorphology; instream flow modeling; climatology/meteorology; glaciology and geological processes; various fish and aquatic habitat investigations; ash-derived hydric soils; vegetation mapping and classification; wetlands mapping and functional assessment; surveys for raptors, waterbirds/waterfowl, shorebirds, and passerines/songbirds; and wildlife surveys and habitat use mapping.

### CHAKACHAMNA STUDY MATRIX

Chakachamna Hydroelectric Project Study Matrix

Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
<i>Geology Soils and Climate</i>					
Glaciology and Geological Processes	1	Utilize imagery historical records, and selected field investigation to: <ul style="list-style-type: none"> <li>Examine recent glacial and erosional processes within the Project area and predict range of conditions that might be expected during the life of the project</li> <li>Examine potential interaction between long term climatic change, glaciology, and total and seasonal water availability for hydropower generation</li> <li>Examine geological conditions in relation to stability of lake shores and stream channels .</li> </ul>	Will provide information needed to assess: <ul style="list-style-type: none"> <li>Hazard assessment of glacier damming of the Nagishlamina River Valley and potential for outburst floods that influence conditions at the outlet from Chakachamna Lake</li> <li>Potential changes in the mass balance of the Glaciers and resulting influence on the hydrologic balance of the lake-river system.</li> <li>Potential for flooding of the Chakachatna River Valley as a result of the melting of glacier ice on Mt. Spurr during an eruption and potential impacts on Project facilities</li> <li>Hazards associated with accelerating the retreat of Barrier Glacier due to the flow of hot volcanic debris onto the glacier.</li> <li>Potential changes to hydrologic regimes that could affect project engineering and operations.</li> <li>Potential Impacts to Chakachamna Lake fish resources that could be affected by changes in seasonal water availability, possibly affecting fish passage and productivity</li> </ul>	2011 – 2012	1, 2, 7, 9, 10, 14
Lake Shoreline Topography and Erosional Processes	2	Utilize information from Project imagery, bathymetric study, and selected field investigations to: <ul style="list-style-type: none"> <li>Investigate soil composition and erodibility at selected sensitive locations.</li> </ul>	Will provide information needed to assess: <ul style="list-style-type: none"> <li>Fish passage into lake tributary streams that may be blocked by steep shoreline topography during low lake levels</li> <li>Possible down-cutting of fluvial fan at outlet of</li> </ul>	2011	1, 8, 9, 10

Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
		<ul style="list-style-type: none"> <li>Integrate topography, soil characteristics, and operations modeling to predict erosion at sensitive sites</li> </ul>	Chilligan River and other tributaries <ul style="list-style-type: none"> <li>Potential for down-cutting of the channel connecting Chakachamna and Kenibuna Lakes and probability of lake level variation in Kenibuna Lake</li> <li>Potential for impact to fish resources in Lake Clark National Park. Especially applies to possible fluctuations in Kenibuna Lake levels as they might affect lake and tributary stream productivity and access to fish.</li> <li>Potential impacts to shoreline spawning areas</li> </ul>		
Sediment Transport and Geomorphology	3	Utilize information from Project imagery (LIDAR topography map), bathymetry and field investigations to: <ul style="list-style-type: none"> <li>Investigate stream hydraulics and material movement potential within the Chakachatna and McArthur Rivers.</li> <li>Model potential stream changes resulting from flow variations.</li> </ul>	Will provide information needed for: <ul style="list-style-type: none"> <li>Input to instream flow model.</li> <li>Assessment of impact on wetland, intertidal, and off channel fish habitats.</li> <li>Assessment of Impact on stream morphology and channel maintenance, especially in the intertidal wetland area.</li> <li>Assessment of need for flood flow mitigation</li> </ul>	2011-2012	2, 3, 5, 8, 9, 10
Meteorology/Climatology	4	Installation of several weather stations and collection of temperature and precipitation data at various locations throughout study area	Will provide essential climate information that is needed for hydrologic and engineering analyses.	Min. 2011 – 2016 Possible extension depending on needs	1, 2, 3, 14, 15
<i>Water Resources</i>					
Chakachamna Lake Bathymetry	5	Measure and chart the topography of the Chakachamna and Kenibuna Lake basins and fish bearing streams inlets to the lake between elevation 1142 to 1130 ft using sonar equipment and bathymetric software	Will provide information essential to analyze the following resource issues: <ul style="list-style-type: none"> <li>Accessibility of Chakachamna and Kenibuna Lake tributary streams to sockeye salmon and other species from Chakachamna Lake when water levels are low</li> <li>Possible down-cutting of channel between Kenibuna and Chakachamna lakes and subsequent lowering of Kenibuna Lake levels</li> <li>Flooding of spawning and incubation habitats in</li> </ul>	2010	1, 6, 7, 8, 9, 10

Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
			<p>lower reaches of Chakachamna Lake tributary streams when lake water level is high</p> <ul style="list-style-type: none"> <li>• Loss of spawning and incubation habitat value for lake spawning sockeye salmon and lake trout in Chakachamna Lake due to lake level fluctuation</li> <li>• Loss of sockeye salmon rearing habitat value in Chakachamna Lake due to fluctuating water levels, including effects of fluctuations on fish food organisms</li> <li>• Protection of fish resources in Lake Clark National Park Especially applies to possible fluctuations in Kenibuna Lake levels as they might affect lake and tributary stream productivity and access to fish</li> <li>• Changes in vegetation in littoral, riparian, and wetland habitats around the shores of Chakachamna Lake due to fluctuation in the water surface elevation of the lake</li> <li>• Potential for loss of, or increase in, shoreline habitats used by wildlife species due to lake level fluctuations; resulting effects on wildlife populations</li> <li>• Provide essential input to fluid dynamics modeling study</li> <li>• Provide data for studying fish passage facilities</li> </ul>		
Chakachamna Lake Fluid Dynamics Modeling	6	<p>Multidisciplinary study program that:</p> <ul style="list-style-type: none"> <li>• Integrates information from bathymetry, hydrology and limnology studies to define water inputs, lake currents, temperature, turbidity and water chemistry.</li> <li>• Constructs a 3-D fluid dynamics model of the seasonal behavior of lake water movements and related physical characteristics of water masses</li> <li>• Integrates model output with information regarding fish distribution, seasonal presence, etc.</li> </ul>	<p>Will provide input to several resource issues:</p> <ul style="list-style-type: none"> <li>• Relationship between lake processes, fish distribution, and fish movements as related to potential for entrainment of fish at the power inlet</li> <li>• Relationship between lake processes and migratory movements of outmigrating sockeye salmon as related to orientation to the outlet fish passage structure</li> <li>• Relationship between lake processes and lake productivity under pre- and post-project conditions</li> <li>• Assessment of alteration to lake currents and water quality caused by the power intake and/or downstream fish passage/water release structure</li> </ul>	2011 - 2012	1, 6, 7, 8, 9, 10, 16

Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
Chakachamna Lake Limnology	7	Collect basic limnological data to include: <ul style="list-style-type: none"> <li>• Water chemistry</li> <li>• Seasonal Temperature and turbidity profiles</li> <li>• Seasonal Lake current profiles and water density layers</li> <li>• Zooplankton and productivity profiles</li> <li>• Model seasonal conditions and integrate with fish distribution and fluid dynamics model</li> </ul>	Provides essential information required for: <ul style="list-style-type: none"> <li>• Fluid dynamics modeling</li> <li>• Downstream water temperature modeling</li> <li>• Assessing lake productivity</li> <li>• Assessing reasons for fish distribution patterns</li> <li>• Predicting behavior of fish relative to depth and season</li> <li>• Assessment of vulnerability to entrainment at power intake</li> <li>• Assess dissolved oxygen levels in the lake with depth and season</li> </ul>	Data collection 2010 – 2012  Model construction 2012/2013 Possible post-construction monitoring of selected parameters	1, 4, 6, 8, 9, 10, 15, 16
Stream Water Quality and Productivity Monitoring	8	Collect water samples from selected locations on the Chakachamna and McArthur rivers, including gage sites, to <ul style="list-style-type: none"> <li>• Establish a record of seasonal fluctuations in surface water chemistry, suspended solids, and productivity</li> <li>• Sample basic water quality parameters and nutrients</li> <li>• Sample chlorophyll-a</li> </ul>	Provides information required to understand impacts on water constituents of transferring water from Chakachamna Lake to the McArthur River drainage and impacts on aquatic habitat quality.	Baseline sampling 2011 – 2013  Post-construction monitoring	2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 15, 16
Integrated Surface and Groundwater Hydrology	9	Installation of continuously-recording stream gages and monitoring wells in selected locations throughout the study area to: <ul style="list-style-type: none"> <li>• Establish a record of both short-term and seasonal fluctuations in surface water flows and levels and water temperature</li> <li>• Establish a record of both short-term and seasonal fluctuations in groundwater elevations to determine flow paths throughout the study area</li> <li>• Investigate how much water is draining off hill slopes adjacent to river systems downstream of Chakachamna Lake</li> <li>• Construct a model of area-wide water</li> </ul>	Will provide essential hydrologic information needed by analyses in several resource areas including: <ul style="list-style-type: none"> <li>• Aquatic habitat and instream flow modeling</li> <li>• Stream geomorphology</li> <li>• Wetland classification and function</li> <li>• Fish spawning distribution</li> <li>• Fish rearing and wintering areas</li> </ul>	Surface water gages 2010 - 2015  Groundwater instruments 2010-2012 Model construction 2012 – 2013 Possible post-construction monitoring at selected stations	1, 2, 3, 4, 5, 7, 8, 9, 10, 15

Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
		movements to provide insight into flow distribution between Chakachatna River and Noaukta Slough, downstream distributaries of the river, and adjacent wetland complexes.			
<b>Fisheries and Aquatic Resources</b>					
Chakachamna Lake Juvenile Sockeye Salmon	10	Investigate the abundance, distribution, and life history of rearing sockeye salmon in Chakachamna and Kenibuna Lakes: <ul style="list-style-type: none"> <li>• Bioacoustic monitoring to determine distribution, abundance, and seasonal movement patterns</li> <li>• Outmigration monitoring to determine timing and behavior of outmigrating smolts</li> <li>• Integration with limnology and fluid dynamics studies to determine interactions of juvenile salmon with lake physical characteristics and model seasonal behavior</li> </ul>	Provide baseline data on Project area fish resources and provide insight into issues as follows: <ul style="list-style-type: none"> <li>• Assist in assessment of downstream fish passage impacts and design of fish passage facilities</li> <li>• Assist in the assessment of entrainment impacts and design of intake structures</li> <li>• Assist in the assessment of salmon rearing conditions as related to changing lake levels</li> <li>• Develop standard methods for estimating or indexing outmigrating smolt numbers that can be used in future studies to evaluate project-induced changes</li> </ul>	2010 - 2012	1, 6, 7, 8, 9, 10
Chakachamna Lake Sockeye Salmon Abundance, distribution, and Run Timing	11	Monitor passage of adult sockeye salmon into Chakachamna Lake using a sonar counter: <ul style="list-style-type: none"> <li>• Determine timing of migration</li> <li>• Determine number of salmon entering Chakachamna Lake</li> <li>• Integrate with system-wide salmon distribution study to determine overall proportion of sockeye salmon using the lake systems</li> <li>• Integrate with system-wide study to help determine distribution of spawning fish within lake and tributaries</li> </ul>	Provide baseline data on Project area fish resources and provide insight into issues as follows: <ul style="list-style-type: none"> <li>• Determine number of salmon potentially at risk from upstream Project impacts</li> <li>• Assist in assessment of upstream fish passage impacts and design of fish passage facilities</li> <li>• Assist in the formulation of operating regimes that optimize reservoir fill timing as it might relate to upstream fish passage</li> <li>• Assist in the assessment of drawdown impacts to shoreline spawning</li> </ul>	2010 - 2012	1, 7, 8, 9, 10
Lake Trout Abundance, distribution, and Life History in Chakachamna Lake	12	Use a variety of methods to determine lake trout abundance, distribution, and life history: <ul style="list-style-type: none"> <li>• Estimate population size (if possible)</li> </ul>	Provide baseline data on Project area fish resources and provide insight into issues as follows: <ul style="list-style-type: none"> <li>• Determine size of population potentially at risk from lake alterations</li> </ul>	2011 - 2013	1, 4, 6, 8, 9, 10

Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
		<ul style="list-style-type: none"> <li>• Determine age and growth characteristics</li> <li>• Determine seasonal distribution within lake</li> <li>• Determine location, depth, and timing of spawning within Chakachamna Lake</li> <li>• Integrate with limnology and fluid dynamics studies to model lake trout seasonal behavior as it relates to lake physical characteristics</li> </ul>	<ul style="list-style-type: none"> <li>• Determine vulnerability of lakeshore spawning areas to lake drawdown</li> <li>• Assess potential ecological impacts to lake trout from lake alterations</li> <li>• Assess vulnerability of lake trout to entrainment into the power intake</li> </ul>		
System-wide Resident and Rearing Fish Distribution and Abundance	13	<p>Use a variety of methods to survey the distribution and abundance of resident and rearing fish within the whole study area:</p> <ul style="list-style-type: none"> <li>• Expand on 1980's reconnaissance to characterize fish use of the project area</li> <li>• Develop standard techniques to estimate fish density within selected representative study sites including protected non-game species</li> <li>• Determine seasonal use patterns</li> <li>• Classify area-wide stream habitat values; identify sensitive areas, and special use areas</li> <li>• Determine habitat preferences and fish use data</li> </ul>	<p>Provide baseline data on Project area fish resources and provide insight into issues as follows:</p> <ul style="list-style-type: none"> <li>• Establish quantitative baseline reference areas</li> <li>• Identify sensitive habitats and seasonal use patterns for special consideration in impact analysis</li> <li>• Identify sensitive habitats and seasonal use patterns for special consideration in habitat modeling and instream flow studies</li> <li>• Provide habitat suitability information for input to instream flow analyses</li> </ul>	<p>Primary effort 2011 – 2013</p> <p>Selected sample sites 2013-2016</p>	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
System-wide Salmon Spawning Distribution	14	<p>Determine system-wide distribution of adult salmon using a combination of fish wheel capture, radio-tracking, and aerial surveys:</p> <ul style="list-style-type: none"> <li>• Estimate relative numbers of various salmon species entering the Chakachamna and McArthur River systems</li> <li>• Determine migration timing</li> <li>• Identify primary spawning areas for all salmon species</li> <li>• Integrate with Chakachamna Lake salmon studies to estimate total numbers</li> </ul>	<p>Provide baseline data on Project area fish resources and provide insight into issues as follows:</p> <ul style="list-style-type: none"> <li>• Determine size and species composition of salmon populations potentially at risk from Project impacts</li> <li>• Identify sensitive spawning habitats for special consideration in impact analysis</li> <li>• Identify spawning areas and seasonal use patterns for input to habitat modeling and instream flow analyses</li> </ul>	2010 -2012	1, 2, 3, 4, 5, 7, 8, 9, 10

Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
		of sockeye salmon using project area <ul style="list-style-type: none"> <li>Determine proportions of total salmon spawning in various Project area locations</li> </ul>			
Fish Passage Structure Design Evaluation	15	Integrate fish study information, engineering design and specifications, lake fluid dynamics modeling, operations model, available literature, and other relevant information to assess the suitability and probable success of proposed fish passage structures	Will provide input to environmental assessment and provide a framework for evaluating fish passage alternatives and optimizing design	Literature review 2011  Completion of analysis 2012 - 2013	1, 6, 7, 8, 9, 10
Tailrace Attraction Risk Assessment	16	Integrate information from salmon distribution study, water quality study, hydrology study, instream flow study, experience from other projects, and other relevant information to provide an initial assessment of the risk of tailrace attraction. If needed, provide a study plan for post-project monitoring of tailrace attraction.	<ul style="list-style-type: none"> <li>Will provide input to overall environmental assessment</li> <li>Provide insight into possible mitigation measures</li> <li>Provide insight into the need for post-project monitoring</li> </ul>	2012-2013  Post-construction monitoring TBD	3, 4, 5, 8, 10
Entrainment Risk Assessment	17	Integrate information from Chakachamna Lake juvenile salmon study, lake trout study, intake engineering design criteria, lake fluid dynamics model, and other relevant information to assess risk of entrainment of fish into the Project intake structure	<ul style="list-style-type: none"> <li>Will provide input to environmental assessment</li> <li>Will assess the level of risk to fish species</li> <li>Will provide a framework for optimizing intake design to minimize fish entrainment</li> </ul>	2012	1, 4, 6, 8, 9, 10
Nitrogen Saturation/Total Dissolved Gas Risk Assessment	18	Integrate information from fish studies, engineering design criteria, and the physics of water/gas interactions to assess the risk of impact to fish in the zone below the tailrace discharge	<ul style="list-style-type: none"> <li>Will provide input to environmental assessment</li> <li>Will assess the level of risk to fish species</li> <li>Will provide a framework for optimizing design of tailrace discharge structure to minimize fish impacts</li> </ul>	2012	5, 8, 9, 10
Stream Macroinvertebrates	19	Sample benthic macroinvertebrate populations at selected locations in the Chakachamna and McArthur river drainages to <ul style="list-style-type: none"> <li>Describe baseline population characteristics (e.g. taxa and density)</li> <li>Describe temporal and spatial variability</li> </ul>	Provide baseline benthic macroinvertebrate data for use in evaluating aquatic habitats and stream productivity.	2011 – 2013  Post Construction Monitoring: TBD	2, 3, 4, 5, 15

Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
		Employ variety of sampling methods to gather quantitative and qualitative information.			
Aquatic Habitat Modeling and Instream Flow	20	Multidisciplinary study program that will utilize various methods to model stream physical characteristics, combine with fish habitat suitability criteria, and predict aquatic habitat values under various flow regimes. Process involves: <ul style="list-style-type: none"> <li>• Stream classification/selection of appropriate model</li> <li>• Field measurements at selected representative locations</li> <li>• Collection of fish habitat suitability information for selected species and life stages</li> <li>• Data processing using specialized software</li> <li>• Model output</li> </ul>	Primarily an impact analysis tool that will: <ul style="list-style-type: none"> <li>• Create an index of baseline habitat conditions</li> <li>• Provide predictions of relative habitat values for selected key species and life stages under various flow regimes</li> <li>• Provide a framework for optimizing and/or negotiating post-project instream flow needs</li> <li>• Provide insight into fish passage barriers related to minimum flows</li> <li>• Provide insight into other potential mitigation needs that may be appropriate such as flushing flows, maintenance of off-channel habitats, etc.</li> </ul>	Field measurements 2011 – 2012  Data analysis 2013	2, 3, 4, 5, 8, 9, 10
Intertidal and Sub-tidal Habitat Survey	21	Study need will be determined by design and operating decisions. If no new marine structures, then a study may not be needed. If new structures, then surveys will be designed as appropriate to assess habitat value and organism presence.	Will provide baseline data on biological characteristics of proposed port sites and will: <ul style="list-style-type: none"> <li>• Assist in environmental assessment</li> <li>• Provide input to design process regarding sensitive habitats and inform mitigation planning</li> </ul>	2012	8, 9, 10, 12
Ramping Rate Study	22	Analysis that will integrate the engineering aspects of flow transition duration and timing with the Aquatic Habitat Modeling and Instream Flow Study	Provide a framework for optimizing ramping rates and duration that will minimize impact to aquatic resources from scheduled changes in instream flows	2013	2, 3, 4, 5, 8, 9, 10
<b>Terrestrial Resources</b>					
Raptor Survey	23	Survey appropriate selected habitats in Project area for presence of raptors to <ul style="list-style-type: none"> <li>• Determine nesting sites of bald eagles, peregrine falcons, northern goshawks, others</li> <li>• Determine distribution and habitat use in Project area</li> </ul>	Provide baseline data on raptor use of Project area habitats and to avoid disturbance (especially during nesting) and mitigate impacts.	2010 – 2011  Pre-construction nesting surveys: 2015, and every year	2, 3, 7, 8, 11, 13, 17

Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
				of construction activity	
Shorebird Survey	24	Survey appropriate selected habitats in Project area for presence of shorebirds to <ul style="list-style-type: none"> <li>• Determine spring/fall staging areas</li> <li>• Determine Project area migration flight paths</li> <li>• Determine distribution and habitat use (e.g. nesting)</li> </ul>	Provide baseline data on shorebird use of Project area habitats – especially migration staging and nesting – to avoid disturbance, understand Project impacts (e.g. nesting on Chakachamna Lake shoreline), aid Project planning, and mitigate impacts.	2011– 2012  Post-construction monitoring	1, 2, 3, 8, 11, 12, 13, 17
Passerine/Songbird Survey	25	Survey representative habitats in Project area for presence of passerines to determine distribution and habitat use.	Provide baseline data on passerine use of Project area habitats to avoid disturbance, understand Project impacts (e.g. construction in habitats with breeding birds), aid Project planning, and mitigate impacts.	2011– 2012	1, 2, 3, 8, 11, 13, 17
Waterfowl/Waterbird Survey	26	Survey appropriate selected habitats in Project area for presence of waterfowl/waterbirds to <ul style="list-style-type: none"> <li>• Determine spring/fall staging areas</li> <li>• Determine Project area migration flight paths</li> <li>• Determine distribution and habitat use (e.g. nesting)</li> </ul>	Provide baseline data on waterfowl/waterbird use of Project area habitats – especially migration staging and nesting – to avoid disturbance, understand Project impacts (e.g. trumpeter swan breeding), aid Project planning, and mitigate impacts.	2011– 2012  Post-construction monitoring	1, 2, 3, 8, 11, 12, 13, 17
Chakachamna Lake Breeding Waterbird Survey	27	Survey Chakachamna Lake shoreline for breeding waterbirds to <ul style="list-style-type: none"> <li>• Determine presence, distribution, and timing of breeding waterbirds on Chakachamna Lake</li> </ul>	Provide baseline data on the presence of breeding waterbirds on Chakachamna Lake to avoid disturbance and understand the impacts of increased lake level fluctuation due to Project operations on breeding habitats.	2011– 2012  Post-construction monitoring	1, 17
Noxious Weeds/Invasive Plant Species Survey	28	Survey appropriate selected habitats in Project area for plants classified as noxious weeds or invasive species.	Provide baseline data on presence of noxious weeds and invasive species in the Project area to aid in plans to avoid their spread due to Project construction or operations.	2011– 2012  Post-construction monitoring	11, 12, 13, 17
Rare, Threatened, and Endangered Plant Species Survey	29	Survey appropriate selected habitats in Project area for plants classified as rare, threatened or endangered.	Provide baseline data on presence of rare, threatened or endangered plant species in the Project area to aid in plans to protect their populations from Project impacts.	2011– 2012  Post-	1, 2, 3, 11, 12, 13, 17

Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
				construction monitoring: If a rare species identified in an impact area	
Vegetation Mapping and Classification	30	Map and classify vegetation in the Project area using <ul style="list-style-type: none"> <li>• Orthorectified aerial photography</li> <li>• Project topographic basemapping and geo-referenced imaging</li> <li>• Sampling vegetation plots at representative locations throughout the Project area</li> <li>• Classification based on Vierek, et al. 1992.</li> </ul>	Provide baseline data on Project area vegetation communities for use in describing habitats (e.g. riparian areas), understanding potential Project impacts, Project planning, and developing impact mitigation. <ul style="list-style-type: none"> <li>• Will be used in wildlife habitat use mapping</li> <li>• Will be used in evaluation of impacts to Chakachamna and McArthur river riparian areas</li> <li>• Will be used in forestry study</li> </ul>	2011– 2012  Post-construction monitoring	1, 2, 3, 8, 9, 11, 12, 13, 17
Wetlands Mapping and Functional Assessment	31	Map Project area wetlands and describe their functions using <ul style="list-style-type: none"> <li>• Study of ash-derived soils to describe hydric soil indicators for the Project area (linked to integrated hydrology study)</li> <li>• Orthorectified aerial photography</li> <li>• Project topographic basemapping and geo-referenced imaging</li> <li>• Sampling representative wetland locations throughout the Project area</li> </ul>	Provide baseline data on Project area wetlands for use in describing habitats and their functions, understanding potential Project impacts, Project planning, and developing impact mitigation. <ul style="list-style-type: none"> <li>• Will be used in wildlife habitat use mapping</li> <li>• Will be used in integrated hydrologic study</li> </ul>	Hydric Soils Indicators Study - 2010  2011– 2012  Post-construction monitoring	1, 2, 3, 8, 9, 11, 12, 13, 15, 17
Wildlife Survey and Habitat Use Mapping	32	Survey wildlife in the Project area using <ul style="list-style-type: none"> <li>• On the ground surveys at representative vegetation plots at locations throughout the Project area</li> <li>• Aerial surveys of bear denning locations</li> <li>• Aerial surveys of moose rutting locations</li> <li>• Aerial surveys of winter use</li> <li>• Orthorectified aerial photography</li> <li>• Project topographic basemapping and geo-referenced imaging</li> </ul>	Provide baseline data on Project area wildlife and use of vegetation communities/habitats (e.g. riparian areas), to aid in understanding potential Project impacts, Project planning, and developing impact mitigation.	2011– 2012  Post-construction monitoring (e.g. bear denning)	1, 2, 3, 6, 7, 8, 9, 11, 12, 13, 17

Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
Forestry	33	Study of commercially valuable timber species in the Project area using <ul style="list-style-type: none"> <li>• Orthorectified aerial photography</li> <li>• Project topographic basemapping and geo-referenced imaging</li> <li>• Vegetation mapping results</li> <li>• Consultations with the Tyonek Native Corporation (has logged in the Project area in the past) and the State Forestry Dept.</li> </ul>	Provide information on Project area timber lands and their use, to aid in understanding potential Project impacts, Project planning, and developing impact mitigation.	2011– 2012	2, 3, 11, 13
<b>Cultural Resources</b>					
Subsistence and Cultural Use and Traditional Cultural Properties	34	Determination of subsistence and traditional cultural use of Project area through <ul style="list-style-type: none"> <li>• Section 106 consultation and consultation with SHPO</li> <li>• Interviews with local Dena'ina</li> <li>• Vegetation mapping</li> <li>• Wildlife habitat use mapping</li> <li>• Fish distribution and abundance studies</li> </ul>	Identify and describe subsistence use and areas with traditional/cultural significance within the Project area to aid in understanding potential Project impacts, Project planning, and developing impact mitigation.	2011– 2012  Post-construction monitoring	1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13
Historical and Archaeological Resources Survey	35	Identification of historical and archaeological sites through consultation and field surveys <ul style="list-style-type: none"> <li>• Section 106 consultation, consultation with SHPO</li> <li>• Development (through consultation) of the Area of Potential Effect (APE)</li> <li>• Field survey of the APE</li> <li>• Determination of eligibility for listing of sites identified</li> </ul>	Identify and describe historical and archaeological resources within the Project area to aid in understanding potential Project impacts, Project planning, and developing impact mitigation.	2011– 2012  Determination of eligibility (as needed) 2013  Post-construction monitoring (e.g. ensure protection of listed sites)	1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13
<b>Recreation Resources</b>					
Recreational Use		Assessment of current recreational use of	Describe recreational use of the Project area to aid in		1, 2, 3, 6, 7, 9,

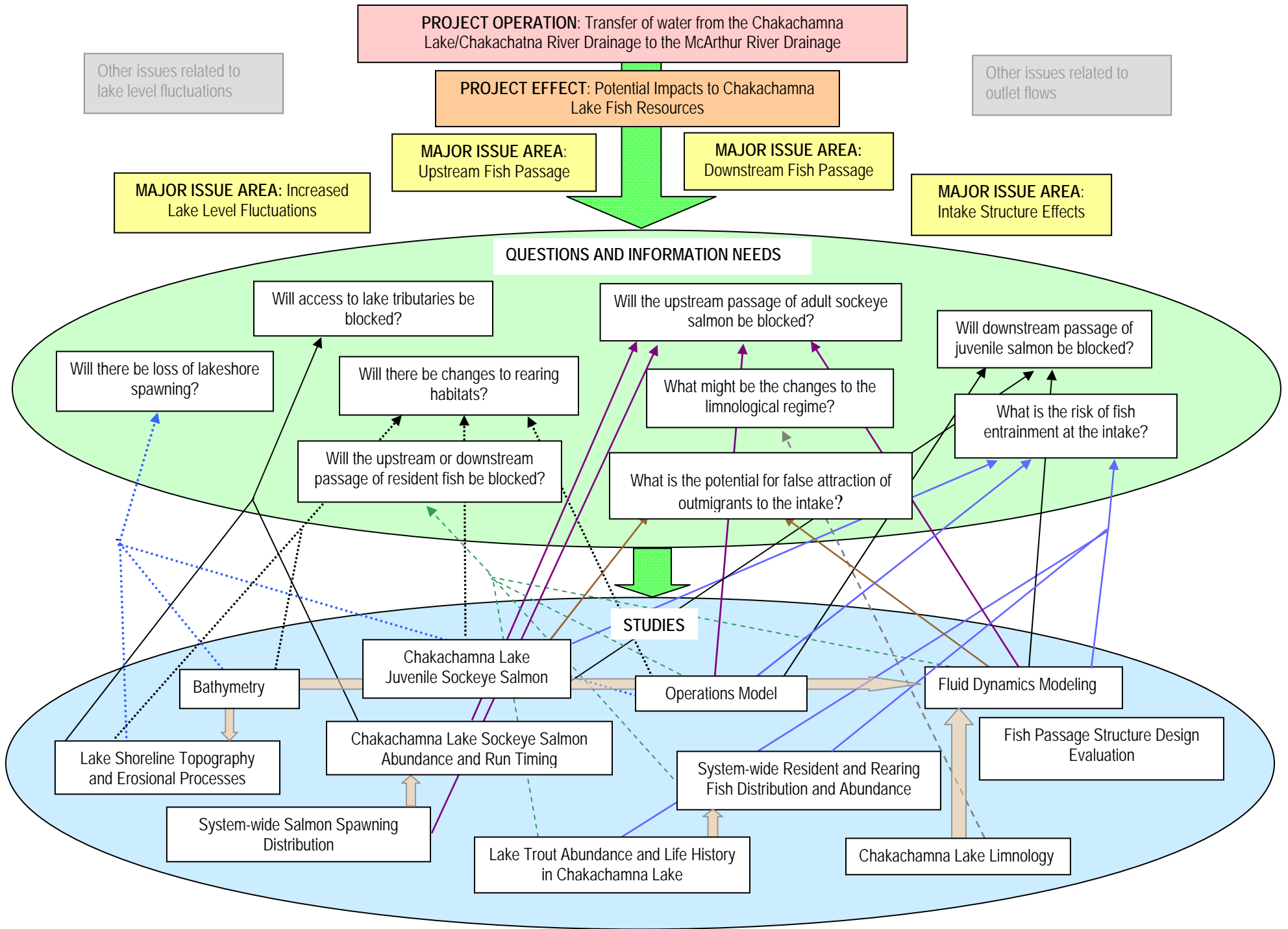
Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
Assessment	36	Project area by <ul style="list-style-type: none"> <li>• Consultation with area land management agencies (e.g. Lake Clark National Park)</li> <li>• Interviews with recreationists</li> <li>• Tracking state hunting records</li> </ul> Recreation Needs Assessment	understanding potential Project impacts, Project planning, and developing impact mitigation.  Development of Recreation Resources Management Plan	2011– 2012  Post-construction monitoring (e.g. may be required to limit access)	10,11, 12, 13
Land use	37	Site investigations to include: <ul style="list-style-type: none"> <li>• Right-of-ways, land rights and project boundary optimization and delineation</li> <li>• Land ownership and status analysis</li> <li>• Land management analysis and consistency with land management plans</li> </ul>	Provide the information required for impact assessment and mitigation for Exhibit E resources.  Define project boundary to meet Exhibit G requirements and assure all rights can be obtained to operate the project.	2011 - 2012	11, 13, 18
<i>Visual and Aesthetic Resources</i>					
Aesthetic/Visual Resources	38	Assess the current aesthetic and visual resources of the Project area through field surveys and interviews with area users.	Describe the aesthetic/visual resources of the Project area to aid in understanding potential Project impacts, Project planning, and developing impact mitigation.	2011– 2012	1, 2, 3, 5, 11, 12, 13
<i>Socioeconomic Resources</i>					
Socioeconomics Survey [TBD]	39	[SM- take shot at outlining goals/objectives of socioeconomics study]			
<i>Engineering and Operations</i>					
Hazards Assessment	40	Investigates the potential for geologic and climatic hazards: <ul style="list-style-type: none"> <li>• Volcanic activity</li> <li>• Glacial movement</li> <li>• Seismic activity</li> <li>• Flooding</li> <li>• Glacial outbreak floods</li> </ul>	Will provide the information required to assess the probability of unlikely events that could create significant hazards for the Project: <ul style="list-style-type: none"> <li>• Potential for flooding of the Chakachatna River Valley as a result of the melting of glacier ice on Mt. Spurr during an eruption and potential impacts on Project facilities</li> <li>• Hazards associated with accelerating the retreat of Barrier Glacier due to the flow of hot volcanic debris onto the glacier.</li> <li>• Hazards associated with advance of Barrier glacier on the proposed weir structure</li> </ul>	2012	Could relate to all issues depending on hazard event

Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
			<ul style="list-style-type: none"> <li>Possible earthquake effects from local fault movement, soil liquifaction, etc</li> </ul>		
Construction Methods Impacts Study/Best Management Practices	41	Update project cost and construction schedule, assess potential construction impacts and develop best management practices: <ul style="list-style-type: none"> <li>Clearing and spoil handling procedures</li> <li>Erosion control</li> <li>Water quality control</li> </ul>	<ul style="list-style-type: none"> <li>Obtain updated project cost information to support project planning</li> </ul> Establishment of standard construction practices to minimize development impacts from all Project facilities.	2012-2013	11, 12, 13
Reservoir Operations Model a. Power Study Modeling b. Ramping Rate Analysis	42	Create a model that simulates operational water regimes including seasonal and inter-annual ranges: <ul style="list-style-type: none"> <li>Seasonal lake levels including potential annual variation</li> <li>Seasonal Chakachatna River outflow</li> <li>Seasonal instream flow releases</li> <li>Seasonal powerhouse discharge</li> <li>Statistical evaluation of potential for water conditions to occur outside of normal operating ranges</li> <li>Effects of Ramping up/down on flow/ water level of McArthur River</li> </ul>	Establishes conditions under which Project impacts will be assessed: <ul style="list-style-type: none"> <li>Conditions relating to upstream migration of salmon into Chakachamna Lake</li> <li>Conditions relating to downstream passage of juvenile salmon out of Chakachamna Lake</li> <li>Conditions relating to seasonal draw down and potential impacts to fish spawning, lake productivity, wildlife use of shore zone, etc.</li> <li>Conditions relating to seasonal flows in the Chakachatna and McArthur Rivers</li> <li>Potential for unusual events that might affect fish passage or maintenance of downstream fish habitats</li> </ul>	2011	1, 2, 3, 5, 6, 7, 8, 9, 10, 18
Geotechnical Study a. Hydropower Facilities b. Fish Passage Facilities	43	Utilize Satellite images and LiDar topography map and other existing data to: <ul style="list-style-type: none"> <li>Prepare for surface mapping</li> <li>Prepare field investigation plan within the main project facilities and structures.</li> <li>Supervise field works and laboratory tests</li> <li>Interpretation and reporting of the field investigation results</li> <li>Assess engineering implication of studies done in item 1 (Glaciology and others Geological Processes and Hazards)</li> </ul>	Will provide information needed to <ul style="list-style-type: none"> <li>design the general lay-out arrangement of the project</li> </ul> Assess the hazards associated with the construction work	2011-2012	

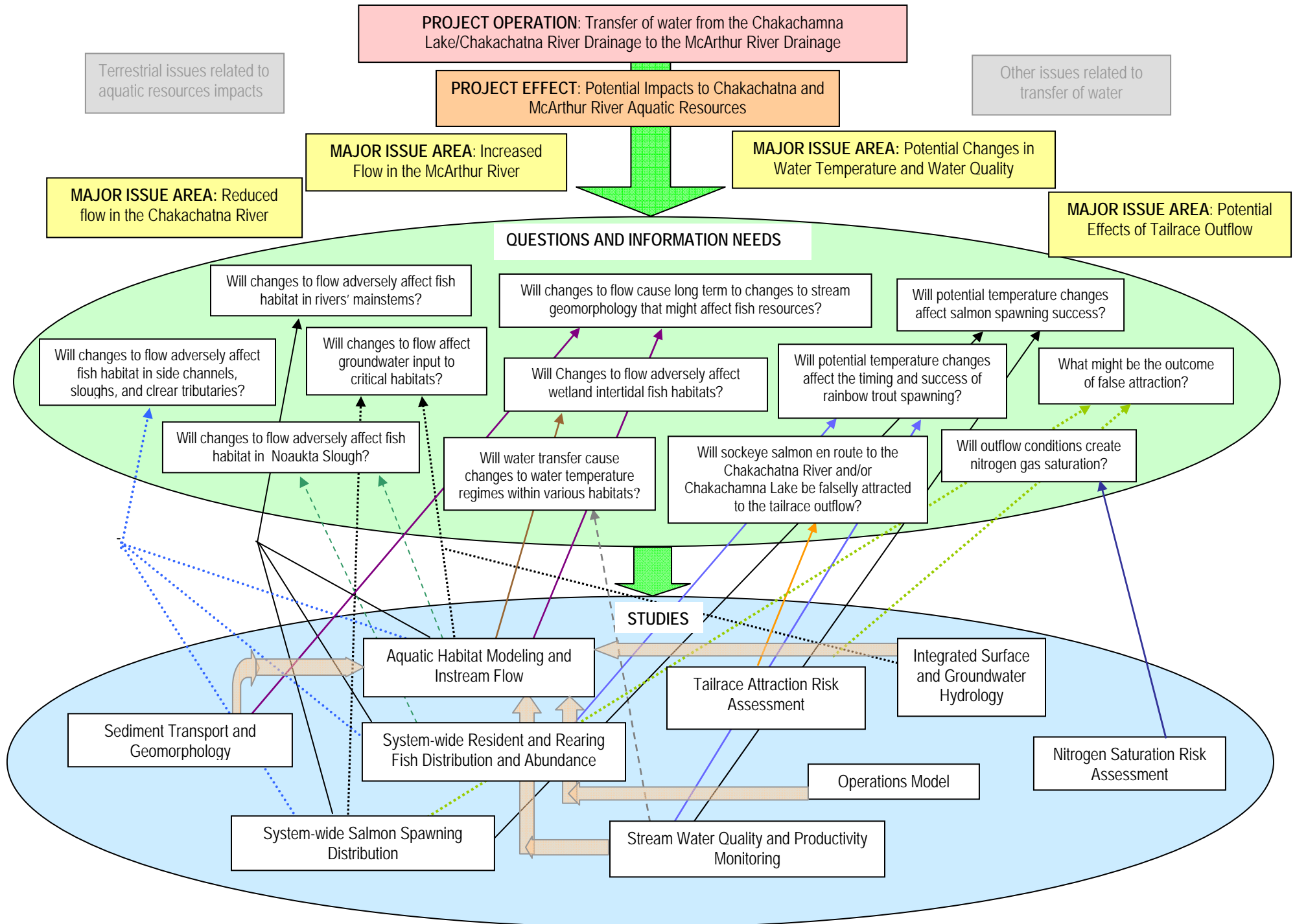
Study Title	No.	Study Components	Objectives/Resource Area Applications	Timeline	Potential Impact Type Addressed
		<ul style="list-style-type: none"> <li>• Determine geotechnical parameters.</li> <li>• Define parameters for TBM Design.</li> </ul>			
Project Site Topography and Bathymetry and topography	44	Develop digital mapping for the project site for engineering purposes. Note that this will be done in conjunction with identified needs of resource studies, but it is expected that there will be unique needs/specifications for engineering		2010	

## FIGURES

**Figure A5.1-1. Chakachamna Lake Aquatic Resource Issues. Diagram of impact issues important questions, and studies needed for issue resolution.**



**Figure A5.1-2. Chakachatna and McArthur River aquatic resource issues. Diagram of impact issues important questions, and studies needed for issue resolution.**



**Figure A5.1-3. Downstream wetland resource issues. Diagram of impact issues important questions, and studies needed for issue resolution.**

