Susitna-Watana Hydroelectric Project Document
ARLIS Uniform Cover Page

Title: Susitna River ice processes study report	**SuWa 40**
Author(s) – Personal:	
Author(s) – Corporate: HDR Alaska, Inc.	
AEA-identified category, if specified: 2012 Environmental Studies	
AEA-identified series, if specified:	
Series (ARLIS-assigned report number): Susitna-Watana Hydroelectric Project document number 40	**Existing numbers on document:**
Published by: [Anchorage, Alaska : Alaska Energy Authority, 2013]	**Date published:** March 2013
Published for: Prepared for Alaska Energy Authority	**Date or date range of report:**
Volume and/or Part numbers:	**Final or Draft status, as indicated:**
Document type:	**Pagination:** x, 82, [1], 21 p.
Related work(s):	**Pages added/changed by ARLIS:**
Notes:	

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Susitna River Ice Processes Study Report

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

HDR Alaska, Inc.

March 2013

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
Active floodplain	The flat valley floor constructed by a river during lateral channel migration and deposition of sediment under current climate conditions.
ADF&G	Alaska Department of Fish and Game
AEA	Alaska Energy Authority
AEIDC	Arctic Environmental Information and Data Center
Anadromous	Fishes that migrate as juveniles from freshwater to saltwater and then return as adults to spawn in freshwater.
Anchor ice	Submerged ice attached or anchored to the bottom, irrespective of the nature of its formation. Often accumulates as frazil slush in open reaches.
APA	Alaska Power Authority
Backwater	Off-channel habitat characterization feature found along channel margins and generally within the influence of the active main channel with no independent source of inflow. Water is not clear.
Bank	The sloping land bordering a stream channel that forms the usual boundaries of a channel. The bank has a steeper slope than the bottom of the channel and is usually steeper than the land surrounding the channel.
Baseline	Baseline (or Environmental Baseline): the environmental conditions that are the starting point for analyzing the impacts of a proposed licensing action (such as approval of a license application) and any alternative.
Border ice	Ice sheet in the form of a long border attached to the bank or shore; shore ice.
Boulder	Substrate particles greater than 12 inches in diameter. Larger than cobble.
Brash ice	Accumulations of floating ice made up of fragments not more than about 2 meters (6 feet) across; the wreckage of other forms of ice.
Break-up	Disintegration of ice cover.
Break-up jam	Ice jam that occurs as a result of the accumulation of broken ice pieces.
Break-up period	Period of disintegration of an ice cover.
Calibration	In the context of hydrologic modeling, calibration is the process of adjusting input variables to minimize the error between predicted and observed water surface elevations or other hydrologic parameters.
Cfs	cubic feet per second
Channel	A natural or artificial watercourse that continuously or intermittently contains water, with definite bed and banks that confine all but overbank stream flows.
Cobble	Substrate particles between 3 and 12 inches in diameter. Larger than gravel and smaller than boulder.
Confluence	The junction of two or more rivers or streams.
Cross-section	A plane across a river or stream channel perpendicular to the direction of water flow.
CRREL	U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.
Datum	A geometric plane of known or arbitrary elevation used as a point of reference to determine the elevation, or change of elevation, of another plane (see gage datum).
Degree-day	Also termed freezing degree-day, a measure of the departure of the mean daily temperature below a given standard, usually 0°C (32°F).
Depth	Water depth at the measuring point (station).
Devils Canyon	Located at approximately Susitna River Mile (RM) 150-161, Devils Canyon contains four sets of turbulent rapids rated collectively as Class VI. This feature is a partial

Abbreviation	Definition
	fish barrier because of high water velocity.
Discharge	The rate of stream flow or the volume of water flowing at a location within a specified time interval.
Duration of ice cover	The time from freeze-up to break-up of an ice cover.
et al.	"*et alia*"; and the rest
FERC	Federal Energy Regulatory Commission
Flood	Any flow that exceeds the bankfull capacity of a stream or channel and flows out on the floodplain.
Floodplain	1. The area along waterways that is subject to periodic inundation by out-of-bank flows. 2. The area adjoining a water body that becomes inundated during periods of over-bank flooding and that is given rigorous legal definition in regulatory programs. 3. Land beyond a stream channel that forms the perimeter for the maximum probability flood. 4. A relatively flat strip of land bordering a stream that is formed by sediment deposition. 5. A deposit of alluvium that covers a valley flat from lateral erosion of meandering streams and rivers.
Frazil	Fine spicules, plates, or discoids of ice suspended in water. In rivers and lakes it is formed in supercooled, turbulent waters.
Frazil pan	A circular agglomerate of loosely packed frazil that floats.
Freeze-up jam	Ice jam formed as frazil ice accumulates and thickens during the freeze-up period.
Freeze-up period	Period of initial formation of an ice cover.
Ft	feet
Gaging station	A specific site on a stream where systematic observations of stream flow or other hydrologic data are obtained.
Geomorphology	The scientific study of landforms and the processes that shape them.
GIS	Geographic Information System. An integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes.
GPS	global positioning system. A system of radio-emitting and -receiving satellites used for determining positions on the earth.
Gradient	The rate of change of any characteristic, expressed per unit of length (see Slope). May also apply to longitudinal succession of biological communities.
Gravel	Substrate particles between 0.1 and 3.0 inches in size, larger than sand and smaller than cobble.
Grounded ice	Ice that has run aground or is in contact with the ground underneath it.
Groundwater (GW)	In the broadest sense, all subsurface water; more commonly that part of the subsurface water in the saturated zone.
Habitat	The environment in which the fish live, including everything that surrounds and affects its life, e.g. water quality, bottom, vegetation, associated species (including food supplies). The locality, site and particular type of local environment occupied by an organism.
Hummocked ice	Ice piled haphazardly, one piece over another, to form an uneven surface.
Ice bridge	A continuous ice cover of limited size extending from shore to shore like a bridge.
Ice concentration	The ratio (in eighths or tenths) of the water surface actually covered by ice to the total area of surface, both ice-covered and ice-free, at a specific location or over a defined area.
Ice cover	A significant expanse of ice of any form on the surface of a body of water.
Ice floe	Free-floating piece of ice greater than about 1 meter (3 feet) in extent.

Abbreviation	Definition
Ice jam	A stationary accumulation of fragmented ice or frazil that restricts or blocks a stream channel.
Ice run	Flow of ice in a river. An ice run may be light or heavy, and may consist of frazil or broken sheet ice.
Ice-free	No floating ice present.
In	Inch
Instream flow	The rate of flow in a river or stream channel at any time of year.
Intergravel	Intergravel refers to the subsurface environment within the riverbed.
Leading edge of ice cover	The upstream extent of a continuous ice cover that is progressing upstream via juxtaposition (accumulation) of frazil ice pans.
Lower segment Susitna	The Susitna River from Cook Inlet (RM 0) to the confluence of the Chulitna River at RM 98.
Main channel	For habitat classification system: a single dominant main channel. Also, the primary downstream segment of a river, as contrasted to its tributaries.
Mainstem	Mainstem refers to the primary river corridor, as contrasted to its tributaries. Mainstem habitats include the main channel, split main channels, side channels, tributary mouths, and off-channel habitats.
Middle segment Susitna	The Susitna River from the confluence of the Chulitna River at RM 98 to the proposed Watana Dam Site at RM 184.
ºF	degrees Fahrenheit
NRCS	National Resources Conservation Services
Off-channel	Those bodies of water adjacent to the main channel that have surface water connections to the main river at some discharge levels.
Off-channel habitat	Habitat within those bodies of water adjacent to the main channel that have surface water connections to the main river at some discharge levels.
Open lead	Elongated opening in the ice cover caused by water current (velocity lead) or warm water (thermal lead).
Overbank flow	Flow that exceeds the level of a river's banks and extends into the floodplain. Also overflow.
Period of record	The length of time for which data for an environmental variable has been collected on a regular and continuous basis.
Porosity	The ratio of the volume of voids in ice, rock or soil to the total volume.
Project	Susitna-Watana Hydroelectric Project
Q	Hydrological abbreviation for discharge, usually presented as cfs (cubic feet per second) or cms (cubic meters per second). Flow (discharge at a cross-section).
Rapid	Swift, turbulent flow including small chutes and some hydraulic jumps swirling around boulders. Exposed substrate composed of individual boulders, boulder clusters, and partial bars. Lower gradient and less dense concentration of boulders and white water than Cascade. Moderate gradient; usually 2.0-4.0% slope.
Reservoir	A body of water, either natural or artificial, that is used to manipulate flow or store water for future use.
Riffle	A fast water habitat with turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. Generally broad, uniform cross-section. Low gradient; usually 0.5-2.0% slope.
Riparian	Pertaining to anything connected with or adjacent to the bank of a stream or other body of water.
Riparian vegetation	Vegetation that is dependent upon an excess of moisture during a portion of the growing season on a site that is perceptively more moist than the surrounding area.
River	A large stream that serves as the natural drainage channel for a relatively large

Abbreviation	Definition
	catchment or drainage basin.
River mile	The distance of a point on a river measured in miles from the river's mouth along the low-water channel.
RM	River Mile(s) referencing those of the 1980s APA Project. These were the distance of a point on a river measured in miles from the river's mouth along the low-water channel.
Sediment	Solid material, both mineral and organic, that is in suspension in the current or deposited on the streambed.
Sediment transport	The movement of solid particles (sediment), typically due to a combination of the force of gravity acting on the sediment, and/or the movement of the fluid in which the sediment is entrained.
Side channel	Lateral channel with an axis of flow roughly parallel to the mainstem, which is fed by water from the mainstem; a braid of a river with flow appreciably lower than the main channel. Side channel habitat may exist either in well-defined secondary (overflow) channels, or in poorly-defined watercourses flowing through partially submerged gravel bars and islands along the margins of the mainstem.
Side slough	Off-channel habitat characterization of an Overflow channel contained in the floodplain, but disconnected from the main channel. Has clear water,
Slough	A widely used term for wetland environment in a channel or series of shallow lakes where water is stagnant or may flow slowly on a seasonal basis. Also known as a stream distributary or anabranch.
Slush ice	An agglomerate of loosely packed frazil floating on the water surface or adhered to the bed or underside of the ice cover.
Stage	The distance of the water surface in a river above a known datum.
Stage-discharge relationship	The relation between the water-surface elevation, termed stage (gage height), and the volume of water flowing in a channel per unit time.
Staging	Increase in water levels upstream of the leading edge of ice cover caused by the partial blockage of the channel by ice.
Supercooled water	Water with a temperature slightly below the freezing point (0°C or 32°F).
Thalweg	A continuous line that defines the deepest channel of a watercourse.
Thermal break-up	Melting in place. Also called in situ break-up.
Thermal ice	Solid ice formed in place in low-velocity areas.
Three Rivers Confluence	The confluence of the Susitna, Chulitna, and Talkeetna rivers at Susitna River Mile (RM) 98.5 represents the downstream end of the Middle River and the upstream end of the Upper River.
Tributary	A stream feeding, joining, or flowing into a larger stream (at any point along its course or into a lake). Synonyms: feeder stream, side stream.
Upper segment Susitna	The Susitna River upstream of the proposed Watana Dam Site at RM 184.
Upwelling	The movement of groundwater into rivers, stream, sloughs and other surface water features. This is also called groundwater discharge and may be associated with a gaining reach of a river or stream.
USGS	DOI, Geological Survey
Watana Dam	The dam proposed by the Susitna-Watana Hydroelectric project. The approximately 750-foot-high Watana Dam (as measured from sound bedrock) would be located at river mile (RM) 184 on the Susitna River. The dam would block the upstream passage of Chinook salmon, possibly other salmon species, and resident fish that migrate through and otherwise use the proposed Watana Dam site and upstream habitat in the Susitna River and tributaries.
Water slope	Change in water surface elevation per unit distance.

Abbreviation	Definition
Water stage	The water surface elevation above the bottom of the river channel or above some arbitrary datum.

SUMMARY

The purpose of the 2012 Ice Processes Study was to document baseline winter ice conditions on the Susitna River between Cook Inlet and the Oshetna River confluence near river mile (RM) 234. The specific information sought included the location of open leads in the ice cover in late winter, the progression of breakup, including the locations and effects of ice jams, the progression of freeze-up, and the interaction between river ice processes and riparian vegetation and fish habitat. This baseline data will help identify the river reaches most likely to experience changes in river ice formation as a result of Project construction and operation.

The following data were collected in 2012:

- Open leads were mapped between Cook Inlet and RM 234.
- The progression of breakup was documented using aerial reconnaissance, aerial videos, and stationary time-lapse cameras.
- Meteorological data were compiled.
- Post-breakup reconnaissance documented interactions between ice, vegetation, and sediment.
- The progression of freeze-up was documented using aerial reconnaissance, videos, stationary time-lapse cameras, and pressure transducers.

The documentation of breakup and freeze-up will be used to supplement ice observations from the 1980s to further our understanding of the natural timing and duration of ice cover on the Susitna River. This will provide a baseline against which to evaluate the potential effects of the Project. The 2012 season also provided an opportunity to view an unusually slow and mild breakup, and unusually high flows during freeze-up. The map of open leads will be used by the Instream Flow and Groundwater studies to identify upwelling habitats and areas of potential surface/groundwater interaction. Observations of ice interactions with riparian vegetation and fish habitat areas (especially side sloughs) will be used by Riparian and Instream Flow Habitat studies to define the effects of freeze-up, ice cover, and breakup on riparian and aquatic resources.

Many open leads documented in 2012 were also documented in the 1980s, indicating that upwelling habitats are likely to be in largely the same areas. Breakup in 2012 was mild, with few large ice jams. The largest jams occurred in the Middle River. There were three ice jams large enough to inundate riparian vegetation and flood sloughs in 2012. Freeze-up in 2012 began with high water levels, as mid-October flows at USGS gages along the river were about twice as high as the long-term average. The ice cover on the Lower River progressed upstream from a bridge formed near the mouth of the river, and followed the same pattern as ice cover progression documented during the 1980s. Water level increases as recorded by pressure transducers in the Lower River reached 2-4 feet.

1. INTRODUCTION

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project (Project) using the Integrated Licensing Process (ILP). The Project is located on the Susitna River, an approximately 300-mile long river in the Southcentral Region of Alaska. The Project's dam site will be located at River Mile (RM) 184. The Project has the potential to affect ice processes, including the timing and extent of ice formation, severity of breakup, ice thickness, and winter water levels on the Susitna River downstream of the dam site.

This report provides the results of the 2012 Susitna River Ice Processes Study from March, 2012 to December, 2012. The primary purpose of the 2012 Ice Processes Study is to document ice cover conditions in the Susitna River from Cook Inlet to the Oshetna River confluence at RM 234. Field activities included aerial breakup and freeze-up reconnaissance, open-lead mapping, and time-lapse camera installation and maintenance. Office activities included meteorological data compilation and georeferencing of observations from the 1980s Susitna River ice studies.

This study provided data to inform the 2013–2014 licensing study program, Exhibit E of the License Application, and FERC's National Environmental Policy Act (NEPA) analysis for the Project license.

2. STUDY OBJECTIVES

The overall objective of the 2012 ice processes study is to document baseline ice conditions and initiate assessment of potential Project effects on downstream river ice processes. The specific objectives are as follows:

- Document the timing and progression of breakup and freeze-up on the Susitna River between Cook Inlet and RM 234 (Oshetna River confluence).
- Document open leads between Cook Inlet and RM 234 throughout the winter.
- Document the interaction between river ice processes and channel morphology, vegetation, and aquatic habitats.
- Provide baseline data to help identify the river reaches most likely to experience changes in river ice formation as a result of Project construction and operation.

3. STUDY AREA

Observations were taken between the mouth at Cook Inlet and the Oshetna River confluence (RM 234) (Figure 3-1). Time-lapse cameras were installed in eleven locations prior to breakup in 2012 and in three additional locations prior to freeze-up (Figure 3-2). Telemetered time-lapse cameras associated with the Open-Water HEC-RAS Flow Routing Model Study (R2 et al. 2013) and pressure transducers were installed in 13 additional locations prior to freeze-up in 2012 (Figure 3-2).

4. METHODS

4.1. Existing Information Review

The 1980s river ice studies were reviewed and synthesized for use in developing the 2012-2014 study plans. Observations of the timing and location of ice formation and break up, ice thickness, ice elevation with respect to discharge, and ice process effects on geomorphology, riparian vegetation, and aquatic habitat were compiled in a geospatial format for comparison with present day observations.

4.2. Open Lead Mapping (March 2012)

In March 2012, open leads from Cook Inlet to RM 234 were mapped aerially and documented using GPS-enabled cameras. Leads were classified by location (main channel, side channel, slough, tributary mouth) and type (thermal or velocity, where identifiable). The upstream and downstream limits of each open lead were located using an Archer handheld mapping GPS, and the width of each lead was estimated visually as a percentage of river width. Open leads in the Middle River were compared with the location of open leads documented in 1983 in the Middle River.

4.3. Time Lapse Camera Installation (March and April, 2012)

Fourteen time lapse-cameras were installed in 11 locations between RM 9 and RM 184 for the purpose of observing ice breakup and ice-cover formation (Table 4.3-1). The cameras were programmed to record one still image per hour. Data cards were retrieved following ice-out (May 8 or 9) and photos downloaded. Break-up progression as documented by the time-lapse photos was summarized in text and video form.

4.4. Breakup Observations (April 2012 – May 2012)

General breakup progression was documented between Cook Inlet and RM 234 from April 2012 through May 2012 during eight aerial reconnaissance flights. Conditions that were documented included the following:

- Locations and width of open leads;
- Locations and floe size in ice runs;
- Locations and general observations of ice jams; and
- General observations of condition of remaining ice cover, including overflow, and evidence of deterioration.

On aerial missions, observers also documented interaction between breakup processes and geomorphology, fish habitat (especially slough/side channel habitats) and riparian vegetation. The specific documentation requested by the Riparian study included locations were ice directly contacted vegetation, locations where ice-induced flooding contacted vegetation, and locations where ice or ice-induced flooding disturbed soils. Specific direction was not provided by other studies as to documenting geomorphic or fish habitat effects. Geomorphic observations consisted of noting differences among open leads, breakup, and freeze-up processes in different channel forms, including wide braided, confined with floodplain, and steep confined cascades. Sloughs and side channels in the Middle River were identified in the 1980s as important salmon habitat, especially those sloughs given names/numbers. For these sloughs, the following were documented: late winter open leads, any overflow or flooding during breakup, any ice runs during breakup, any ice-induced scour during breakup, and any flooding during freeze-up.

Observations were documented using GPS-enabled still cameras and a helicopter-mounted video camera.

4.5. Meteorological, Snow Depth, and Stream Temperature Data Compilation (April 2012 - May 2012)

All meteorological and surface water measurements described below for 2011-2012 are included in Appendix A.

Meteorological data were obtained daily starting April 1 from the National Weather Service (NWS) station in Talkeetna. A tabulation of freezing degree-days was kept, along with water temperature data from Willow Creek, Talkeetna River, and Montana Creek, which were the only real-time water temperature monitoring stations in the Susitna Basin in spring of 2012.

River stage data from the NWS observer at Sunshine Station (Parks Highway Bridge), and the Gold Creek gage (USGS) were obtained daily, along with any pilot reports or other observations taken for the Susitna River by the NWS.

SNOTEL data for Tokositna Valley, Bentalit Lodge, Point Mackenzie, and Susitna Valley High (Talkeetna) were downloaded daily. Snow course data for an additional 28 sites in the Susitna Basin were downloaded monthly, as updated by the National Resources Conservation Services (NRCS).

USGS winter gaging records were obtained and included in the documentation.

4.6. Observations and Documentation of Freeze-up Progression (October 2012 – December 31, 2012)

Freeze-up was documented during twelve reconnaissance flights between the onset of frazil accumulation in October and December 31, 2012. The following routine observations were documented with GPS, and GPS-enabled still photographs and video:

- Presence of frazil by location (main channel, side channel, slough, tributary) and type (frazil ice, anchor ice, pans)
- Ice bridges, including downstream and upstream extents
- Ice cover, including type (hummocky accumulation, overflow ice, shore ice)
- Snow cover

In addition to aerial observations, the progression of freeze-up at 13 sites was documented using the time-lapse cameras described above, although the processing of the freeze-up time-lapse data is not included in this report. Where pressure transducers are located, the staging elevation associated with ice-front progression was estimated. On aerial missions, observers also documented interaction between freeze-up ice processes and geomorphology, fish habitat (especially slough/side channel habitats) and riparian vegetation. The specific documentation requested by the Riparian study included locations where ice directly contacted vegetation, locations where ice-induced flooding contacted vegetation, and locations where ice or ice-induced flooding disturbed soils. Of these, only the flooding of sloughs and side channels and minor ice encroachment into vegetation were actually observed during freeze-up of 2012.

4.7. Deviations from Study Plan

The following deviations from the 2012 study plan were made:

- The 2012 study plan included in the existing information review a summary of studies of northern regions hydroelectric projects. This was not completed in 2012, and instead has been incorporated into the 2013-2014 Revised Study Plan as part of a more thorough literature review.
- Several of the 14 time-lapse cameras installed during breakup were moved for the 2012 freeze-up period, and additional cameras were installed as a result of consultation with the instream flow study team (Table 3-1). Thirteen additional telemetered time-lapse cameras associated with the Open-Water HEC-RAS Flow Routing Model Study (R2 et al. 2013) were installed prior to the 2012 freeze-up event at pressure transducer locations. It was found to be impractical to install readable staff gages in view of the time-lapse cameras as they were placed as high as possible in trees in order to have a wide view of the river. Staging during breakup was instead estimated using records from pressure transducers. Two time-lapse cameras were destroyed during summer flooding and bank erosion and were replaced in October. One camera (Slough 9A) malfunctioned during the breakup season and did not record images. One camera (Curry Slough) malfunctioned during freeze-up and did not record images.
- USGS field measurement records were obtained, but did not contain information on ice thickness or frazil ice.
- Freeze-up reconnaissance required twelve aerial missions as of December 31, 2012 as opposed to the six anticipated.
- During the freeze-up period, air and water temperature data and meteorological data were collected by the water quality and instream flow hydrology teams, rather than compiled from stations further from the river such as were available during breakup.
- Ice thickness and elevation measurements were postponed from spring of 2012 because of ice safety concerns.

5. RESULTS

5.1. Existing Information Review

Eight studies from the 1980s were used to identify historic river miles, location names, river ice observations, and data collected to place them into a geodatabase (Keklak and Quane, 1984; LaBelle, 1984; R&M Consultants Inc. 1981, 1982, and 1986; Schoch 1983, 1984, and 1985).

Freeze-up was observed from 1980-1985 (Table 5.1-1), and breakup from 1981-1985 (Table 5.1-2). Open leads were mapped in 1983 (Table 5.1-3). Other measurements, such as ice thickness, frazil concentration, frazil ice porosity, staging, and winter conditions at selected fish habitats varied between study years (Table 5.1-4). Historical observations were compared to observations from 2012 where they occurred on the same reach of river, and the comparisons are discussed in the results for open lead mapping, breakup observations, and freeze-up observations below. Historical observations of ice processes interactions with riparian vegetation, geomorphology, and fish habitat varied each year by study plan objectives and actual conditions. Table 5.1-5 lists specific locations where these interactions were observed.

No systematic attempt was made by ice observers to document effects on riparian vegetation, although removal and scarring of vegetation during breakup were noted in some study years. The most systematic discussion is included in the Riparian Vegetation Succession Report (AFES 1985), which divides the river into Middle (Oshetna confluence to Chulitna confluence), and Lower (below Chulitna confluence). The study authors found that downstream of the Oshetna confluence, vegetation showed signs of frequent scraping and bending by ice. The riparian vegetation line in ice jam affected reaches appeared to be determined by the elevation of the ice jams and subsequent flooding. Ice jams also scarred or removed vegetation from the heads of islands, toppled trees, and scarred trees in the middle of stands on islands. The wide braided morphology and weaker breakup drive on the Lower River appeared to reduce the occurrence of ice-induced overbank flooding, and consequently, effects of ice on vegetation. No ice jam scars were reported for this reach.

Observations of ice effects on geomorphology of the river channel and floodplain are primarily bank erosion and scour from the breakup periods and located in the Middle River, between Talkeetna and Gold Creek (Table 5.1-5). Additional documentation of the interaction between ice and geomorphology was reported in the 1982-1983 Ice Study Report (Schoch, G.C. 1983):

- Scour holes in the Middle River are often indicators of ice jam locations
- Ice jams in the Middle River generally occur in shallow channels with a narrow confined thalweg along one bank.
- Ice jams in the Middle River commonly occur adjacent to side channels and sloughs, which act as bypass channels during extreme ice jam flood events in the main channel. Ice jam flooding probably formed the majority of sloughs between Curry and Gold Creek.
- The wide, braided morphology and low winter discharges in the Lower River seem to limit the extent of flooding during freeze-up and jamming during breakup. Open water floods during summer storms seem to have a greater effect on channel form in the Lower River than ice processes.
- Sediment transport is affected by both freeze-up and breakup processes.
    - During freeze-up, frazil ice nucleates around suspended sediment, buoying it up to the surface in frazil pans. This silt may remain entrained in the ice cover until it melts out in the spring.
    - Anchor ice adheres to bed sediment, and if it gains enough mass will rise to the surface, bringing gravel with it.

- During breakup, shore-fast ice can be lifted and shoved laterally, moving sediment up to boulder sized and creating ridges of floodplain material.
- During breakup, ice jam releases can scour the channel bed and erode many feet of bank quickly.

Observations of ice effects on fish habitat included documentation of sloughs and side channels that were overtopped during freeze-up as water levels increased, open water in sloughs and side channels during winter that may have resulted from ice driving water laterally into the floodplains, and scouring or flooding of sloughs and side channels during breakup. The locations of these observations are listed in Table 5.1-5.

5.2. Open Lead Mapping

Open leads were documented throughout the lower 234 miles of the Susitna River in March of 2012, before temperatures rose above freezing. Observers classified the leads as thermal, velocity, or unknown. Leads classified as thermal in origin were generally shallow, located in marginal areas (sloughs, side channels, or bank toes), and did not appear from the air to have strong current. Velocity leads were located in the main channel or substantial side channels and had visible current. Velocity leads often had broken or jumbled ice along the margins or accumulated at the downstream end. It is likely that many leads in the main channel exist because of a combination of thermal input and rapid current. R&M mapped open leads on March 2, 1983, between RM 85 and RM 151 (Schoch 1983b). R&M recorded river mile at upstream end, length, width, location (main channel, side channel, or slough) and type (thermal or velocity). However, the criteria for establishing the origin of the lead as thermal or velocity were not documented in the study report. Because the majority of the 1983 leads were classified as velocity leads, including sloughs, it appears that different criteria were used in 1983 than that applied in 2012.

5.2.1. Lower River Open Leads

Most of the open leads documented in the Lower River (Cook Inlet to the Three Rivers Confluence) appeared to be thermal leads associated with upwelling through gravel bar complexes and bank toes. They were small compared with the width of the channel (less than 5%), and were shallow trickles emerging from gravel bars (Figure 5.2-1). Some open leads had a distinct rust color, suggesting that they drained peat or other tannic material (Figure 5.2-2). There were approximately the same concentration of open leads in side channels and sloughs as there were in the main channel. The longest main channel open leads occurred near the town of Talkeetna, around RM 97.

Observations in 1983 of open leads covered the section of the Lower River upstream of RM 84. Main channel open leads were generally not comparable as the channel has shifted eastward since 1983 in this reach. However, the Birch Creek Slough complex at RM 87 was documented as open in 1983 and in 2012. In both 1983 and 2012, persistent velocity leads were documented near the town of Talkeetna between RM 96 and 97 (Figure 5.2-3).

5.2.2. Middle River Open Leads

Open leads were more frequent in the Middle River (Three Rivers Confluence to the proposed dam site at RM 184) than the Lower River, both in the main channel and in sloughs. Thermal leads were concentrated around sloughs, including Slough 1 (RM 99), Whiskers Slough/Whiskers Creek entrance (RM 103), Slough 6A (RM 112), Slough 7 (RM 122), Slough 8 (RM 125) (Figure 5.2-4), Slough 8A (RM 127), Slough 9 (RM 129), Slough 11 (RM 135) (Figure 5.2-5), Slough 16 (RM 138), Slough 20 (RM 141), and Slough 21 (RM 142). All of these except for Whiskers Slough and Slough 1 were also documented in 1983, although a number of them were classified as velocity leads. Downstream of RM 130, the 2012 mainstem open leads were generally classified as thermal, while the 1983 mainstem open leads were classified as velocity. Upstream of RM 130, most mainstem open leads were classified as velocity leads in both studies, corresponding to an increase in river gradient. Numerous velocity leads were documented in both studies near the Portage Creek confluence and throughout the Devils Canyon reach (Figure 5.2-6 and 5.2-7), although the exact locations of the leads likely differ from year to year. The 1983 survey ended at RM 151. In 2012, velocity leads continued up to the confluence of Devil Creek at RM 163. Upstream of this confluence, the river gradient decreases, and the open leads were a mix of thermal and velocity-derived. Thermal leads occurred more often in side channels and along gravel bar complexes, while velocity leads occurred near bedrock outcrops and sharp bends.

5.2.3. Upper River Open Leads

The Upper River, from the proposed dam site at RM 184 upstream to the Oshetna River confluence had fewer open leads in general than the Middle and Lower Rivers. Short thermal leads were documented in side channels and gravel bar complexes, and velocity leads were documented between Vee Canyon (RM 221) (Figure 5.2-8) and the Oshetna River (RM 234). Open leads were also documented at tributary mouths, including the mouths of Watana Creek, Kosina Creek, Jay Creek, and the Oshetna River (Figure 5.2-9).

5.3. Time Lapse Camera Installation and Maintenance

Fourteen time-lapse cameras were installed prior to breakup in April 2012 (Table 4.3-1). The cameras were installed in trees facing either the mainstem of the river or side channels or side sloughs of interest. The cameras were installed April 9-11, 2012, and pictures retrieved May 9, 2012 after breakup. The breakup summaries are included in the breakup observations below.

Freeze-up camera installation included the replacement of two cameras (at RM 9.5 and RM 184) lost to bank erosion, probably during the September 2012 floods. One camera at RM 59 was moved to face the main channel, and one camera was removed from this location. Additional cameras were placed at RM 102 on the left bank across from Whisker Slough, and on the right bank adjacent to Whisker Slough, at Slough 8A, and at Slough 11. Other cameras were maintained by swapping out batteries and memory cards, and clearing of brush where needed.

5.4. Breakup Observations

Breakup observations included aerial reconnaissance flights, time-lapse camera observations, and post-breakup ground reconnaissance at time-lapse camera locations. Breakup on the Susitna

River was slow and uneventful in 2012. Snowpack was 138% of normal in the Susitna Basin on April 1, 2012 but intermittent above-freezing temperatures in April and cool temperatures in May caused the snowpack to melt slowly. Because of the slow melt, the river ice weakened and decayed in place before river discharges increased enough to mechanically break up the ice cover. When break up did occur, the remaining ice was too weak to form large jams. Ice and water stayed within the channel except in a few places in the Middle River.

5.4.1 Lower River Observations

Between April 11 and April 19, 2012, open leads on the Lower River gradually widened. Ice began to break off of the edges of open leads and accumulate against the solid ice cover on April 19 between RM 97 and RM 53. Leads continued to widen until ice runs began on April 25. Intermittent ice runs continued until May 6, when the Lower River was generally ice free.

The largest ice jam occurred near RM 62 (Figure 5.4-1). Much of the main channel was jammed, forcing water overbank and into a short side channel on the left bank. This was the largest instance of overbank flooding seen in the Lower River during the 2012 breakup.

Four time lapse camera installations recorded breakup on the Lower River at Alexander (RM 9.5), Susitna Station (RM 26), Rustic Wilderness Side Channel (RM 59) and Birch Creek Slough (RM 88).

RM 9.5, Alexander

This camera views the main river looking upstream from the right bank. Overflow was visible in tracks in the snow from the beginning of the image sequence (April 5, 2012). The overflow went through daily freeze/thaw cycles until April 19 when a lead opened completely (though continuing to freeze at night until April 23). The near-shore ice began to break up April 23 at 16:00. Ice in the near-shore channel alternately jammed up/flowed from April 24 until April 30. At this time ice from the main channel was pushed to the near shore, which is on the outside of a sweeping bend (Figure 5.4-2). The ice went out completely on April 30, with runs of broken ice on May 1, 2, and 5.

RM 26, near Susitna Station

Viewed from the left bank looking upstream, this image sequence ran from April 11 to May 9. The river was completely ice covered on April 11. Water was visible in the snow/ice near the left bank beginning on April 15. A lead opened in the mid-channel on April 23 and flowed freely on April 28. Overflow near the left bank opened up to a lead on April 29. The ice broke up completely on May 1 at approximately 16:00. Broken ice flowed downstream freely by May 5. Only stranded ice was left to melt when the sequence ended on May 9.

RM 60, near Rustic Wilderness Side Channel

One camera at this site recorded images of two side channels near the right bank. This sequence includes images from April 5 through May 9. Snow melt was fairly continuous and consistent from the beginning of the sequence. In the image there are two channels visible, a small gut in the foreground and a more sizable channel in the background. Overflow on top of the ice was first visible on the foreground channel on April 24, with overflow increasing during daily freeze/thaw cycles until a lead opened on April 29. Flow continued (and diminished) until the channel was dry on May 3, 2012.

The larger channel in the background was open on April 5, and the channel widened until the water level began to recede on May 3. The channel was first ice free on April 28 until an ice run on May 2 left large ice chunks stranded in the channel (Figure 5.4-3). The channel was almost dry by May 6, 2012.

A second camera at this site recorded images of the main channel. The main channel was completely ice covered on April 5. Overflow in the snow was first visible in the afternoon of April 7 and increased until open water was visible beginning April 22. Daily freeze/thaw cycles closed the lead at night and opened it during the day until on April 25 the lead remained open. Ice began to break up and flow on April 27 in the evening. The water level dropped on May 2, stranding ice on the banks. The water level rose and ice began to flow again on May 5. The channel was ice-free and flowing freely May 6.

RM 88, near Birch Creek

This camera recorded images facing the mouth of a slough and side channel from April 5 through May 9. There was an open lead in the side channel all winter. The lead began to widen on April 13. The last of the ice went out on April 22. Occasional chunks of ice flowed by on April 26; otherwise the channel was ice-free after April 22. By April 28 dry ground was appearing on the bank and by May 9 all that was left was some snow on the bank.

The second camera in this location recorded images of the main channel across two side channels from the left bank. Open water was visible in a hole in the foreground from the start of the images on April 9. The channel continued to grow until it opened into a freely flowing channel on April 12. A second channel opened up and joined the first channel on April 24. Bank ice receded or broke off and the channel grew continuously until it was ice-free on April 27. Ice chunks could be seen flowing out in the main channel April 25, 2012.

5.4.2 Middle River Observations

Ice began moving and jamming in the Middle River between April 11 and April 19. On April 11, observers noted that open leads were widening and open water began appearing in Fog Creek (RM 162) and Portage Creek (RM 148) (Figure 5.4-4). On April 19, numerous small jams were observed from RM 159 to RM 134 (Figures 5.4-5-6). Upstream of RM 159, the open leads had widened. Downstream of RM 134, open leads remained narrow but lengthened.

By April 23, snow had melted from the banks and bars, and open sections of river had increased. Small ice jams within open leads were observed between the mouth of Devils Canyon (RM 150) and Slough 8 (RM 127) (Figures 5-4.7).

From April 27 to May 4, most of the ice jam activity occurred in the mainstem and side sloughs in the Middle River between RM 136 and RM 121. Below RM 121, the river opened up gradually as open leads widened, but few jams were observed. By May 9, the Middle River was largely ice-free.

The largest jams with the greatest potential to affect vegetation, geomorphology, and fish habitat were near Sloughs 11, 8 and 9. Near RM 134-136, a large ice jam occupied the main channel and right bank side channel from April 27 to May 2 (Figure 5.4-8). While the jam held, water was forced overbank into Slough 11 (Figure 5.4-9). After the jam released, ice was observed overbank and in the riparian vegetation at RM 135.8 on May 2, 2012 (Figure 5.4-10). Neither scouring of the banks nor scarring of vegetation was observed following the jam release.

A large jam was also documented in the mainstem, Slough 9, and Slough 8 from RM 130.2 to RM 126.4 on May 2 that collapsed by May 4 to span from RM 130.1 to RM 128.2 (Figure 5.4-11). Following the release of this jam, ice floes were observed in the trees lining Slough 8A from RM 127.8 to RM 126.6. The build-up and release of this jam is also documented on the Slough 9 time-lapse camera. Again, post-breakup reconnaissance did not document significant scour or vegetation scars resulting from this jam release, possibly because the ice was relatively weak.

Six time-lapse camera installations monitored breakup on the Middle River:

RM 99, Slough 1

The image sequence ran from April 6 through May 24. Open water was visible from the beginning of the sequence in Slough 1 near the camera. A lead opened in the main channel on April 19. Ice began to break up and move on April 27. During the night of April 27 the water level rose by several feet, covering gravel bars that had been visible earlier in the day. The water level began dropping by the afternoon of April 28. The remaining river ice went out early morning May 1. The water level dropped continuously until May 7 and then rose continuously until the sequence ended May 24.

RM 103, Talkeetna Station

The camera is on the left bank facing across the main channel and upstream. A small lead on the left bank is visible from the beginning (April 6). Water was visible on the ice mid-channel on April 12. A lead in the mid-channel opened and closed daily from April 17 until April 21, when it opened for good. Ice jammed the center lead on April 25 and the near-shore lead on April 28. Both jams broke sometime after 22:00 on April 30. A small jam formed on the side channel upstream of the camera on May 1. The jam broke May 3. The river flowed freely from this point on, with stranded ice melting by May 18.

RM 120, Curry Slough

This camera views the main channel from the left bank looking upstream across a side channel. The snow melt is continuous and consistent throughout this sequence. On April 9, an open lead is visible against the left bank of the side channel. The lead widened and lengthened into a continuous channel on April 13, 2012. A snow storm on May 1obscured the camera’s view. Broken ice can be seen flowing on May 6. The channel was open and ice free (except for bank and bar snow) when the sequence ended May 9.

RM 129, Slough 9

Viewed from the left bank looking downstream, this sequence runs from April 9 through May 9. Meltwater/overflow in a depression in the ice closest to the camera melted through to running water on April 17. Ice jammed downstream on April 19, and at 16:00 on April 22 the channel jammed completely with ice. The jam broke on April 25 at 16:00. A second jam occurred on April 26 and released on April 28. A snow storm passed through May 1. The largest jam occurred on May 2 and released on May 3, sending ice floes up onto the banks. Broken ice ran through on the morning of May 5 and when the sequence ended on May 9 the river was flowing freely with stranded ice from the jams on the banks.

RM 141, Slough 20

An open lead is visible from the beginning of this image sequence, April 10. The lead widened consistently from the beginning with no visible broken ice flowing. As snow melted and receded from the gravel bar, the surrounding brush sprang up and increasingly obscured the view until the sequence ended May 9, 2012.

RM 148, Portage Creek

This camera looks upstream across the mouth of Portage Creek. Small leads and depressions in the snow can be seen from the beginning of the image sequence in both Portage Creek and the Susitna River (April 11). Water was visible in the snow/ice beginning April 13. A lead in the Susitna River opened April 14 and went through daily freeze/thaw cycles until April 25, when Portage Creek opened up. Broken ice runs occurred in the main channel April 26 to April 28. Ice in the channel was gone April 29. A snow storm moved through on May 1. The channel was ice-free (excepting bank ice) through May 9.

5.4.3 Upper River Observations

Breakup commenced on the Upper River between April 11 and April 19. On April 19, two small ice jams were observed near RM 221. By April 27, larger jams had formed at RM 221.5, RM 231, and RM 207 (Figures 5.4-12, 5.4-13, 5.4-14). Ice jam activity had subsided by May 4, and the Upper River main channel was ice free with stranded ice on the banks and bars by May 9. Especially large slabs of stranded ice were observed downstream of Vee Canyon at RM 221 (Figure 5.4-15), and at RM 196 (Figure 5.4-16).

Despite the presence of ice jams, both ice and water generally remained below the vegetated bank throughout the breakup observation period. Exceptions to this were found at RM 184, where water and ice flows severely undercut an island, uprooting several trees, and an ice slab bulldozed the elevated point of the island (Figure 5.4-17). There were no other observed ice-vegetation interactions or recent ice scouring.

One time-lapse camera recorded breakup in the Upper River:

RM 184, Proposed Watana Dam site

In this image sequence (viewed upstream from the right bank), a large puddle of melt water went through a daily freeze/thaw cycle, first opening to the river on April 16. A lead opened upstream of the site on April 22. The freeze/thaw cycle near-shore continued until April 23 when a lead opened completely. On April 30 an ice jam formed in the main channel upstream and a lead opened from the main channel to the right side. The ice jam upstream broke on May 2 and ice ran through May 3. The main drive of the jam occurred after dark on May 2, thus the floes that impacted the island were missed by the camera.

5.4.1. Ice Processes Effects on Other Resources

5.4.1.1. Riparian Vegetation and LWD

The mild breakup in 2012 resulted in less out-of-channel flow than reported for other years, and consequently little apparent effect on floodplain vegetation and large woody debris. Flooding (primarily backwater) associated with ice jams reached the vegetation line in the Lower River near RM 62. In the Middle River, water and ice inundated the vegetated floodplains adjacent to Sloughs 11, 9, and 8, but no scarring or removal of vegetation was noted following breakup. The only damaged vegetation documented were trees at the upstream end of the island near RM 184. These toppled trees are also the only potential contribution of breakup to large woody debris in 2012.

5.4.1.2. Geomorphology

The only documented geomorphic impact caused by breakup in 2012 was scour to the island at RM 184.

5.4.1.3. Aquatic Habitat

The presence of open water and increases in stage in side channels and sloughs were the only documented interactions between ice processes and aquatic habitat. Some Lower River sloughs and side channels and most sloughs between Talkeetna and Indian River had open water in them in March prior to snowmelt, indicating upwelling. During breakup, Sloughs 11, 9, and 8 were flooded by ice jams, although the events were relatively mild and did not appear to scour the beds. Time-lapse cameras indicated that Slough 1 flooded during breakup with water, but not ice. Time-lapse cameras on the Lower River documented similar brief rises in water level in side channels during breakup.

5.5 Meteorological Data

The compiled meteorological data (Appendix A) indicated that several factors likely contributed to the mild breakup in 2012. The April 1 snowpack was 38% above normal in the Susitna Basin. April was slightly warmer than normal at Talkeetna, however May was cooler than normal, so that melting occurred over a long period of time rather than rapidly. The warmer temperatures in April also likely allowed the ice cover to weaken prior to a rise in flow. Tributary temperatures at Willow Creek, Montana Creek, and Talkeetna River increased above freezing prior to the Susitna River because they opened up earlier. River stage data from the Talkeetna River, Denali gage, Gold Creek gage, and Sunshine gage are considered invalid for estimating discharge during ice-affected periods, but the graphs indicate when ice-out occurred and when the largest ice jams occurred at Gold Creek.

5.6 Freeze-up Observations

Freeze-up commenced in the Project Area around October 12, 2012. This was the date upon which frazil ice was first recorded at the ESS80 camera at RM 223. By October 16, 2012, frazil ice was flowing past Talkeetna (Figure 5.6-1). Between October 17 and October 22, two long ice bridges formed in Devils Canyon, with one short bridge in between (Figure 5.6-2). A short ice bridge also formed just upstream of the proposed dam site at RM 186.5. More detailed timing of the bridge formation is unknown. None of these bridges were captured on cameras, and they were far enough removed from pressure transducers that any staging associated with their formation was not recorded. Frazil concentrations did not appear to drop at ESS70 (RM 184.1) or ESS55 (RM 148) during this period, which would have indicated the timing of the upper river ice bridge formation, or Devils Canyon ice bridge formations, respectively. This indicates that the total volume of frazil removed from the river by these bridges was negligible compared to the volume generated between the bridges and flowing downstream underneath them.

On October 23, two bridges formed near the mouth of the river and the ice cover began progressing upstream via juxtaposition (frazil pans flowed downstream, hit the upstream edge of the bridge, and froze into place) (Figure 5.6-3). Observers at RM 9.5 noted that ice was still flowing out to Cook Inlet in the afternoon, but had slowed greatly and ice pans were pushing against each other. The tide began rising after 17:30, and the bridges likely formed as accumulating frazil pans flowing into the mouth were halted by the rising tide. Late in the evening, the pressure transducer at RM 10 (ESS10) recorded a sharp increase in stage of about 2.5 feet, which was likely caused by the advancing ice front (Figure 5.6-4). Soon thereafter, the pressure transducer at RM 15 followed suit. By the October 26 reconnaissance flight, the ice cover had progressed up to RM 33, at a rate of nearly 12 miles per day. The rapid progression was likely aided by contributions of frazil from the Yenta River, which supplied ice to the reach below RM 27. By October 29, the ice cover had extended to RM 54, a rate of 7 miles per day (Figure 5.5-5). By November 1, it had reach RM 68, also about 7 miles per day. On November 7, ice cover reached RM 90; the rate had slowed to about 4 miles per day.

The slowing of the ice cover progression between November 1 and November 7 does not appear to have been caused by either warmer weather or blockage of frazil upstream, but by factors related to the geometry of the river channel. Talkeetna weather indicates steady temperatures. Time-lapse photos from ESS30 (Susitna River at Twister Creek, below the Three Rivers Confluence) show fairly steady frazil concentrations between November 1 and November 7. The bridges in Devils Canyon did not appear to increase in size, although a few additional short bridges formed. The slowing of the ice front was most likely due to the increased gradient of the river, which increases the hydraulic thickening of the ice cover, and thus the volume of ice necessary to allow the ice cover to progress upstream.

Staging associated with ice cover advance through RM 90 was indicated by progressive flooding of gravel bars and side channels. Figures 5.6-6 and 5.6-7 show the Parks Highway Bridge area near RM 84 before and after ice cover advance.

A short summary of freeze-up through November 7 is below:

October 12: Frazil ice appeared in the river between ESS80 (RM 223) and Portage Creek (RM 148). Little frazil ice was seen at Curry Station (RM 121).

October 13: Frazil ice appeared between Curry Station and Twister Creek (RM 128 and RM 96).

October 14: Frazil ice appeared at Susitna Station (RM 26).

October 15: Too much frazil ice near Deshka Landing (RM 44) to operate a jet boat.

October 16 and 17: Frazil ice concentrations of 5-40% were observed at Talkeetna. No bridges were visible from RM 184 downstream.

October 17: Frazil ice appeared at ESS10 below Flathorn Lake (RM 10).

October 22: One short bridge formed in the Upper River just upstream of the proposed Watana Dam site (RM 186.5). In the Middle River, a short bridge formed at RM 154.9, and two longer bridges formed over segments of Devils Canyon rapids. These bridges extended from RM 150.2 - 151, and from RM 159.5 - 161. No bridges were visible in the main channel downstream of Devils Canyon on October 22. Anchor ice observed upstream of Devils Canyon.

October 23: Bridging appeared imminent at RM 9 in afternoon. Pressure transducer readings at RM 10 indicate ice cover progressed past in the late evening. Pressure transducer reading at Susitna Station indicated ice cover progressed past on October 25.

October 26: Ice bridges were visible in west and east side channels at Big Island near Susitna mouth. The first ice bridge extended from RM 1 to RM 5, and a second ice bridge extended from RM 6 upstream. Open water was visible between the two bridges. An ice cover progressed upstream from the second ice bridge to RM 20. A third ice bridge extended from RM 21.5 past the Yentna confluence to RM 33. On the Yenta, the ice cover extended about three miles upstream from the confluence.

Short ice bridges had formed in Devils Canyon at RM 154, 155, and 156, while the two longer bridges seen on October 22 were unchanged. The same short bridge was seen in the Upper River at RM 186.5.

October 29: Ice cover extended from the mouth up to RM 54. One additional ice bridge had formed in the Devils Canyon area.

November 1: Ice cover extended up to RM 68. Nine short ice bridges had formed in Devils Canyon and upstream. Devils Canyon ice cover was otherwise the same. A short bridge formed at RM 223.

November 7: Ice cover extended up to RM 90. An ice cover formed in the south channel of Chulitna River, but two other channels of the Chulitna remained open. Two additional ice bridges formed just upstream of Portage Creek mouth. The ice bridge at RM 223 had broken.

6. DISCUSSION

The 2012 ice processes observations provide baseline data useful for extending the observations from the 1980s. In particular, the 2012 year provided the first open lead observations below RM 85 and upstream of RM 161, and the first breakup and freeze-up observations in the Upper River.

6.1. Open Leads

Open leads followed the same general pattern in 2012 as 1983, despite using different criteria for establishing the origin of the lead. Side channels and sloughs in the Middle River were mapped as open or partially open during both surveys, while velocity leads were common in the steep reach upstream of Indian River in both surveys. Lower River open leads were difficult to compare because the main channel appears to have shifted eastward since 1983. After watching open leads form and evolve over the 2012 freeze-up season, observers have determined that many velocity leads slowly grow in over time while thermal leads tend to remain open or even erode further. Therefore the photos obtained during freeze-up 2012 will also be used to determine the origin of open leads where differentiation is not clear.

6.2. Breakup

Compared to earlier reports, breakup in 2012 was exceptionally mild, with few large jams and little observed flooding. It is likely the mildest breakup that has been systematically observed.

The Lower River was subject to relatively uneventful breakups in the 1980s as well as 2012. Breakup does not appear to frequently cause extensive damage as it does in the Middle River. The 1981 breakup study observed an ice jam at the Deshka River (RM 40.5) and Montana Creek (RM 77) confluences. In 1982, two large ice jams (RM 85.5 and RM 89) released with a high enough stage to entrain logs stranded from summertime flooding (R&M 1981, R&M 1983). During the 1985 breakup, jams were observed at RM 78 and RM 86 (R&M 1986).

The Middle River experienced severe ice jams during breakup in the 1980s and earlier, although the 2012 breakup did little or no damage. Ice floes accumulated in the same general reaches as those reported previously in the Middle River. The majority of ice-jam observations in the Middle River during the 1981-1985 breakup studies were within the same 15-mile section of the river from RM 136 to RM 121 as in the 2012 breakup observations, although ice jams were more frequent, extensive, and severe in 1981-1985. The following locations were subject to ice jam activity and flooding in 2012 and in the 1980s:

- Slough 11 (RM 134 - 136): Major ice jams and ice-jam flooding were documented near Slough 11 (RM 136) in 1983 and 1985 (LaBelle 1984; R&M 1985). Previous observers documented that Slough 11 was in fact created by an extensive ice jam breakout in May of 1976 (R&M, 1983).
- Slough 8 and Slough 9 (RM 126.4-RM 130.2): Historically, RM 129 (Slough 9 area) was a very active breakup location with many observations of ice jams and side channel and slough ice-induced flooding (LaBelle 1984, R&M 1983). In 1985, a breakup jam released from the same location and caused ice to flow through and possibly scour Slough 8A (R&M 1986).
- RM 121-123: In May of 1983 and 1985, a 1-mile long major ice jam was observed at RM 122 (R&M 1983). A smaller jam was documented here in 2012.

Breakup was not systematically documented in the Upper River prior to 2012, with the exception of the Watana Dam site area, where jams were reported in May of 1983. Large stranded chunks and damaged vegetation observed in 2012 indicated that more recent jams had inundated the floodplain.

6.3. Freeze-up

Only the initial freeze-up period is covered in this report. However, 2012 provided an opportunity to observe freeze-up during relatively high flows (discharges at Gold Creek were about 15,000 cfs on October 12, compared to a mean of 7,600 cfs, and at Sunshine were about 42,000 cfs on October 12, compared to a mean of 19,600 cfs). The high flows prevented intermediate bridges and ice cover from forming between tidewater and Devils Canyon, and likely somewhat delayed the initial ice bridge formation at tidewater, although the timing of ice bridge formation was similar to previous reports. The following aspects of freeze-up were consistent with R&M's observations between 1980 and 1985:

- Frazil flow begins in the Upper Susitna in October.
- The greatest frazil concentrations are in the Susitna and Yentna Rivers, with minor frazil contribution from the Chulitna or Talkeetna Rivers to the lower Susitna River.

- Earliest ice bridges are short, thick frazil ice bridges in Devils Canyon, which do not progress upstream.
- Ice cover is initiated by bridging in the lower five miles of the Susitna River.
- Ice cover advances rapidly to the Yentna confluence, and gradually slows as it advances upstream.
- Staging associated with ice cover advance in the Lower River is between 1-4 feet.

An ice cover had not yet formed on the Middle River by November 7, 2012. Shore ice was gradually widening, and frazil ice was thick enough to clog constrictions in the main channel, giving the appearance of imminent bridging. Similar observations were documented in 1981 and 1982 in the Middle River. The early appearance of anchor ice in shallow riffles upstream of Devils Canyon is also consistent among study years.

In the Upper River, an ice cover had not yet formed by November 7, 2012. Although ice observations did not extend to the Upper River in the 1980s, it was speculated that reductions in frazil concentrations at Gold Creek were associated with an ice cover forming upstream of Devils Canyon. The formation of the intermittent Devils Canyon ice cover on October 22 did not have a noticeable effect on frazil concentrations at Portage Creek in a preliminary evaluation of telemetered camera images. When the time-lapse camera images are available from above and below Devils Canyon for the freeze-up period, a more detailed evaluation of frazil concentrations during the Devils Canyon ice bridge formation will be undertaken.

6.4. Ice Processes Effects on Other Resources

As described in Section 5.1, river ice processes locally have had significant effects on riparian vegetation, geomorphology, and fish habitat, especially in the Middle River between Indian River and Talkeetna. In 2012, very minor effects to vegetation and geomorphology were documented because of the mild breakup. The influence of a river ice cover on stage and flow in lateral habitats was indicated by open water in sloughs and side channels in April of 2012. Flooding during breakup inundated many sloughs and side channels in the Middle River, but did not appear to change the channels. The progression of the ice cover during freeze-up in 2012 caused stage to increase several feet in the Lower River, flooding side channels and sloughs. The high initial discharges may have resulted in a greater total extent of ice cover compared to previous years. The final processing of 2012 freeze-up data may indicate whether these higher discharges resulted in more inundation than seen in previous years.

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8. TABLES

Table 4.3-1. Location of time-lapse cameras installed for Ice Processes Study.

Historic River Mile Location	Bank	View	Location Name	Time Period Recording
9.5	Right	Main channel upstream	Alexander	April – May, 2012; October - December, 2012. Camera replaced in October 2012 in a different tree.
26	Left	Main channel upstream	Susitna Station	April – December 2012
60	Island	Camera 1 facing side channel toward right bank,	Rustic Wilderness Side Channel	April – October, 2012.
60	Island	Camera 2 facing main channel downstream across a side channel.	Rustic Wilderness Side Channel	April – December, 2012. Camera moved to face main channel better in October, 2012
88	Island	Camera 1 looking upstream at head of Birch Creek Slough.	Birch Creek Slough	April – October, 2012
88	Island	Camera 2 looking downstream at main channel.	Birch Creek Slough	April – December, 2012
99	Left	Upstream across Slough 1	Slough 1	April – September, 2012. Camera moved in October, 2012.
103	Left	Upstream across main channel	Talkeetna Station	April – December, 2012
120	Left	Upstream across main channel	Curry Slough	April – December, 2012
126	Left	Upstream across entrance to Slough 8A toward main channel.	Slough 8A	October – December, 2012
129	Left	Camera 1 looking downstream at left bank and slough mouth	Slough 9	April –October, 2012
129	Left	Camera 2 looking downstream at right bank and main channel	Slough 9	April – October, 2012

Historic River Mile Location	Bank	View	Location Name	Time Period Recording
135	Left	Upstream across side channel	Slough 11	October – December, 2012
141	Left	Upstream toward slough mouth	Slough 21	April – December, 2012
148	Right	Upstream towards the bottom of Devils Canyon and the confluence with Portage Creek	Portage Creek	April – December, 2012
184	Right	Main channel upstream toward dam site	Watana Dam	April – May, 2012; October - December, 2012. Camera replaced in October 2012 in a different tree.

Table 5.1-1. Freeze up Observations from 1980-1985

River Mile	Location Information	Observations Made	Date of Observation	Reference Document
1.9		Ice bridge	23 Oct 1985	R&M Consultants, Inc 1986
5		Ice bridge	27 Oct 1984	Schoch 1985
8		Ice bridge	23 Oct 1985	R&M Consultants, Inc 1986
9		Ice bridge	Winter 1982	LaBelle 1984
24		Ice bridges - intermediate (through RM 26)	Winter 1984	Schoch 1985
26		Ice bridge	30 Oct 1984	Schoch 1985
35.2	Hooligan Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
36.2	Eagles Nest Side Channel	Flooded snow during freeze-up	Winter 1984	Schoch 1985
36.3	Kroto Slough, head	no winter flow from main channel	Winter 1984	Schoch 1985
39	Rolly Creek, mouth	no winter flow from main channel	Winter 1984	Schoch 1985
43	Bear Bait Side Channel	Ice bridges - intermediate (West channel through RM 46)	Winter 1984	Schoch 1985
43	Bear Bait Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
45.4	Last Chance Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
49		Ice bridges - intermediate (East channel through RM 52)	Winter 1984	Schoch 1985
52		Ice bridge	30 Oct 1984	Schoch 1985
59.5	Rustic Wilderness Side Channel	overflow into side channel during freeze-up	Winter 1984	Schoch 1985
63	Caswell Creek, mouth	no winter flow from main channel	Winter 1984	Schoch 1985
63.2	Island Side Channel	Flooded snow during freeze-up	Winter 1984	Schoch 1985
74.4	Mainstem West Bank	Flooded snow during freeze-up	Winter 1984	Schoch 1985
74.8	Goose 2 Side Channel	overflow into side channel during freeze-up	Winter 1984	Schoch 1985
75.3	Circular Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
79.8	Sauna Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
84.5	Sucker Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
86.3	Beaver Dam Slough	no winter flow from main channel	Winter 1984	Schoch 1985
86.9	Sunset Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
87	Sunrise Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
88.4	Birch Creek Slough	no winter flow from main channel	Winter 1984	Schoch 1985
91.6	Trapper Creek Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
92		Ice bridges - intermediate (through RM 105)	Winter 1984	Schoch 1985

River Mile	Location Information	Observations Made	Date of Observation	Reference Document
98.6		Freeze-up ice bridge	Winter 1982	LaBelle 1984
98.6		Staging during ice cover formation	Winter 1980	R&M Consultants, Inc 1982
105		Freeze-up ice bridge	03 Nov 1984	Schoch 1985
130.9		open water - intermediate ice bridges through RM 135	Dec 1984	Schoch 1985
136.9		open water - intermediate ice bridges through RM 147	Dec 1984	Schoch 1985
149	Portage Creek	Freeze-up ice bridge	Winter 1982	Schoch 1983a

Table 5.1-2. Breakup observations from 1981-1985

River Mile	Location Information	Observations Made	Date of Observation	Reference Document
25.5	Susitna Station	Breakup	01 Apr - 12 May 1983	Schoch 1985
40.5	Deshka River	Breakup	01 Apr - 15 May 1983	Schoch 1985
40.5	Deshka River	Ice jam at Deshka confluence	May 1980	R&M Consultants, Inc 1981
77	Montana Creek confluence	Ice jam - flooded Montana Creek confluence	03 May 1983	Schoch 1983b
85.5		Ice jam - flood released logs stranded from summertime flooding	04 May 1983	Schoch 1983b
89		Ice jam - flood released logs stranded from summertime flooding	04 May 1983	Schoch 1983b
95		severe bank erosion from breakup	5/27/1982	R&M Consultants, Inc 1983
97		10-15 feet of bank erosion on left bank from breakup	5/27/1982	R&M Consultants, Inc 1983
98		2-3 feet bank erosion from breakup	5/27/1982	R&M Consultants, Inc 1983
99		large stranded jam, ice blocks 20-30 ft long	5/27/1982	R&M Consultants, Inc 1983
100		large stranded jam, ice blocks 20-30 ft long	5/27/1982	R&M Consultants, Inc 1983
101.5		Ice jam	May 1983	Schoch 1983b
102		4-5 feet bank erosion from breakup	5/27/1982	Schoch 1983a
103.3		Historical flood damage during breakup		R&M Consultants, Inc 1981
103.5		ice jam	5/10/1982	R&M Consultants, Inc 1983
106		ice jam	5/10/1982	R&M Consultants, Inc 1983
107		3-day ice jam over one mile in length	Winter 1981	Schoch 1983a
107		ice jam with 10-15 of water level rise	5/12/1982	R&M Consultants, Inc 1983
109		ice jam and railroad damage	5/12/1982	R&M Consultants, Inc 1983
110		erosion and vegetation damage from ice in mid-river islands	5/27/1982	R&M Consultants, Inc 1983

River Mile	Location Information	Observations Made	Date of Observation	Reference Document
110.4		Historical flood damage during breakup		R&M Consultants, Inc 1981
110.4		Significant ice scouring (through RM 113)	May 1976	R&M Consultants, Inc 1981
112.5	Slough 6A	Major ice jam during breakup	07 May 1983	Schoch 1983b
113		Breakup ice jam	Spring 1985	Schoch 1985
113		Major ice jam during breakup	06 May 1983	Schoch 1983b
113.2		Breakup ice jam	04 May 1983	LaBelle 1984
113.5		Grounded ice jam	Spring 1983	Schoch 1983b
115		ice jam	5/10/1982	R&M Consultants, Inc 1983
116		ice jam	5/10/1982	R&M Consultants, Inc 1983
117		ice jam	5/10/1982	R&M Consultants, Inc 1983
117		ice jam and railroad damage	5/12/1982	R&M Consultants, Inc 1983
117.2		Historical flood damage during breakup		R&M Consultants, Inc 1981
118		ice jam and railroad damage	5/12/1982	R&M Consultants, Inc 1983
118.4		Ice jam (through RM 123)	May 1976	R&M Consultants, Inc 1981
118.8		Historical flood damage during breakup		R&M Consultants, Inc 1981
118.9		Breakup ice jam	Spring 1985	Schoch 1985
119.4		Breakup ice jam (through RM 120.5)	Spring 1983	LaBelle 1984
119.5		Breakup ice jam	04 May 1983	Schoch 1983b
120		Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1983b
120.5		Breakup ice jam	04 May 1983	Schoch 1983b
120.5		Breakup ice jam	Spring 1985	Schoch 1985
120.5		Major ice jam during breakup	06 May 1983	Schoch 1983b
120.9	Deadhorse Creek	mile-long ice jam	5/17/1982	R&M Consultants, Inc 1983
121.9		Breakup ice jam	Spring 1985	Schoch 1985
122		Breakup ice jam	04 May 1983	Schoch 1983b

River Mile	Location Information	Observations Made	Date of Observation	Reference Document
122		Major ice jam during breakup	06 May 1983	Schoch 1983b
122		Major ice jam during breakup (1 mile long)	07 May 1983	Schoch 1983b
122.5		ice jam and railroad damage	5/15/1982	R&M Consultants, Inc 1983
123	Slough 7	sloughs regularly flooded during breakup	Spring 1983	LaBelle 1984
124.5		Major ice jam during breakup	06 May 1983	Schoch 1983b
125		severe ice jam redirecting flow into Slough 8	5/15/1982	R&M Consultants, Inc 1983
126		Breakup ice jam	06 May 1983	Schoch 1983b
126.4		Breakup ice jam	23 May 1985	Schoch 1985
127	Slough 8, 8A	slough regularly flooded during breakup	Spring 1983	LaBelle 1984
127.5		Historical flood damage during breakup		R&M Consultants, Inc 1981
128		Breakup dry jam - diverted flows to side channel	Winter 1982	Schoch 1983b
128	Slough 9	scour and deposition from breakup floods in Slough 9	5/27/1982	R&M Consultants, Inc 1983
128.9		Breakup ice jam	Spring 1983	LaBelle 1984
129		Breakup ice jam	04 May 1983	Schoch 1983b
129		ice jam	5/10/1982	R&M Consultants, Inc 1983
129		Major ice jam during breakup	06 May 1983	Schoch 1983b
129		severe ice jam redirected flow into Slough 9, breaching slough berm	5/15/1982	R&M Consultants, Inc 1983
129	Slough 9	sloughs regularly flooded during breakup	Spring 1983	LaBelle 1984
129.4	Slough 9	Side channel regularly flooded during breakup	Spring 1983	LaBelle 1984
130		ice jam	5/10/1982	R&M Consultants, Inc 1983
131	Sherman - Slough 9	Breakup ice jam	Spring 1985	Schoch 1985
131	Sherman - Slough 9	Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1983b
131.3		Breakup ice jam	Spring 1983	LaBelle 1984
131.4		Breakup ice jam	04 May 1983	Schoch 1983b
131.4		Side channel regularly flooded during breakup	Spring 1983	LaBelle 1984
131.5	Sherman Creek	Major ice jam during breakup	06 May 1983	Schoch 1983b

River Mile	Location Information	Observations Made	Date of Observation	Reference Document
131.5	Sherman Creek	Major ice jam during breakup (3.5 miles long)	07 May 1983	Schoch 1983b
134.4	Side channel upstream of Slough 10	Breakup ice jam	Spring 1983	LaBelle 1984
134.5		Breakup ice jam	04 May 1983	Schoch 1983b
134.5		Side channel regularly flooded during breakup	Spring 1983	LaBelle 1984
134.9		Breakup ice jam	Spring 1985	Schoch 1985
135.9	Slough 11	Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1983b
135.9	Slough 11	Extreme ice jam created Slough 11	May 1976	Schoch 1983b
136	Slough 11	ice jam flood breached Slough 11	5/12/1982	R&M Consultants, Inc 1983
136.5	Slough 11	Breakup observations	11 Apr - 11 May 1983	Schoch 1983b
139		Breakup ice jam	Spring 1985	Schoch 1985
140.9		Side channel regularly flooded during breakup	Spring 1983	LaBelle 1984
141.7		Breakup ice jam	Spring 1983	LaBelle 1984
141.8		Breakup ice jam	04 May 1983	Schoch 1983b
141.8		Ice jam	Spring 1983	Schoch 1983b
142		Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1983b
142		Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1983b
143.9		Breakup ice jam	Spring 1985	Schoch 1985
144.4	Slough 22	Slough regularly flooded during breakup	Spring 1983	LaBelle 1984
144.9	Slough 22	Breakup ice jam	Spring 1985	Schoch 1985
145.5		Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1983b
147.9	Mouth of Portage Creek	Breakup ice jam	Spring 1985	Schoch 1985
148.8		Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1985
153		ice jam	5/12/1982	R&M Consultants, Inc 1983
184		Major ice jam during breakup	06 May 1983	Schoch 1985
184		Major ice jam during breakup	07 May 1983	Schoch 1985

Table 5.1-3. Open leads mapped March 2, 1983 (Schoch, G.C. 1983)

River Mile	Channel Location	Origin of Lead	Length	Widest Point	Continuous or Discontinuous
85.0	Mainstem	Velocity	550	80	Continuous
87.1	Slough	Velocity	4,500	50	Discontinuous
87.6	Mainstem	Velocity	700	100	Continuous
89.0	Mainstem	Velocity	1,200	100	Continuous
89.3	Side Channel	Velocity	2,500	40	Continuous
89.5	Mainstem	Velocity	1,400	60	Discontinuous
91.0	Mainstem	Velocity	1,700	80	Discontinuous
92.3	Mainstem	Velocity	1,300	110	Discontinuous
93.7	Mainstem	Velocity	3.5	110	Continuous
94.0	Mainstem	Thermal	3,500	20	Discontinuous
95.2	Side Channel	Velocity	2,400	100	Continuous
96.9	Side Channel	Velocity	5,600	150	Discontinuous
97.0	Mainstem	Velocity	1,100	30	Continuous
102.0	Mainstem	Velocity	2,400	100	Discontinuous
102.9	Mainstem	Velocity	600	100	Continuous
103.5	Mainstem	Velocity	1,850	100	Discontinuous
104.1	Mainstem	Velocity	280	70	Continuous
104.5	Mainstem	Velocity	1,700	110	Continuous
104.9	Mainstem	Velocity	900	150	Continuous
105.9	Mainstem	Velocity	1,050	100	Continuous
106.1	Mainstem	Velocity	200	60	Continuous
106.4	Mainstem	Velocity	370	50	Continuous
106.6	Mainstem	Velocity	350	50	Discontinuous
107.4	Mainstem	Velocity	200	50	Continuous
109.1	Mainstem	Velocity	550	100	Discontinuous
110.3	Mainstem	Velocity	150	100	Discontinuous
110.4	Mainstem	Velocity	290	50	Continuous
110.9	Mainstem	Velocity	450	50	Discontinuous
111.5	Mainstem	Velocity	1,600	100	Continuous
111.7	Mainstem	Velocity	500	90	Continuous
111.9	Mainstem	Velocity	900	150	Continuous
112.5	Mainstem	Velocity	700	100	Discontinuous
112.9	Mainstem	Velocity	500	110	Continuous
113.8	Mainstem	Velocity	600	110	Continuous
117.4	Mainstem	Thermal	780	60	Continuous
117.9	Side Channel	Thermal	1,260	120	Discontinuous
119.6	Side Channel	Thermal	550	50	Continuous
119.7	Mainstem	Velocity	350	50	Continuous

River Mile	Channel Location	Origin of Lead	Length	Widest Point	Continuous or Discontinuous
120.3	Mainstem	Velocity	800	100	Continuous
121.1	Mainstem	Velocity	550	100	Continuous
121.8	Side Channel	Thermal	1,450	30	Discontinuous
122.4	Slough (7)	Thermal	1,850	60	Discontinuous
122.5	Slough (7)	Thermal	380	50	Continuous
122.9	Slough (7)	Thermal	1,950	80	Discontinuous
123.1	Mainstem	Velocity	1,000	80	Continuous
123.9	Side Channel	Thermal	200	50	Continuous
124.4	Side Channel	Velocity	270	40	Continuous
124.9	Mainstem	Thermal	600	90	Continuous
125.3	Slough (8)	Thermal	3,500	50	Discontinuous
125.5	Mainstem	Velocity	2,140	100	Continuous
125.5	Slough (8)	Thermal	800	500	Continuous
125.6	Mainstem	Velocity	350	60	Continuous
125.9	Slough (8)	Thermal	580	50	Continuous
126.1	Slough (8)	Thermal	500	30	Continuous
126.3	Slough (8)	Thermal	250	50	Continuous
126.8	Slough (8)	Thermal	1,500	80	Discontinuous
127.2	Side Channel	Thermal	2,450	50	Continuous
127.5	Mainstem	Velocity	700	80	Continuous
128.5	Side Channel	Thermal	1,210	30	Discontinuous
128.8	Side Channel	Thermal	380	20	Continuous
128.9	Slough (9)	Thermal	5,060	100	Continuous
129.2	Slough	Thermal	4,000	30	Discontinuous
130.0	Mainstem	Velocity	600	90	Continuous
130.7	Mainstem	Velocity	150	50	Continuous
130.8	Side Channel	Thermal	5,000	50	Discontinuous
131.1	Mainstem	Velocity	490	90	Continuous
131.3	Mainstem	Velocity	800	100	Continuous
131.4	Side Channel	Thermal	900	90	Discontinuous
131.5	Side Channel	Thermal	5,000	80	Discontinuous
132.0	Mainstem	Velocity	150	20	Continuous
132.1	Mainstem	Velocity	500	20	Discontinuous
132.3	Mainstem	Velocity	400	80	Continuous
132.6	Mainstem	Velocity	1,350	80	Continuous
133.1	Slough	Thermal	6,000	60	Continuous
133.7	Mainstem	Velocity	1,110	100	Continuous
134.0	Side Channel	Thermal	1,200	50	Continuous
134.3	Slough (10)	Thermal	4,500	40	Continuous

River Mile	Channel Location	Origin of Lead	Length	Widest Point	Continuous or Discontinuous
134.5	Side Channel	Thermal	850	100	Continuous
135.2	Mainstem	Velocity	1,580	90	Discontinuous
135.4	Slough (11)	Thermal	5,500	80	Continuous
136.0	Mainstem	Velocity	230	80	Continuous
136.3	Side Channel	Thermal	2,050	40	Continuous
136.7	Mainstem	Thermal	1,620	80	Continuous
137.1	Mainstem	Velocity	750	60	Continuous
137.4	Side Channel	Thermal	2,500	20	Discontinuous
137.8	Slough (16)	Thermal	1,400	30	Discontinuous
138.2	Mainstem	Velocity	2,000	150	Continuous
138.9	Mainstem	Thermal	2,100	150	Continuous
139.0	Mainstem	Velocity	780	20	Continuous
139.1	Mainstem	Velocity	500	30	Continuous
139.4	Mainstem	Velocity	600	30	Continuous
140.6	Side Channel	Thermal	1,900	100	Discontinuous
141.0	Slough (20)	Thermal	1,100	20	Continuous
141.5	Mainstem	Velocity	850	40	Continuous
142.0	Mainstem	Velocity	950	50	Continuous
142.0	Slough (21)	Thermal	3,850	40	Discontinuous
142.6	Mainstem	Velocity	1,600	150	Discontinuous
142.8	Mainstem	Velocity	850	150	Continuous
143.6	Mainstem	Velocity	550	20	Discontinuous
143.7	Mainstem	Velocity	280	20	Continuous
143.8	Mainstem	Velocity	780	100	Continuous
143.9	Mainstem	Velocity	500	30	Continuous
144.5	Mainstem	Velocity	900	100	Discontinuous
144.6	Slough (22)	Thermal	250	20	Continuous
144.7	Slough (22)	Thermal	300	20	Continuous
145.5	Mainstem	Velocity	1,150	100	Continuous
146.9	Mainstem	Velocity	700	100	Continuous
147.1	Mainstem	Velocity	850	80	Discontinuous
147.7	Mainstem	Velocity	150	40	Continuous
148.1	Mainstem	Velocity	420	50	Oiscontinuous
148.5	Mainstem	Velocity	680	140	Continuous
149.0	Mainstem	Velocity	400	60	Continuous
149.5	Mainstem	Velocity	500	80	Continuous
150.0	Mainstem	Velocity	350	20	Discontinuous
150.2	Mainstem	Velocity	750	100	Continuous
151.2	Mainstem	Velocity	2,800	100	Discontinuous

Table 5.1-4. Measurements taken on the Susitna River relevant to ice processes prior to 1986.

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
9		Frazil ice porosity	19 Oct 1984	Schoch 1985
9		Frazil ice porosity	26 Oct 1984	Schoch 1985
10	Alexander	Ice thickness	Jan, Mar, May 1972	NWS Alaska-Pacific River Forecast Center
10	Alexander	Ice thickness	Jan-Apr , Dec 1971	NWS Alaska-Pacific River Forecast Center
10	Alexander	Ice thickness	Oct-Nov 1970	NWS Alaska-Pacific River Forecast Center
10	Alexander	Snow depth	Jan, Mar, May 1972	NWS Alaska-Pacific River Forecast Center
10	Alexander	Snow depth	Jan-Apr , Dec 1971	NWS Alaska-Pacific River Forecast Center
10	Alexander	Snow depth	Oct-Nov 1970	NWS Alaska-Pacific River Forecast Center
28	Yentna River	Frazil ice porosity	19 Oct 1984	Schoch 1985
28	Yentna River	Frazil ice porosity	26 Oct 1984	Schoch 1985
29.5		Water temperature	Sep - Oct 1982	Schoch 1983a
40		Freeze-up water level	11 Oct 1985	Schoch 1985
40		Freeze-up water level	29 Oct 1985	Schoch 1985
40		Ice thickness	Feb 1985	Schoch 1985
40		River cross-section	Sep 1984	Schoch 1985
40		Stage and discharge	Oct 1984	Schoch 1985
40		Stage and discharge	Sep 1984	Schoch 1985
40		Water temperature	Oct 1984	Schoch 1985
40		Water temperature	Sep 1984	Schoch 1985
47.8		Freeze-up water level	11 Oct 1985	R&M Consultants, Inc 1986
47.8		Freeze-up water level	29 Oct 1985	R&M Consultants, Inc 1986
47.8		River cross-section	Sep 1984	Schoch 1985
47.9	Both East and West	Air temperature	Oct -Dec 1984	Schoch 1985
47.9	Both East and West	Air temperature	Oct -Dec 1985	Schoch 1985
47.9	Both East and West	Freezing degree days	Oct -Dec 1984	Schoch 1985
47.9	Both East and West	Freezing degree days	Oct -Dec 1985	Schoch 1985
47.9	Both East and West	Stage and discharge	Sep - Nov 1984	Schoch 1985
47.9	Both East and West	Water temperature	Sep - Nov 1984	Schoch 1985

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
48	Delta Islands	Ice thickness	Feb 1985	Schoch 1985
59.7	Rustic Wilderness Side Channel	Freeze-up water level	29 Oct 1985	R&M Consultants, Inc 1986
59.7	Rustic Wilderness Side Channel	Freeze-up water level	11 Oct 1985	R&M Consultants, Inc 1986
59.7	Rustic Wilderness Side Channel	River cross-section	Sep 1984	Schoch 1985
59.7	Rustic Wilderness Side Channel	Stage and discharge	Sep - Nov 1984	Schoch 1985
59.7	Rustic Wilderness Side Channel	Water temperature	Sep - Nov 1984	Schoch 1985
60		Ice thickness	Feb 1985	Schoch 1985
60		Frazil ice porosity	03 Nov 1984	Schoch 1985
76.8		Freeze-up water level	11 Oct 1985	R&M Consultants, Inc 1986
76.8		Freeze-up water level	29 Oct 1985	R&M Consultants, Inc 1986
76.8		River cross-section	Sep 1984	Schoch 1985
76.8		Stage and discharge	Sep - Nov 1984	Schoch 1985
76.8		Water temperature	Sep - Nov 1984	Schoch 1985
77		Ice thickness	Feb 1985	Schoch 1985
78		Frazil ice porosity	03 Nov 1984	Schoch 1985
83.9		Water temperature	Sep - Oct 1982	Schoch 1983a
84		Freeze-up water level	06 Nov 1985	R&M Consultants, Inc 1986
84		Freeze-up water level	11 Oct 1985	R&M Consultants, Inc 1986
84		Freeze-up water level	21 Nov 1985	R&M Consultants, Inc 1986
84		Freeze-up water level	29 Oct 1985	R&M Consultants, Inc 1986
84.6		River cross-section	Sep 1984	Schoch 1985
84.6		Stage and discharge	Jun-Oct 1984	Schoch 1985
84.6		Water temperature	Jun-Oct 1984	Schoch 1985
86.3		River cross-section	Sep 1984	Schoch 1985
86.3		Stage and discharge	Jun-Nov 1984	Schoch 1985
86.3		Water temperature	Jun-Nov 1984	Schoch 1985
87.8		River cross-section	Sep 1984	Schoch 1985
87.8		Stage and discharge	Jun-Oct 1984	Schoch 1985

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
87.8		Water temperature	Jun-Oct 1984	Schoch 1985
90		River cross-section	Sep 1984	Schoch 1985
90		Stage and discharge	Jun, Aug-Nov 1984	Schoch 1985
90		Water temperature	Jun, Aug-Nov 1984	Schoch 1985
91.6		Ice thickness	1967-1971	LaBelle 1984
91.7		River cross-section	Sep 1984	Schoch 1985
91.7		Stage and discharge	Jun-Nov 1984	Schoch 1985
91.7		Water temperature	Jun-Nov 1984	Schoch 1985
93.1		Freeze-up water level	06 Nov 1985	R&M Consultants, Inc 1986
93.1		Freeze-up water level	11 Oct 1985	R&M Consultants, Inc 1986
93.1		Freeze-up water level	29 Oct 1985	R&M Consultants, Inc 1986
93.3	Both East and West	River cross-section	Sep 1984	Schoch 1985
93.3	Both East and West	Stage and discharge	Jun-Nov 1984	Schoch 1985
93.3	Both East and West	Water temperature	Jun-Nov 1984	Schoch 1985
95.9		River cross-section	Sep 1984	Schoch 1985
95.9		Stage and discharge	Sep-Oct 1984	Schoch 1985
95.9		Water temperature	Sep-Oct 1984	Schoch 1985
97		Air temperature	Oct - Dec 1984	Schoch 1985
97		Air temperature	Sep - Oct, Dec 1985	Schoch 1985
97		Freezing degree days	Oct - Dec 1984	Schoch 1985
97		Freezing degree days	Sep - Oct, Dec 1985	Schoch 1985
97		Freezing degree days	Sep-May 1980-1983	Schoch 1985
97		Ice thickness	1961-1966	LaBelle 1984
97		Frazil ice porosity	19 Oct 1984	Schoch 1985
97		Frazil ice porosity	26 Oct 1984	Schoch 1985
97.1		River cross-section	Sep 1984	Schoch 1985
97.1		Stage and discharge	Sep-Oct 1984	Schoch 1985
97.1		Water temperature	Sep-Oct 1984	Schoch 1985

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
98		River cross-section	Sep 1984	Schoch 1985
98		Stage and discharge	Sep-Oct 1984	Schoch 1985
98		Water temperature	Sep-Oct 1984	Schoch 1985
98.5		Ice thickness	04 Feb 1983	Schoch 1983b
98.5		Ice thickness	12 Apr 1983	Schoch 1983b
98.5		Freeze-up water level	Winter 1982	Schoch 1983
98.5		Frazil ice porosity	03 Nov 1984	Schoch 1985
98.5		Frazil ice porosity	19 Oct 1984	Schoch 1985
98.5		Frazil ice porosity	26 Oct 1984	Schoch 1985
98.6		Breakup ice thickness	28 Apr 1983	Schoch 1983b
98.6		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
98.6		Freeze-up water level	Winter 1982	LaBelle 1984
98.6		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
99.6		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
99.6		Rating curves	Winter 1981	R&M Consultants, Inc 1982
99.6		Crest gage	Winter 1980	R&M Consultants, Inc 1982
99.6		Crest gage	Winter 1981	R&M Consultants, Inc 1982
99.6		Freeze-up water level	Winter 1981	R&M Consultants, Inc 1982
100.4		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
100.4		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
101		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
101		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
101.5		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
102.4		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
102.4		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
103		Surface water temperature	Sep - Oct 1982	Schoch 1983a
103.2	Talkeetna Fish Camp	Intragravel water temperature	Winter 1983	Keklak and Quane 1984
103.2	Talkeetna Fish Camp	Surface water temperature	Winter 1983	Keklak and Quane 1984
103.3		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
103.3		Breakup ice thickness	28-30 Apr 1983	Schoch 1983b
103.3		Ice thickness	05 Mar 1981	R&M Consultants, Inc 1981
103.3		Ice thickness	Winter 1982	LaBelle 1984
103.3		Rating curves	Winter 1981	R&M Consultants, Inc 1982
103.3		Freeze-up water level	1980, 1982, 1983	R&M Consultants, Inc 1986
103.3		Crest gage	Winter 1980	R&M Consultants, Inc 1982
103.3		Crest gage	Winter 1981	R&M Consultants, Inc 1982
103.3		Freeze-up water level	Winter 1981	R&M Consultants, Inc 1982
104.8		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
104.8		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
104.8		Freeze-up water level	07 Oct 1980	R&M Consultants, Inc 1981
106.2		Freeze-up water level	Winter 1982	Schoch 1983a
106.2		Freeze-up water level	Winter 1982	LaBelle 1984
106.2		Freeze-up water level	Winter 1983	LaBelle 1984
106.7		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
106.7		Breakup ice thickness	28-30 Apr 1983	R&M Consultants, Inc 1982
106.7		Breakup water level	28-30 Apr 1983	R&M Consultants, Inc 1982
106.7		Freeze-up water level	02 Dec 1980	R&M Consultants, Inc 1981
106.7		Freeze-up water level	07 Oct 1980	R&M Consultants, Inc 1981
108		Ice thickness	Winter 1980	LaBelle 1984
108.4		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
108.4		Freeze-up water level	02-03 Dec 1980	R&M Consultants, Inc 1981
108.4		Freeze-up water level	07 Oct 1980	R&M Consultants, Inc 1981
110.4		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
110.4		Freeze-up water level	02-03 Dec 1980	R&M Consultants, Inc 1981
110.4		Freeze-up water level	07 Oct 1980	R&M Consultants, Inc 1981
110.9		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
111.8		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
112.3		Bed material distribution	Winter 1981	LaBelle 1984
112.3		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
112.3		Freeze-up water level	03 Dec 1980	R&M Consultants, Inc 1981
112.3		Freeze-up water level	07 Oct 1980	R&M Consultants, Inc 1981
112.7		Freeze-up water level	03 Dec 1980	R&M Consultants, Inc 1982
112.7		Freeze-up water level	07 Oct 1980	R&M Consultants, Inc 1981
113		Freeze-up water level	06 Nov 1985	R&M Consultants, Inc 1986
113		Freeze-up water level	21 Nov 1985	R&M Consultants, Inc 1986
113		Ice thickness	Winter 1983	LaBelle 1984
113		Freeze-up water level	Winter 1980	LaBelle 1984
113		Freeze-up water level	Winter 1983	LaBelle 1984
113		Freeze-up water level	03 Dec 1980	R&M Consultants, Inc 1981
113		Freeze-up water level	07 Oct 1980	R&M Consultants, Inc 1981
113.2		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
113.2		Freeze-up water level	03 Dec 1980	R&M Consultants, Inc 1981
113.2		Freeze-up water level	07 Oct 1980	R&M Consultants, Inc 1982
113.7		Breakup ice thickness	28 Apr - 02 May 1983	Schoch 1983b
113.7		Freeze-up water level	06 Nov 1985	R&M Consultants, Inc 1986
113.7		Freeze-up water level	21 Nov 1985	R&M Consultants, Inc 1986
113.7		Freeze-up water level	Winter 1982	Schoch 1983b
113.7		Freeze-up water level	Winter 1982	LaBelle 1984
116.4		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
116.4		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
116.7		Freeze-up water level	Winter 1982	Schoch 1983b
117.2		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
119.3		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
119.4		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
120.3		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
120.4		Breakup ice thickness	28 Apr - 01 May 1983	Schoch 1983b
120.4		Breakup water level	28 Apr - 01 May 1983	Schoch 1983b
120.4		Freeze-up water level	Winter 1982	LaBelle 1984
120.4		Freeze-up water level	Winter 1983	LaBelle 1984
120.5		Ice thickness	Winter 1980	LaBelle 1984
120.5		Ice thickness	Winter 1981	LaBelle 1984
120.5		Ice thickness	Winter 1982	LaBelle 1984
120.5		Ice thickness	Winter 1983	LaBelle 1984
120.7		Ice thickness	04 Feb 1983	Schoch 1983b
120.7		Ice thickness	12 Apr 1983	Schoch 1983b
120.7		Rating curves	Winter 1981	R&M Consultants, Inc 1982
120.7		Freeze-up water level	Winter 1982	Schoch 1983a
120.7		Surface water temperature	Sep - Oct 1982	Schoch 1983a
120.7		Crest gage	Winter 1980	R&M Consultants, Inc 1982
120.7		Crest gage	Winter 1981	R&M Consultants, Inc 1982
120.7		Freeze-up water level	Winter 1981	R&M Consultants, Inc 1982
120.9		Frazil ice porosity	14 Nov 1984	Schoch 1985
120.9		Surface water temperature	Winter 1983	Schoch 1983b
120.9		Water quality data	Winter 1983	Keklak and Quane 1984
122.6		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
123.2		Freeze-up water level	Winter 1980	LaBelle 1984
123.2		Freeze-up water level	Winter 1983	LaBelle 1984
123.3		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
123.3		Freeze-up water level	05 Dec 1985	R&M Consultants, Inc 1986
123.3		Ice thickness	Winter 1983	LaBelle 1984
123.3		Freeze-up water level	06 Nov 1980	R&M Consultants, Inc 1981
123.3		Freeze-up water level	07 Nov 1980	R&M Consultants, Inc 1981
123.3		Freeze-up water level	08 Dec 1980	R&M Consultants, Inc 1981

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
124.4		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
124.4		Breakup ice thickness	28-30 Apr 1983	Schoch 1983b
124.4		Breakup ice thickness	Winter 1981	R&M Consultants, Inc 1982
124.4		Freeze-up water level	06 - 07 Nov 1980	R&M Consultants, Inc 1981
124.4		Crest gage	Winter 1980	R&M Consultants, Inc 1982
124.4		Crest gage	Winter 1981	R&M Consultants, Inc 1982
124.4		Freeze-up water level	Winter 1980	LaBelle 1984
124.4		Freeze-up water level	Winter 1982	LaBelle 1984
124.4		Freeze-up water level	06 Nov 1980	R&M Consultants, Inc 1981
124.4		Freeze-up water level	07 Nov 1980	R&M Consultants, Inc 1981
124.4		Freeze-up water level	08 Dec 1980	R&M Consultants, Inc 1981
124.4		Freeze-up water level	Winter 1981	R&M Consultants, Inc 1982
124.5		Frazil ice porosity	14 Nov 1984	Schoch 1985
125.5		Freeze-up water level	Winter 1982	Schoch 1983a
125.6		Intragravel water temperature	Winter 1983	Keklak. and Quane 1984
125.6		Surface water temperature	Winter 1983	Keklak and Quane 1984
126		Freeze-up water level	Winter 1980	LaBelle 1984
126		Freeze-up water level	Winter 1983	LaBelle 1984
126.1		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
126.1		Freeze-up water level	06 Nov 1985	R&M Consultants, Inc 1986
126.1		Freeze-up water level	21 Nov 1985	Schoch 1985
126.1		Ice thickness	Winter 1983	LaBelle 1984
126.1		Intragravel water temperature	Winter 1983	Keklak and Quane 1984
126.1		Surface water temperature	Winter 1983	Keklak and Quane 1984
126.1		Surface water temperature	Sep-Oct 1982	Schoch 1983b
126.1		Freeze-up water level	06 Nov 1980	R&M Consultants, Inc 1981
126.1		Freeze-up water level	07 Nov 1980	R&M Consultants, Inc 1981

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
126.1		Freeze-up water level	08 Dec 1980	R&M Consultants, Inc 1981
126.6	Slough 8A	Intragravel water temperature	Winter 1983	Keklak and Quane 1984
126.6	Slough 8A	Surface water temperature	Winter 1983	Keklak and Quane 1984
126.9		Breakup ice thickness	28 Apr - 04 May 1983	Schoch 1983b
126.9		Breakup ice thickness	Winter 1982	LaBelle 1984
126.9		Breakup water level	28 Apr - 04 May 1983	Schoch 1983b
127		Freeze-up water level	Winter 1982	Schoch 1983b
127.5		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
127.5		Freeze-up water level	06 Nov 1980	R&M Consultants, Inc 1981
127.5		Freeze-up water level	07 Nov 1980	R&M Consultants, Inc 1981
127.5		Freeze-up water level	08 Dec 1980	R&M Consultants, Inc 1981
128.2		Breakup ice thickness	27-30 Apr 1983	Schoch 1983b
128.2		Breakup ice thickness	Winter 1982	LaBelle 1984
128.2		Breakup water level	27-30 Apr 1983	Schoch 1983b
128.3		Freeze-up water level	Winter 1982	Schoch 1983b
128.4	Slough 9 mouth	Ice thickness	Winter 1983	LaBelle 1984
128.5		Surface water temperature	Winter 1983	Keklak and Quane 1984
128.6		Intragravel water temperature	Winter 1983	Keklak and Quane 1984
128.6		Freeze-up water level	Winter 1980	LaBelle 1984
128.6		Freeze-up water level	Winter 1983	LaBelle 1984
128.6		Surface water temperature	Winter 1983	Keklak and Quane 1984
128.7		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
128.7		Freeze-up water level	06 Nov 1985	R&M Consultants, Inc 1986
128.7		Freeze-up water level	21 Nov 1985	R&M Consultants, Inc 1986
128.7		Freeze-up water level	06 Nov 1980	R&M Consultants, Inc 1981
128.7		Freeze-up water level	07 Nov 1980	R&M Consultants, Inc 1981

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
128.7		Freeze-up water level	08 Dec 1980	R&M Consultants, Inc 1981
129.7		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
130.8		Breakup ice thickness	27-30 Apr 1983	Schoch 1983b
130.8		Breakup ice thickness	Winter 1982	LaBelle 1984
130.8		Breakup water level	27-30 Apr 1983	Schoch 1983b
130.8		Ice thickness	05 Mar 1981	R&M Consultants, Inc 1981
130.8		Ice thickness	05 May 1983	Schoch 1983b
130.8		Freeze-up water level	Winter 1983	LaBelle 1984
130.8		Freeze-up water level	05 May 1983	Schoch 1983b
130.9		Ice thickness	Winter 1984	Schoch 1985
130.9		Stage and discharge	Jul - Nov 1980	R&M Consultants, Inc 1982
130.9		Rating curves	Winter 1981	R&M Consultants, Inc 1982
130.9		Freeze-up water level	Winter 1982	Schoch 1983b
130.9		Freeze-up water level	Winter 1980	LaBelle 1984
130.9		Freeze-up water level	Winter 1981	R&M Consultants, Inc 1982
131	Sherman - Slough 9	Freezing degree days	Sep-May 1982	Schoch 1985
131	Sherman - Slough 9	Freezing degree days	Sep-May 1983	Schoch 1985
131	Sherman - Slough 9	Freezing degree days	Sep-May 1984	Schoch 1985
131	Sherman - Slough 9	Frazil ice porosity	14 Nov 1984	Schoch 1985
131	Sherman - Slough 9	Crest gage	Winter 1980	R&M Consultants, Inc 1982
131	Sherman - Slough 9	Crest gage	Winter 1981	R&M Consultants, Inc 1982
131.1		Intragravel water temperature	Winter 1983	Keklak and Quane 1984
131.1		Surface water temperature	Winter 1983	Keklak and Quane 1984
134		Intragravel water temperature	Winter 1983	Keklak and Quane 1984
134		Surface water temperature	Winter 1983	Keklak and Quane 1984
134.1		Freeze-up water level	Winter 1983	LaBelle 1984
134.2	Side Channel 10	Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
134.2	Side Channel 10	Freeze-up water level	05 Dec 1985	R&M Consultants, Inc 1986

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
135.3		Freeze-up water level	Winter 1982	Schoch 1983a
135.4	Side channel downstream of Slough 11	Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
135.5		Intragravel water temperature	Winter 1983	Keklak and Quane 1984
135.7		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
135.7		Intragravel water temperature	Winter 1983	Keklak and Quane 1984
135.7		Surface water temperature	Winter 1983	Keklak and Quane 1984
135.7		Freeze-up water level	12 Dec 1980	R&M Consultants, Inc 1981
135.7		Freeze-up water level	Oct 1980	R&M Consultants, Inc 1981
136.1		Intragravel water temperature	Winter 1983	Keklak and Quane 1984
136.1		Surface water temperature	Winter 1983	Keklak and Quane 1984
136.3		Breakup ice thickness	27 Apr - 03 May 1983	Schoch 1983b
136.3		Breakup ice thickness	Winter 1983	Keklak and Quane 1984
136.3		Breakup water level	27 Apr - 03 May 1983	Schoch 1983
136.3		Surface water temperature	Winter 1983	Keklak and Quane 1984
136.5	Slough 11	Bed material distribution	Winter 1983	Schoch 1985
136.5	Slough 11	Breakup ice thickness	27 Apr - 10 May 1983	Schoch 1983b
136.5	Slough 11	Breakup ice thickness	27 Feb 1981	R&M Consultants, Inc 1981
136.5	Slough 11	Breakup water level	27 Apr - 10 May 1983	Schoch 1983b
136.5	Slough 11	Freeze-up water level	06 Nov 1985	R&M Consultants, Inc 1986
136.5	Slough 11	Freeze-up water level	11 Oct 1985	R&M Consultants, Inc 1986
136.5	Slough 11	Freeze-up water level	21 Nov 1985	R&M Consultants, Inc 1986
136.5	Slough 11	Freeze-up water level	29 Oct 1985	R&M Consultants, Inc 1986
136.5	Slough 11	General met observations	01 Oct - 02 Dec 1985	R&M Consultants, Inc 1986
136.5	Slough 11	Ice thickness	04 Feb 1983	Schoch 1983b
136.5	Slough 11	Ice thickness	12 Apr 1983	Schoch 1983b
136.5	Slough 11	Ice thickness	12 Dec 1980	R&M Consultants, Inc 1981
136.5	Slough 11	Ice thickness	14 Jan 1981	R&M Consultants, Inc 1981

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
136.5	Slough 11	Ice thickness	1950-1956	R&M Consultants, Inc 1981
136.5	Slough 11	Ice thickness	1963-1967	R&M Consultants, Inc 1981
136.5	Slough 11	Ice thickness	1969-1970	R&M Consultants, Inc 1981
136.5	Slough 11	Ice thickness	Winter 1961	R&M Consultants, Inc 1981
136.5	Slough 11	Ice thickness	Winter 1970	R&M Consultants, Inc 1981
136.5	Slough 11	Ice thickness	Winter 1980	LaBelle 1984
136.5	Slough 11	Ice thickness	Winter 1981	LaBelle 1984
136.5	Slough 11	Ice thickness	Winter 1982	LaBelle 1984
136.5	Slough 11	Ice thickness	Winter 1983	LaBelle 1984
136.5	Slough 11	Frazil ice porosity	19 Oct 1984	Schoch 1985
136.5	Slough 11	Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
136.5	Slough 11	Freeze-up water level	Winter 1982	R&M Consultants, Inc 1982
136.5	Slough 11	Freeze-up water level	Winter 1983	R&M Consultants, Inc 1982
136.5	Slough 11	Stream flow measurements	Sep 1980 - May 1981 (no Dec)	R&M Consultants, Inc 1981
136.5	Slough 11	Freeze-up water level	12 Dec 1980	R&M Consultants, Inc 1981
136.5	Slough 11	Freeze-up water level	Oct 1980	R&M Consultants, Inc 1981
136.6		Freeze-up water level	Winter 1982	Schoch 1983b
136.7	Gold Creek	Rating curves	Winter 1981	R&M Consultants, Inc 1982
136.7	Gold Creek	Discharge	Winter 1980	R&M Consultants, Inc 1982
136.7	Gold Creek	Discharge	Winter 1981	R&M Consultants, Inc 1982
136.7	Gold Creek	Freeze-up water level	12 Dec 1980	R&M Consultants, Inc 1981
136.7	Gold Creek	Freeze-up water level	Oct 1980	R&M Consultants, Inc 1981
136.7	Gold Creek	Freeze-up water level	Winter 1981	R&M Consultants, Inc 1982
137		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
137		Freeze-up water level	12 Dec 1980	R&M Consultants, Inc 1981
137		Freeze-up water level	Oct 1980	R&M Consultants, Inc 1981
137.2		Freeze-up water level	12 Dec 1980	R&M Consultants, Inc 1981
137.2		Freeze-up water level	Oct 1980	R&M Consultants, Inc 1981
137.4		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
137.4		Freeze-up water level	12 Dec 1980	R&M Consultants, Inc 1981

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
137.4		Freeze-up water level	Oct 1980	R&M Consultants, Inc 1981
138.2		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
138.5		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
138.6	Indian River	Intragravel water temperature	Winter 1983	Keklak and Quane 1984
138.6	Indian River	Surface water temperature	Winter 1983	Keklak and Quane 1984
138.9		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
140.2		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
140.8		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
140.8		Breakup ice thickness	27 Apr - 03 May 1983	Schoch 1983b
140.8		Breakup ice thickness	Winter 1982	Schoch 1983b
140.8		Breakup water level	27 Apr - 03 May 1983	Schoch 1983b
141		Intragravel water temperature	Winter 1983	Keklak and Quane 1984
141		Surface water temperature	Winter 1983	Keklak and Quane 1984
141.5		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
141.8		Intragravel water temperature	Winter 1983	Keklak and Quane 1984
141.8		Surface water temperature	Winter 1983	Keklak and Quane 1984
142		Intragravel water temperature	Winter 1983	Keklak and Quane 1984
142		Surface water temperature	Winter 1983	Keklak and Quane 1984
142.1		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
142.3	Slough 21	Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
142.3	Slough 21	Breakup ice thickness	27 Apr - 02 May 1983	Schoch 1983b
142.3	Slough 21	Breakup ice thickness	Winter 1983	Keklak and Quane 1984
142.3	Slough 21	Breakup water level	27 Apr - 02 May 1983	Schoch 1983b
142.3	Slough 21	Freeze-up water level	Winter 1982	Schoch 1983b
142.3	Slough 21	Surface water temperature	Winter 1983	Keklak and Quane 1984
143.2		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
144.8		Bed material distribution	Winter 1981	R&M Consultants, Inc 1982
148.8		Breakup ice thickness	27 Apr - 02 May 1983	Schoch 1983b
148.8		Breakup ice thickness	Winter 1982	LaBelle 1984
148.8		Breakup water level	27 Apr - 02 May 1983	Schoch 1983b
148.8		Ice thickness	05 Mar 1981	R&M Consultants, Inc 1981
148.8		Freeze-up water level	Winter 1982	LaBelle 1984
148.9		Ice thickness	04 Feb 1983	Schoch 1983b
148.9		Ice thickness	12 Apr 1983	Schoch 1983b
148.9		Rating curves	Winter 1981	R&M Consultants, Inc 1982
148.9		Freeze-up water level	Winter 1982	Schoch 1983b
148.9		Crest gage	Winter 1980	R&M Consultants, Inc 1982
148.9		Crest gage	Winter 1981	R&M Consultants, Inc 1982
148.9		Freeze-up water level	Winter 1981	R&M Consultants, Inc 1982
149.7		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
149.9		Freezing degree days	Winter 1980	Schoch 1983a
149.9		Freezing degree days	Winter 1981	Schoch 1983a
149.9		Freezing degree days	Winter 1982	Schoch 1985
149.9		Ice thickness	13 Apr 1981	R&M Consultants, Inc 1981
150.1	Devils Canyon, mouth	Surface water temperature	Winter 1982	Schoch 1983a
150.2		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
150.2		Rating curves	Winter 1981	R&M Consultants, Inc 1982
150.2		Staff gage	Installed Apr 1981	R&M Consultants, Inc 1982
150.2		Freeze-up water level	Winter 1981	R&M Consultants, Inc 1982
151		Freeze-up water level	Winter 1980	R&M Consultants, Inc 1982
162.1		Ice thickness	13 Mar 1981	R&M Consultants, Inc 1981
162.1		Rating curves	Winter 1981	R&M Consultants, Inc 1982
162.1		Crest gage	Winter 1980	R&M Consultants, Inc 1982
162.1		Crest gage	Winter 1981	R&M Consultants, Inc 1982
162.1		Freeze-up water level	Winter 1981	R&M Consultants, Inc 1982
167		Ice thickness	12 Mar 1981	R&M Consultants, Inc 1981
173.1		Ice thickness	12 Mar 1981	R&M Consultants, Inc 1981

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
174		Ice thickness	11 Mar 1981	R&M Consultants, Inc 1981
176		Ice thickness	11 Mar 1981	R&M Consultants, Inc 1981
176.7		Ice thickness	11 Mar 1981	R&M Consultants, Inc 1981
178.8		Ice thickness	10 Mar 1981	R&M Consultants, Inc 1981
180.1		Ice thickness	09 Mar 1981	R&M Consultants, Inc 1981
181		Ice thickness	09 Mar 1981	R&M Consultants, Inc 1981
181.8		Ice thickness	08 Mar 1981	R&M Consultants, Inc 1981
182.1		Air temperature	Oct - Dec 1984	Schoch 1985
182.1		Air temperature	Sep - Dec 1985	R&M Consultants, Inc 1982
182.1		Freezing degree days	Oct - Dec 1984	Schoch 1985
182.1		Freezing degree days	Sep - Dec 1985	R&M Consultants, Inc 1982
182.1		Ice thickness	01 Apr 1981	R&M Consultants, Inc 1981
182.1		Rating curves	Winter 1981	R&M Consultants, Inc 1982
182.1		Discharge	Winter 1980	R&M Consultants, Inc 1982
182.1		Discharge	Winter 1981	R&M Consultants, Inc 1982
182.1		Freeze-up water level	Winter 1981	R&M Consultants, Inc 1982
182.5		Ice thickness	08 Mar 1981	R&M Consultants, Inc 1981
182.8		Ice thickness	07 Mar 1981	R&M Consultants, Inc 1981
183.5		Ice thickness	07 Mar 1981	R&M Consultants, Inc 1981
183.8		Ice thickness	07 Mar 1981	R&M Consultants, Inc 1981
184		Air temperature	Oct - Dec 1984	Schoch 1985
184		Air temperature	Sep - Dec 1985	R&M Consultants, Inc 1982
184		Freezing degree days	Oct - Dec 1984	Schoch 1985
184		Freezing degree days	Sep - Dec 1985	R&M Consultants, Inc 1982
184		Freezing degree days	Winter 1980	Schoch 1985
184		Freezing degree days	Winter 1981	Schoch 1985
184		Freezing degree days	Winter 1982	Schoch 1985
184		Ice thickness	04 Feb 1983	Schoch 1983b
184		Ice thickness	12 Apr 1983	Schoch 1983b
184		Ice thickness	27 Feb 1981	R&M Consultants, Inc 1981
184		Frazil ice porosity	19 Oct 1984	Schoch 1985
184.2	Watana Dam Site	Ice thickness	06 Apr 1981	R&M Consultants, Inc 1981
184.4		Ice thickness	06 Apr 1981	R&M Consultants, Inc 1981
184.4		Rating curves	Winter 1981	R&M Consultants, Inc 1982
184.4		Crest gage	Winter 1980	R&M Consultants, Inc 1982

River Mile	Location Information	Data Collected	Date of Measurement	Reference Document
184.4		Crest gage	Winter 1981	R&M Consultants, Inc 1982
184.4		Water surface elevations	Winter 1981	R&M Consultants, Inc 1982
184.8		Ice thickness	05 Apr 1981	R&M Consultants, Inc 1981
185.4		Ice thickness	05 Apr 1981	R&M Consultants, Inc 1981
185.9		Ice thickness	04 Apr 1981	R&M Consultants, Inc 1981
186.5		Ice thickness	04 Apr 1981	R&M Consultants, Inc 1981
186.8		Ice thickness	04 Apr 1981	R&M Consultants, Inc 1981
186.8		Rating curves	Winter 1981	R&M Consultants, Inc 1982
186.8		Crest gage	Winter 1980	R&M Consultants, Inc 1982
186.8		Crest gage	Winter 1981	R&M Consultants, Inc 1982
186.8		Water surface elevations	Winter 1981	R&M Consultants, Inc 1982
223	Vee Canyon	Stage and Discharge	1961-1972, 1980-1986	USGS Surface Water Data Collection Program
281	Denali Highway	Stage and Discharge	1956-1986	USGS Surface Water Data Collection Program
281	Denali Highway	Frazil ice Porosity	10/19/1984	Schoch, G.C. 1985

Table 5.1-5. Documentation of Ice Processes Effects on Riparian Vegetation, Geomorphology, and Aquatic Habitat

River Mile	Location Information	Observations Made	Date of Observation	Reference Document
Ice Effects on Vegetation and LWD Recruitment				
85.5		Ice jam - flood released logs stranded from summertime flooding	04 May 1983	Schoch 1984
89		Ice jam - flood released logs stranded from summertime flooding	04 May 1983	Schoch 1984
101.5		Ice scarring on trees following ice jam release	May, 1981	R&M Consultants, Inc 1981
103		Flooded vegetation during ice jam	5/5/1981	R&M Consultants, Inc 1981
110		erosion and vegetation removed by ice in mid-river islands. 15-20" cottonwood and birch damaged.	5/27/1982	R&M Consultants, Inc 1983
141		Ice scarred mature cottonwoods 5 ft above ground along Slough 21	5/27/1982	R&M Consultants, Inc 1983
Ice Effects on Geomorphology				
95		severe bank erosion from breakup at outside of bends and cut banks	5/27/1982	R&M Consultants, Inc 1983
97		10-15 feet of bank erosion on left bank from breakup	5/27/1982	R&M Consultants, Inc 1983

River Mile	Location Information	Observations Made	Date of Observation	Reference Document
98		2-3 feet bank erosion from breakup	5/27/1982	R&M Consultants, Inc 1983
102		4-5 feet bank erosion from breakup	5/27/1982	R&M Consultants, Inc 1983
107		ice jam scour on east bank	May 12-15, 1982	R&M Consultants, Inc 1983
110		erosion and vegetation damage from ice in mid-river islands	5/27/1982	R&M Consultants, Inc 1983
110.4		Significant ice scouring (through RM 113)	May 1976	R&M Consultants, Inc 1981
120		Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1984
126.1	Slough 8	Slough breached at freezeup	Fall 1982	LaBelle 1984
128	Slough 9	scour and deposition from breakup floods in Slough 9	5/27/1982	R&M Consultants, Inc 1983
131	Sherman - Slough 9	Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1984
135.9	Slough 11	Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1984
135.9	Slough 11	Extreme ice jam created Slough 11	May 1976	Schoch 1984
136	Slough 11	ice jam flood breached Slough 11	5/12/1982	R&M Consultants, Inc 1983
142	Slough 21	Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1984
145.5		Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1984
148.8		Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1984
Ice Effects on Fish Habitat				
19	Alexander Slough (Upper)	Minimal winter flow from main channel	October, 1982	Schoch 1984
35.2	Hooligan Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
36.2	Eagles Nest Side Channel	Flooded snow during freezeup	Winter 1984	Schoch 1985
36.3	Kroto Slough, head	no winter flow from main channel	Winter 1984	Schoch 1985
39	Rolly Creek, mouth	no winter flow from main channel	Winter 1984	Schoch 1985
40.5	Deshka River	Ice jam at Deshka confluence	May 1980	R&M Consultants, Inc 1981

River Mile	Location Information	Observations Made	Date of Observa tion	Reference Document
43	Bear Bait Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
45.4	Last Chance Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
59.5	Rustic Wilderness Side Channel	overflow into side channel during freeze-up	Winter 1984	Schoch 1985
63	Caswell Creek, mouth	no winter flow from main channel	Winter 1984	Schoch 1985
63.2	Island Side Channel	Flooded snow during freezeup	Winter 1984	Schoch 1985
72	Goose Creek Slough	no winter flow from main channel	Octobe r, 1982	Schoch 1984
74.4	Mainstem West Bank	Flooded snow during freezeup	Winter 1984	Schoch 1985
74.8	Goose 2 Side Channel	overflow into side channel during freeze-up	Winter 1984	Schoch 1985
75.3	Circular Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
77	Montana Creek confluence	Ice jam - flooded Montana Creek confluence	03 May 1983	Schoch 1984
79.8	Sauna Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
83	Rabideaux Slough	Minimal winter flow from main channel	Octobe r, 1982	Schoch 1984
84	Sunshine Slough	Minimal winter flow from main channel	Octobe r, 1982	Schoch 1984
84.5	Sucker Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
86.3	Beaver Dam Slough	no winter flow from main channel	Winter 1984	Schoch 1985
86.9	Sunset Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
87	Sunrise Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
88.4	Birch Creek Slough	no winter flow from main channel	Winter 1984	Schoch 1985
88.4	Birch Creek Slough	Minimal winter flow from main channel	Octobe r, 1982	Schoch 1984
91.6	Trapper Creek Side Channel	no winter flow from main channel	Winter 1984	Schoch 1985
112.5	Slough 6A	Major ice jam during breakup	07 May 1983	Schoch 1984
112.5	Slough 6A	Open slough	Winter 1982-1983	Schoch 1984
112.5	Slough 6A	Open slough	Winter 1983-1984	Schoch 1985

River Mile	Location Information	Observations Made	Date of Observation	Reference Document
122.9	Slough 7	Open slough	Winter 1982-1983	Schoch 1984
125	Slough 8	severe ice jam redirecting flow into Slough 8	5/15/1982	R&M Consultants, Inc 1983
126.1	Slough 8	Slough breached at freezeup	Fall 1982	LaBelle 1984
126.2	Slough 8A	Open slough	Winter 1982-1983	Schoch 1984
126.2	Slough 8A, West Channel	Open slough	Winter 1983-1984	Schoch 1985
127	Slough 8	Open slough -- groundwater upwelling	Winter 1982	LaBelle 1984
127	Slough 8	Side channels and sloughs regularly influenced by ice-induced flooding during breakup (Slough 8 and 8A)	Spring 1983	LaBelle 1984
127.1	Slough 8	Open slough	Winter 1982-1983	Schoch 1984
127.1	Slough 8	Open slough	Winter 1983-1984	Schoch 1985
128	Slough 9	scour and deposition from breakup floods in Slough 9	5/27/1982	R&M Consultants, Inc 1983
129	Slough 9	severe ice jam redirecting flow into Slough 9, breaching slough berm	5/15/1982	R&M Consultants, Inc 1983
129	Slough 9	Side channels and sloughs regularly influenced by ice-induced flooding during breakup (Slough 9)	Spring 1983	LaBelle 1984
129.2	Slough 9	Open slough	Winter 1982-1983	LaBelle 1984
129.4	Slough 9	Side channels and sloughs regularly influenced by ice-induced flooding during breakup (through RM 130.5 - side channel)	Spring 1983	LaBelle 1984
130.7	Side channel upstream of Slough 9	Open leads	Winter 1982	Schoch 1984
130.7	Side channel upstream of Slough 9	Open leads	Winter 1983	Schoch 1985
130.9	Slough 9	Late December open water - some intermediate ice bridges (through RM 135)	Dec 1984	Schoch 1985
131	Sherman - Slough 9	Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1984
131	Sherman - Slough 9	Breakup ice jam	Spring 1985	Schoch 1985

River Mile	Location Information	Observations Made	Date of Observa tion	Reference Document
131	Sherman - Slough 9	Open leads	Winter 1983	Schoch 1985
131.5	Sherman Creek	Major ice jam during breakup (3.5 miles long)	07 May 1983	Schoch 1984
131.5	Sherman Creek	Open leads	Winter 1982	Schoch 1984
131.5	Sherman Creek	Open leads	Winter 1983	Schoch 1985
131.9	Side channel upstream from 4th of July Creek	Open leads	Winter 1982	Schoch 1984
131.9	Side channel upstream from 4th of July Creek	Open leads	Winter 1983	Schoch 1985
134.2	Slough 10	Open slough -- groundwater upwelling	Winter 1982-1983	LaBelle 1984
134.4	Side channel upstream of Slough 10	Breakup ice jam	Spring 1983	LaBelle 1984
134.5	Side Channel 10	Side channels and sloughs regularly influenced by ice-induced flooding during breakup	Spring 1983	LaBelle 1984
135.9	Slough 11	Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1984
135.9	Slough 11	Extreme ice jam created Slough 11	May 1976	Schoch 1984
136	Slough 11	ice jam flood breached Slough 11	5/12/19 82	R&M Consultant s, Inc 1983
136.3	Slough 11	Open slough -- groundwater upwelling	Winter 1982-1983	Schoch 1984
UNK	Slough 16	Open slough -- groundwater upwelling	Winter 1982-1983	Schoch 1984
140.4	Slough 20	Open slough -- groundwater upwelling	Winter 1982-1983	Schoch 1984
141	Slough 21	Side channels and sloughs regularly influenced by ice-induced flooding during breakup	Spring 1983	LaBelle 1984
141.9	Slough 21	Open slough	Winter 1983-1984	Schoch 1985
142	Slough 21	Extensive channel enlargements and small ice jams	27 Apr 1983	Schoch 1984
142.1	Slough 21	Open slough -- groundwater upwelling	Winter 1982-1983	Schoch 1984
144.4	Slough 21	Side channels and sloughs regularly influenced by ice-induced flooding during breakup (Slough 22)	Spring 1983	LaBelle 1984
144.9	Slough 22	Breakup ice jam	Spring 1985	Schoch 1985

River Mile	Location Information	Observations Made	Date of Observation	Reference Document
144.5	Slough 22	Open slough -- groundwater upwelling	Winter 1982-1983	Schoch 1984

9. FIGURES

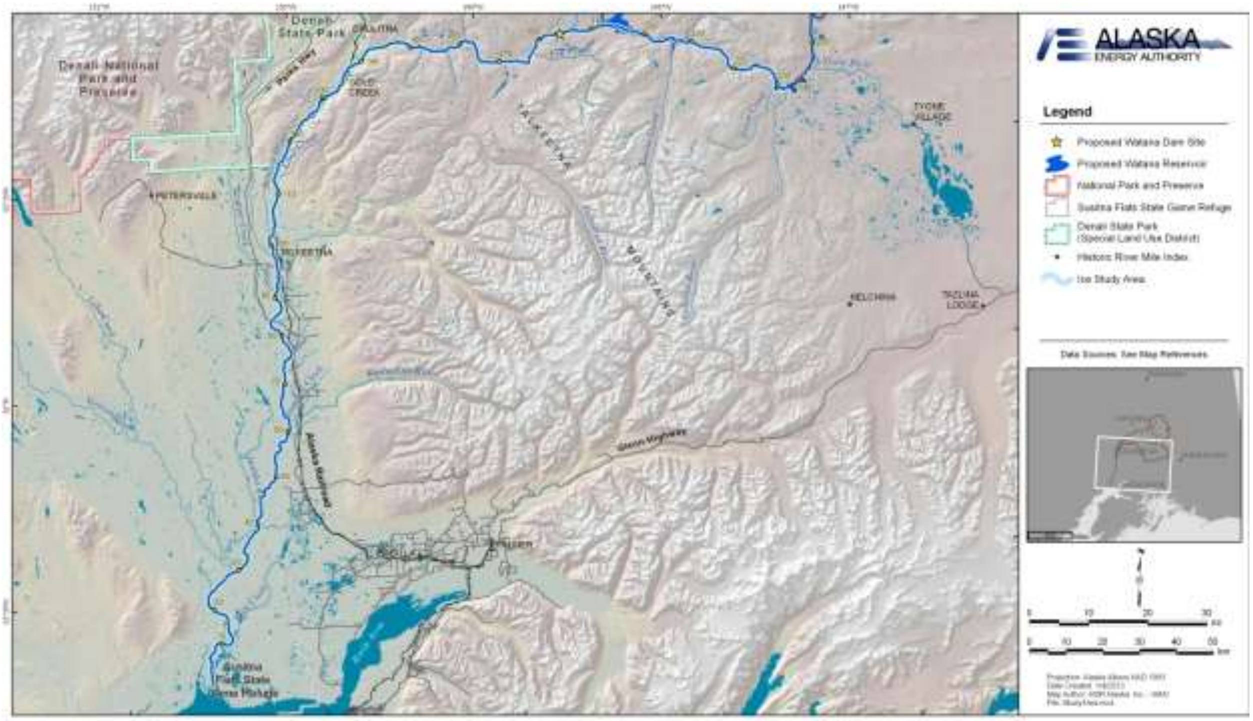


Figure 3-1. Map of Study Area

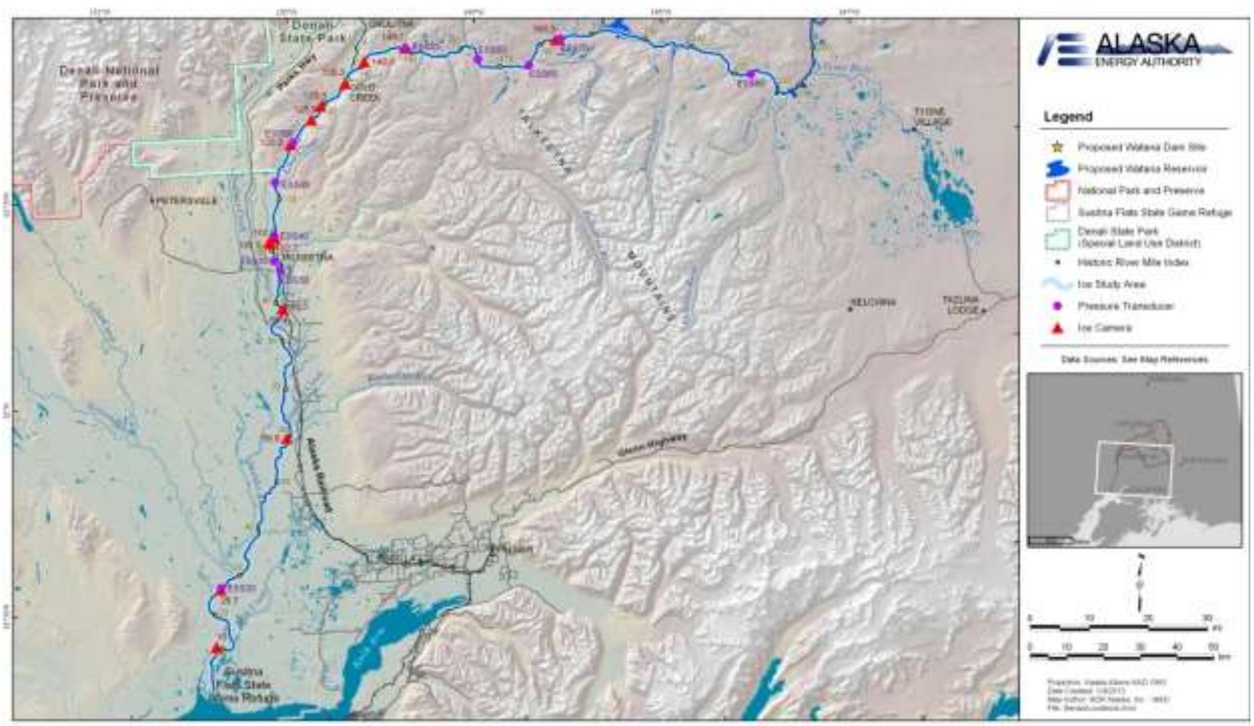


Figure 3-2. Locations of Time-Lapse Cameras and Pressure Transducers.

Figure 5.2-1. Thermal lead in gravel bar near RM 32, March 20, 2012. Main channel is to the left. View is looking upstream.

Figure 5.2-2. Tannic color of thermal lead at bank toe, near RM 15, March 20, 2012.

Figure 5.2-3. Velocity leads near RM 97 March 20, 2012. Snowmachine tracks for scale.

Figure 5.2-4. Thermal lead in Slough 8A, RM 126, March 21, 2012.

Figure 5.2-5. Thermal lead in Slough 11, RM 136, March 21, 2012

Figure 5.2-6. Velocity lead in Devils Canyon, March 21, 2012.

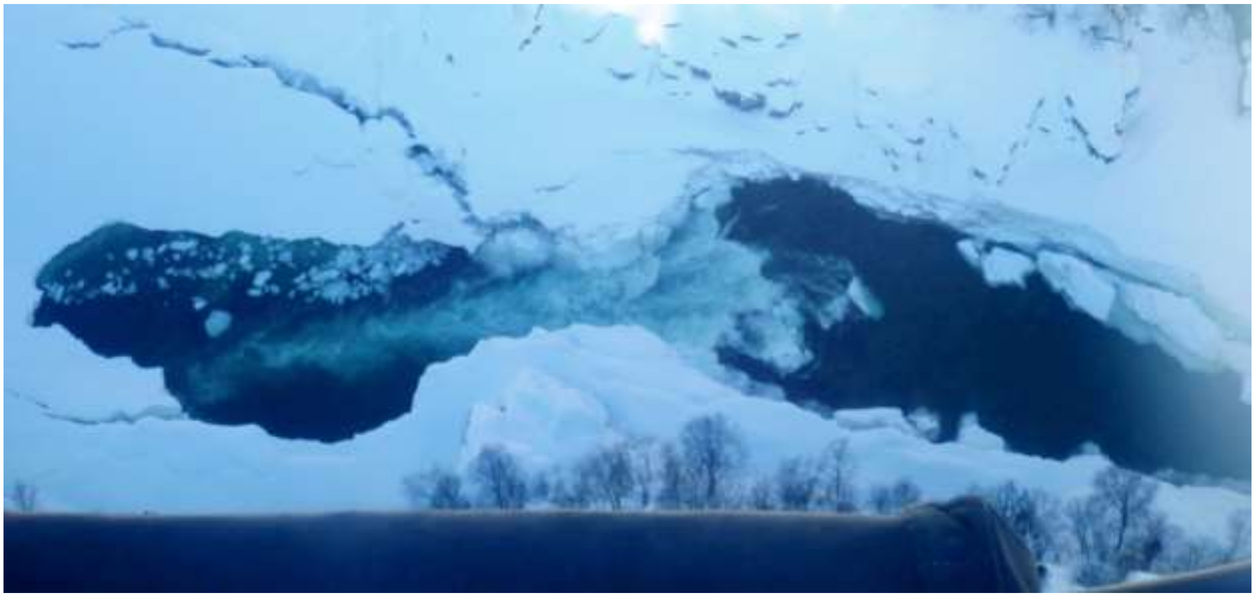


Figure 5.2-7. Close up view of velocity lead in Devils Canyon, March 22nd, 2012. Note rapid and broken ice.

Figure 5.2-8. Velocity lead in Vee Canyon, RM 222, March 22, 2012.

Figure 5.2-9. Open leads in the Oshetna River (bottom of photo) and Susitna River (top of photo), March 22, 2012.

Figure 5.4-1. Ice jam near RM 62 on the Lower Susitna River, April 30, 2012.

Figure 5.4-2. Breakup near RM 9.5 on April 30, 2012 as recorded on a time-lapse camera.

Figure 5.4-3. Stranded ice on banks near RM 59 after ice out on May 2, 2012.

Figure 5.4-4. Open water at the mouth of Portage Creek, April 11, 2012. Lead is about 4 feet wide.

Figure 5.4-5. A velocity lead in Devils Canyon, RM 151, widening on April 19, 2012. Ice is slumping from the sides and accumulating in the lead. Note small avalanches from the canyon walls.

Figure 5.4-6. Velocity lead opening near Gold Creek Bridge (RM 136) on April 19, 2012. Broken ice is accumulating in the lead.

Figure 5.4-7. Ice floes accumulated in open lead near RM 127 on April 23, 2012. Thermal leads are opening up near the channel margin and overflow is appearing at the head of Slough 8.

Figure 5.4-8. Ice jam near RM 136 on April 27, 2012. Slough 11 is in the upper left side of the photo.

Figure 5.4-9. RM 136 and Slough 11 after the ice jam collapsed and moved downstream, May 2, 2012.

Figure 5.4-10. Ice floes stranded on the bank near Slough 11 entrance (RM 135.6) on May 2, 2012.

Figure 5.4-11. Ice jam forcing water into Slough 9, RM 128, May 2, 2012.

Figure 5.1-12. Ice jam in Vee Canyon (RM 221.5), April 27, 2012.

Figure 5.4-13. Ice jam at RM 231, April 27, 2012.

Figure 5.4-14. Ice jam at RM 207, mouth of Kosina Creek, April 27, 2012.

Figure 5.4-15. Remnant ice slabs downstream of Vee Canyon at RM 221, May 2, 2012.

5.4-16. Ice jam remnants stranded on gravel island at RM 196, May 2, 2012.

Figure 5.4-17. Ice bulldozing head of island at RM 184, May 2, 2012.

Figure 5.6-1. Frazil ice pans flowing past RM 100, October 16, 2012.

Figure 5.6-2. Ice bridge in Devils Canyon, RM 151. Flow is from bottom to top. October 22, 2012.

Figure 5.6-3. Ice bridges at RM 2 in the west channel of the Lower River, October 26, 2012.

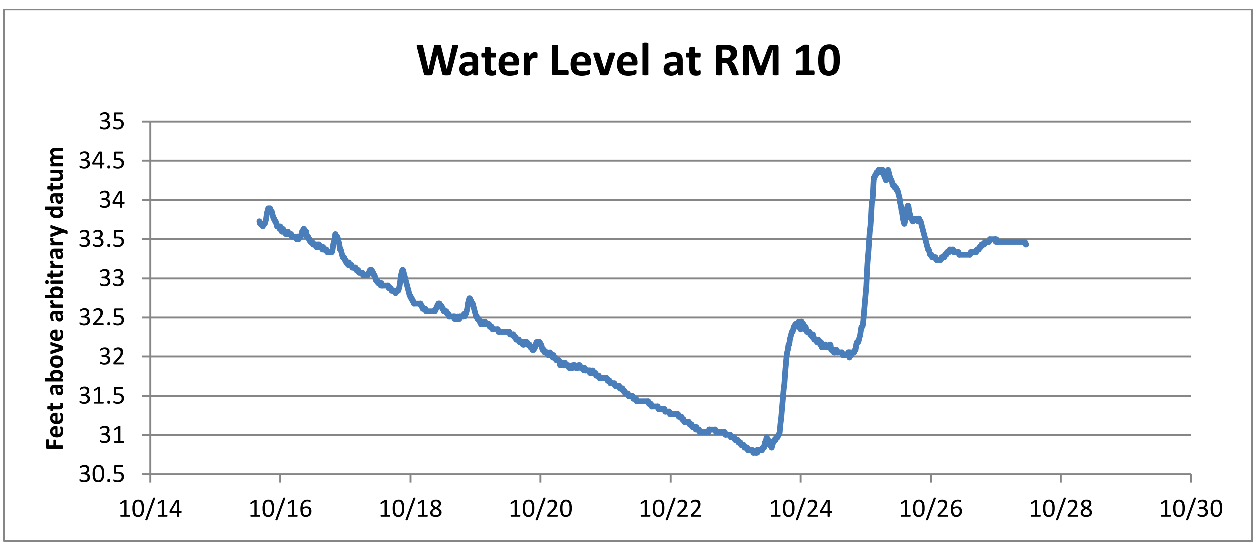


Figure 5.6-4. Pressure transducer readings from RM 10, showing a spike in pressure late on October 23, 2012.

Figure 5.6-5. Upstream end of ice cover, October 29, 2012 at RM 54. The thalweg is on the lower part of the photo -- water is being pushed into side channels in the upper part of the photo as the ice front progresses.

Figure 5.6-6. Parks Highway bridge at RM 84 on November 1, 2012, prior to ice cover progression.

Figure 5.6-7. Parks Highway Bridge at RM 84 on November 7, 2012, after ice cover progression. Note flooded gravel bars on both sides of the river.

Appendix A. Meteorological and Streamflow Data

Appendix A-1
Talkeetna Weather Station Data Tables

January 2012

Date	Temperature (°F)			Wind Speed (mph)		Precipitation
	Minimum	Maximum	Mean	Maximum	Mean	(in)
1	-27	-4	-16	5	1	0
2	-20	-2	-11	5	1	0
3	-20	3	-8	6	1	0
4	-24	-4	-14	4	0	0
5	-24	15	-4	12	5	0.06
6	-5	10	2	13	2	0.07
7	0	16	8	8	6	0.01
8	6	12	10	5	0	0.13
9	-11	5	-3	13	1	0
10	6	23	14	18	12	0.29
11	23	28	26	13	7	0.07
12	10	28	19	13	4	0.25
13	-18	10	-3	4	0	0.01
14	-26	-9	-18	5	3	0
15	-22	-6	-14	5	1	0
16	-20	12	-4	6	3	0
17	3	12	8	14	8	0.02
18	-9	19	5	16	6	0
19	-15	16	0	14	3	0
20	15	23	19	26	15	0
21	8	23	16	20	13	0
22	7	17	12	15	7	0
23	1	15	9	9	5	0
24	-16	6	-2	9	3	0
25	-27	-5	-16	4	0	0
26	-11	-2	-6	4	0	0.02
27	-13	-5	-9	0	0	0
28	-27	1	-12	4	1	0
29	-27	0	-14	4	1	0
30	-11	10	0	12	5	0.19
31	6	12	9	4	0	0

Appendix A-1

Talkeetna Weather Station Data Tables (continued)

February 2012

Date	Temperature (°F)			Wind Speed (mph)		Precipitation
	Minimum	Maximum	Mean	Maximum	Mean	(in)
1	12	32	22	17	7	0.18
2	21	32	26	10	5	0
3	17	32	24	12	4	0.17
4	-4	14	5	5	1	0
5	6	32	19	13	6	0
6	10	35	24	12	7	0
7	3	34	18	9	2	0
8	1	36	18	13	7	0
9	7	34	20	15	5	0
10	23	35	29	8	2	0.04
11	28	37	32	14	6	0
12	18	33	26	9	2	0.04
13	30	36	33	9	5	0
14	25	32	28	14	8	0.03
15	26	33	30	15	7	0.01
16	23	33	28	12	4	0
17	28	35	32	8	4	0
18	18	32	25	12	6	0
19	18	30	24	12	6	0
20	19	35	27	12	8	0
21	21	28	24	5	0	0.13
22	21	28	24	5	0	0.02
23	8	25	16	7	1	0.06
24	1	19	10	4	0	0
25	1	19	10	8	2	0.13
26	17	28	22	13	7	0.34
27	24	30	28	6	2	0.08
28	-2	25	12	6	2	0
29	-2	24	11	6	1	0

Appendix A-1

Talkeetna Weather Station Data Tables (continued)

March 2012	Date	Temperature (°F) Minimum	Temperature (°F) Maximum	Temperature (°F) Mean	Wind Speed (mph) Maximum	Wind Speed (mph) Mean	Precipitation (in)
	1	-4	23	10	13	6	0
	2	12	30	21	6	2	0
	3	1	25	16	5	0	0.04
	4	-8	17	4	5	0	0
	5	-6	15	4	6	2	0.2
	6	10	18	14	5	0	0.05
	7	10	25	20	8	3	0
	8	-8	26	9	8	3	0
	9	-5	18	6	6	1	0
	10	-11	25	7	15	3	0
	11	-2	19	8	8	2	0
	12	-9	24	7	7	1	0
	13	-6	28	11	10	3	0
	14	21	35	28	15	9	0
	15	12	41	28	9	5	0
	16	1	33	16	6	2	0
	17	-2	30	14	7	1	0
	18	10	30	20	7	1	0
	19	5	34	20	5	1	0
	20	-2	34	16	12	2	0
	21	0	28	14	8	1	0
	22	-6	28	10	6	1	0
	23	-6	28	11	8	2	0.04
	24	19	35	28	8	6	0.02
	25	3	35	19	8	2	0
	26	3	36	20	7	3	0
	27	21	41	30	12	7	0
	28*	33	48	40	9	5	0
	29	21	48	34	6	1	0
	30	18	45	32	8	2	0
	31*	33	43	38	5	2	0.13

*Daily temperature min/max stayed above 32*F

Observation flight

Appendix A-1

Talkeetna Weather Station Data Tables (continued)

April 2012

Date	Temperature (°F)			Wind Speed (mph)		Precipitation (in)
	Minimum	Maximum	Mean	Maximum	Mean	
1	28	45	37	8	1	0.02
2	19	43	31	16	3	0
3	16	39	28	6	3	0
4	16	42	28	6	1	0
5*	32	42	36	9	5	0.04
6	30	39	34	6	1	0.27
7	28	37	32	9	2	0.14
8	27	39	34	13	4	0.01
9	19	42	30	6	2	0
10	17	46	32	8	1	0
11	19	51	35	6	1	0
12	19	53	36	6	1	0
13	23	52	38	4	1	0
14	24	55	39	8	1	0
15	30	53	41	9	2	0
16*	34	53	44	6	1	0
17	30	52	41	4	0	0
18*	34	51	42	6	1	0
19	28	55	42	6	1	0
20	27	53	40	8	1	0
21*	34	51	42	10	1	0
22	30	52	41	8	1	0
23	25	51	38	7	2	0
24	24	59	40	10	2	0
25	28	57	42	14	4	0
26*	32	59	44	17	7	0
27	27	55	41	9	2	0
28*	36	51	43	8	3	0.01
29	28	55	42	8	2	0
30	28	55	42	7	2	0

*Daily temperature min/max stayed above 32*F

Observation flight

Appendix A-1

Talkeetna Weather Station Data Tables (continued)

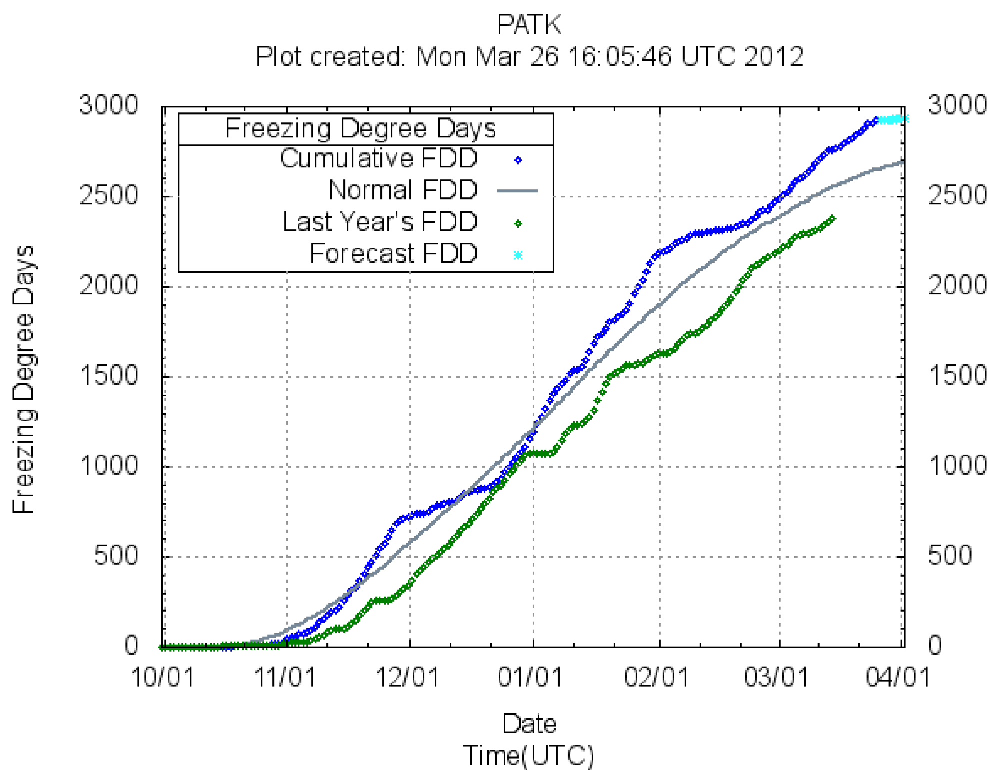
May 2012

Date	Temperature (°F)			Wind Speed (mph)		Precipitation
	Minimum	Maximum	Mean	Maximum	Mean	(in)
1	28	46	37	10	2	0
2	21	39	30	8	3	0
3	24	43	34	8	2	0
4	28	48	37	7	1	0
5	27	55	40	9	3	0
6	30	57	44	13	3	0.01
7*	37	54	46	7	2	0
8	28	57	42	16	3	0.01
9*	37	50	44	12	7	0.01
10*	37	51	44	8	2	0
11*	36	48	42	14	3	0.01
12	30	50	38	12	2	0.04
13*	32	51	42	16	4	0.02
14	28	54	41	13	3	0
15*	36	55	46	14	6	0

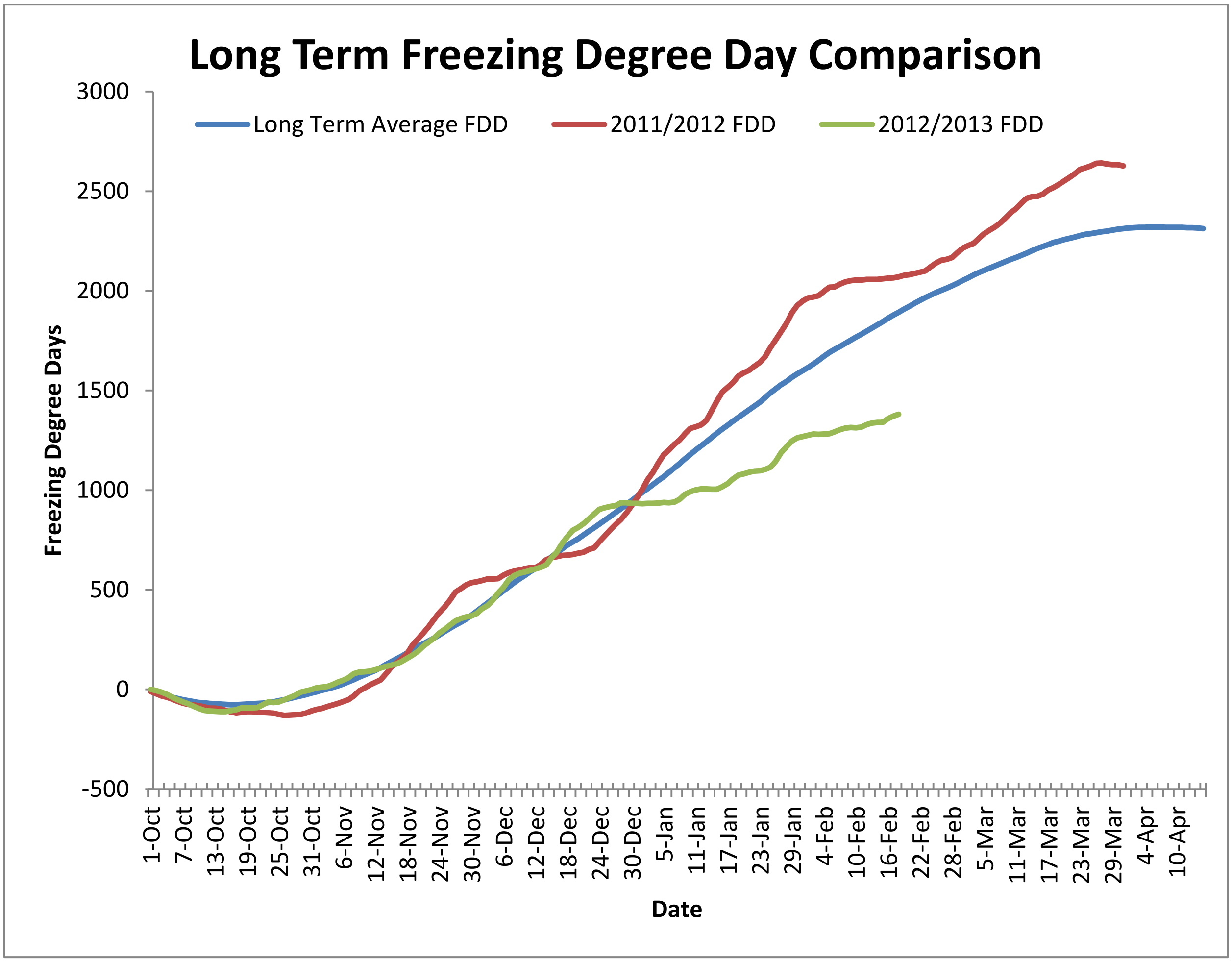
*Daily temperature min/max stayed above 32*F

Observation flight

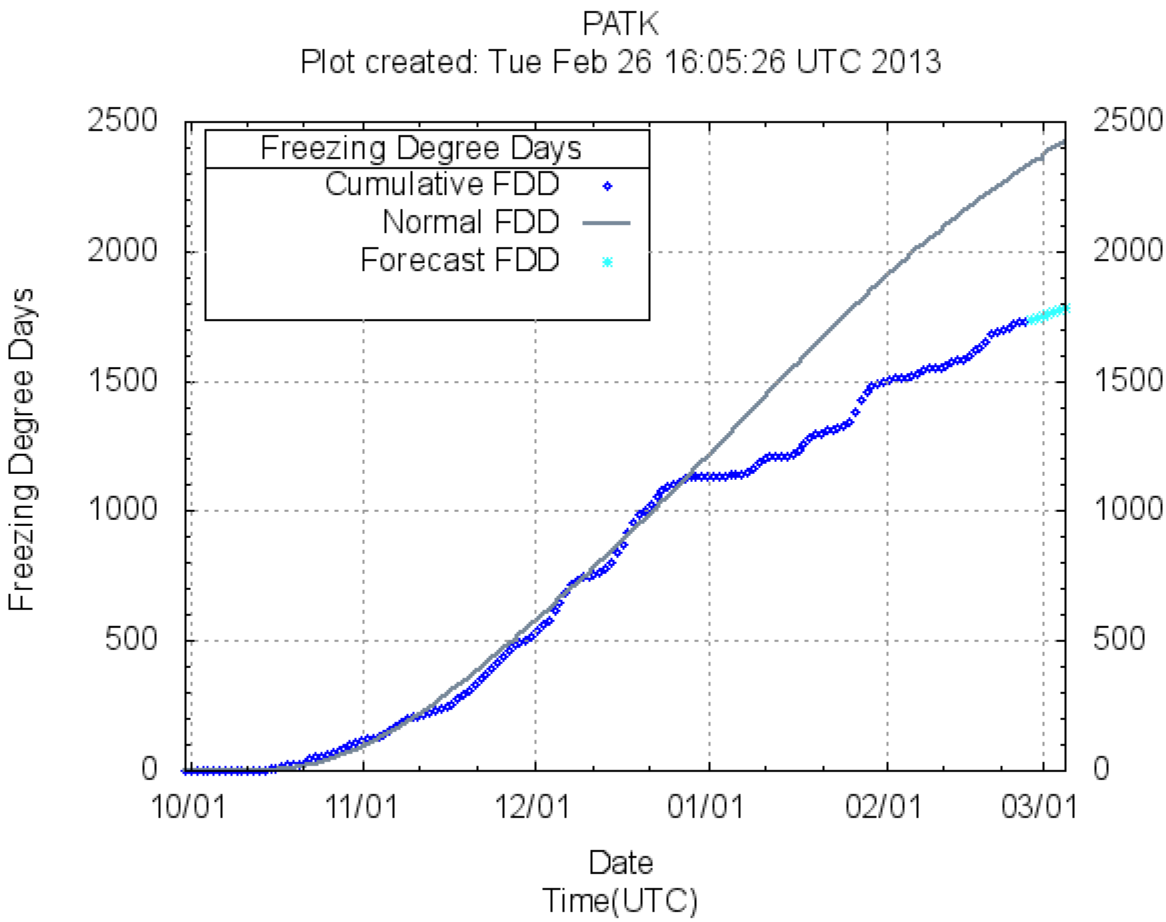
Appendix A-2
Freezing Degree Days



Winter 2011-2012 Cumulative Freezing Degree Days at Talkeetna compared to previous year and long-term average. Plot created by National Weather Service Alaska River Forecast Center



Winter 2012-2103 Cumulative Freezing Degree Days at Talkeetna compared to previous year and long-term average.



Winter 2012-2013 Cumulative Freezing Degree Days at Talkeetna and forecast through 3/01/2013 compared to long-term average. Plot created by National Weather Service Alaska River Forecast Center.

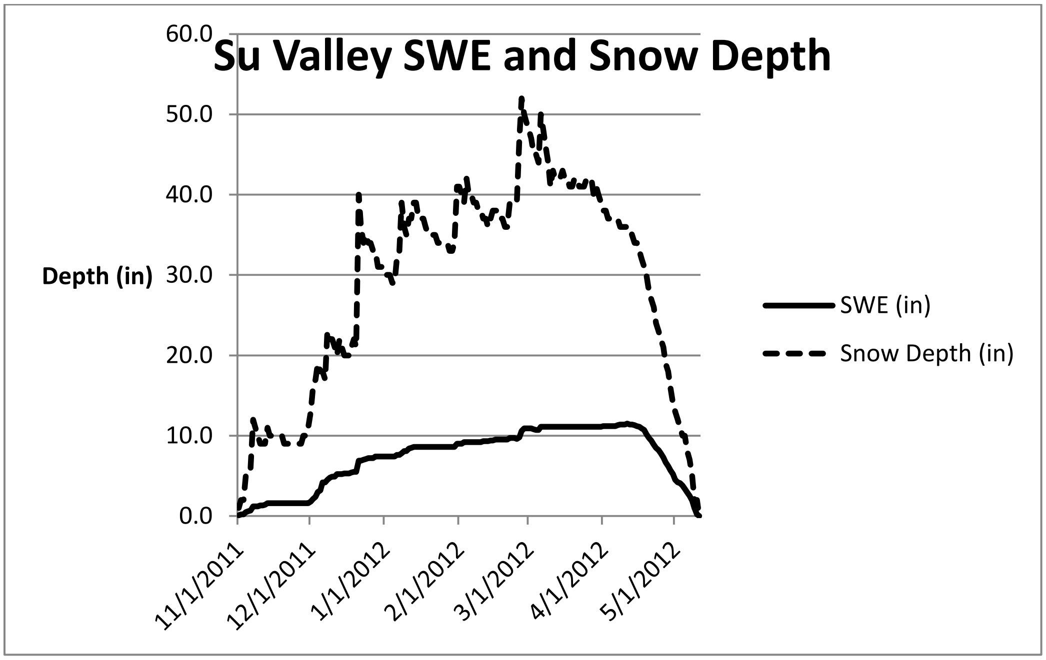
Appendix A-3
Surface Water Temperature (ºF) for Susitna Basin Streams
Collected by the National Weather Service Alaska River Forecast Center

Date	Montana Creek (near Montana)	Susitna River (near Sunshine)	Talkeetna River (above RR bridge)	Willow Creek (near Canyon)
26 Mar 2012	31.6	31.5	32.2	32.5
27 Mar 2012	31.6	31.5	32.2	32.5
28 Mar 2012	31.6	31.5	32.2	32.5
29 Mar 2012	31.6	31.5	32.2	32.5
30 Mar 2012	31.6	31.5	32.2	32.5
31 Mar 2012	31.6	31.5	32.2	32.5
01 Apr 2012	31.6	31.5	32.2	32.5
02 Apr 2012	31.6	31.5	32.2	32.5
03 Apr 2012	31.6	31.6	32.2	32.6
04 Apr 2012	31.6	31.6	32.2	32.7
05 Apr 2012	31.6	31.5	32.2	32.8
06 Apr 2012	31.6	31.5	32.2	33.1
07 Apr 2012	31.6	31.5	32.2	33.4
08 Apr 2012	31.6	31.5	32.2	33.4
09 Apr 2012	31.6	31.5	32.2	33.3
10 Apr 2012	31.6	31.5	32.2	33.3
11 Apr 2012	31.6	31.5	32.2	33.4
12 Apr 2012	31.6	31.5	32.2	33.3
13 Apr 2012	31.6	31.5	32.2	33.4
14 Apr 2012	31.6	31.5	32.2	33.3
15 Apr 2012	31.6	31.5	32.2	33.2
16 Apr 2012	31.6	31.5	32.2	33.3
17 Apr 2012	32.2	31.5	32.2	33.1
18 Apr 2012	32.4	31.5	32.2	33.1
19 Apr 2012	32.4	31.5	32.2	33.1
20 Apr 2012	32.4	31.5	32.2	33.1
21 Apr 2012	32.4	31.5	32.6	33.2
22 Apr 2012	32.4	31.5	32.8	33.5
23 Apr 2012	33.1	31.6	34.5	34.3

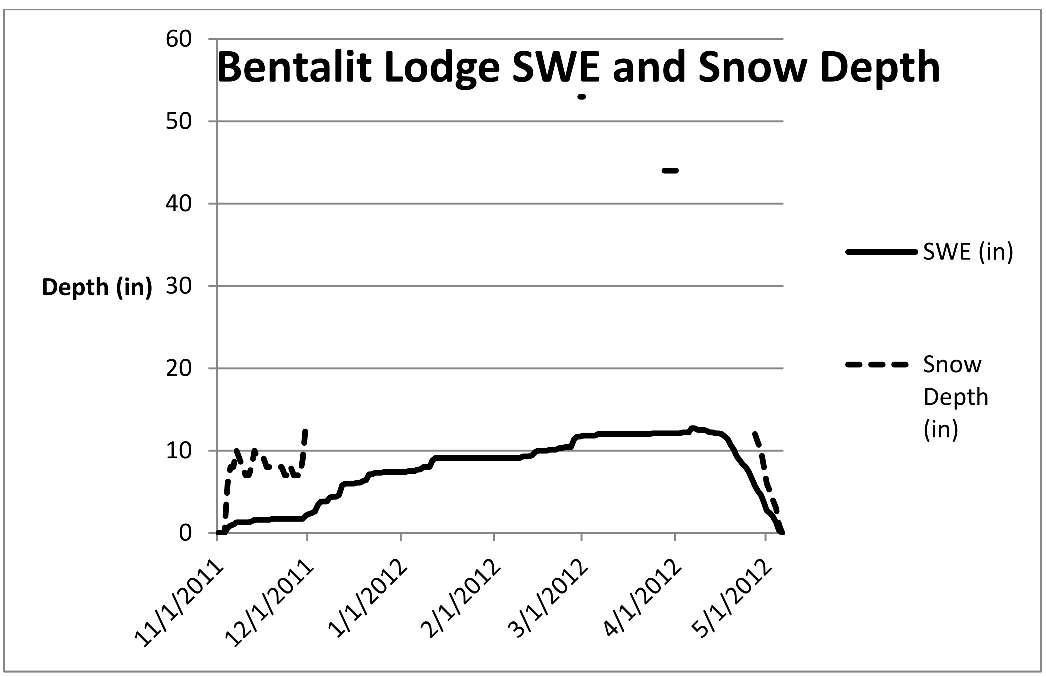
Date	Montana Creek (near Montana)	Susitna River (near Sunshine)	Talkeetna River (above RR bridge)	Willow Creek (near Canyon)
24 Apr 2012	33.5	31.6	34.8	34.3
25 Apr 2012	33.8	31.6	35.1	34.5
26 Apr 2012	33.8	31.4	35.1	34.5
27 Apr 2012	33.5	31.5	35.1	34.8
28 Apr 2012	33.2	31.6	35.1	35.1
29 Apr 2012	32.9	31.6	35.1	35.2
30 Apr 2012	32.7	31.8	35.1	35.2
01 May 2012	34.3	33.1	37.6	36.1
02 May 2012	34.3	33.1	37.6	36.1
03 May 2012	34.9	34.4	37.9	36.8
04 May 2012	35.2	33.8	38.3	37.4
05 May 2012	35.7	35.8	38.9	38.2
06 May 2012	36.1	36.7	39.6	38.9
07 May 2012	36.5	37.9	40.3	39.6
08 May 2012	36.8	38.4	40.3	39.6
09 May 2012	37.1	38.9	40.5	39.9
10 May 2012	36.7	39.1	39.9	39.6
11 May 2012	36.9	39.6	40.1	39.8
12 May 2012	37.5	40.2	40.3	39.7
13 May 2012	38.2	41.1	40.7	40.1
14 May 2012	39.1	41.6	40.9	40.2
15 May 2012	39.8	41.9	41.2	40.6

Appendix A-4

Susitna Basin Snow Depth Measurements, 2011-2012



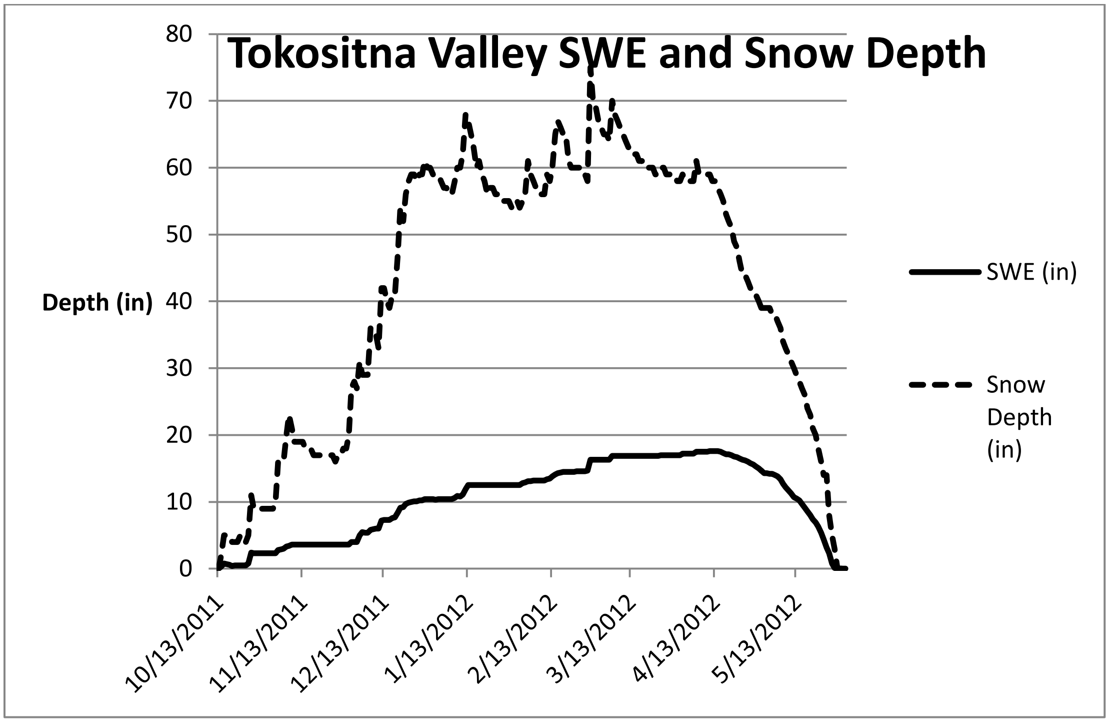
Su-Valley High SNOTEL Site Daily Measurements of Snow Depth and Snow Water Equivalent, 2011-2012. Compiled by the NRCS



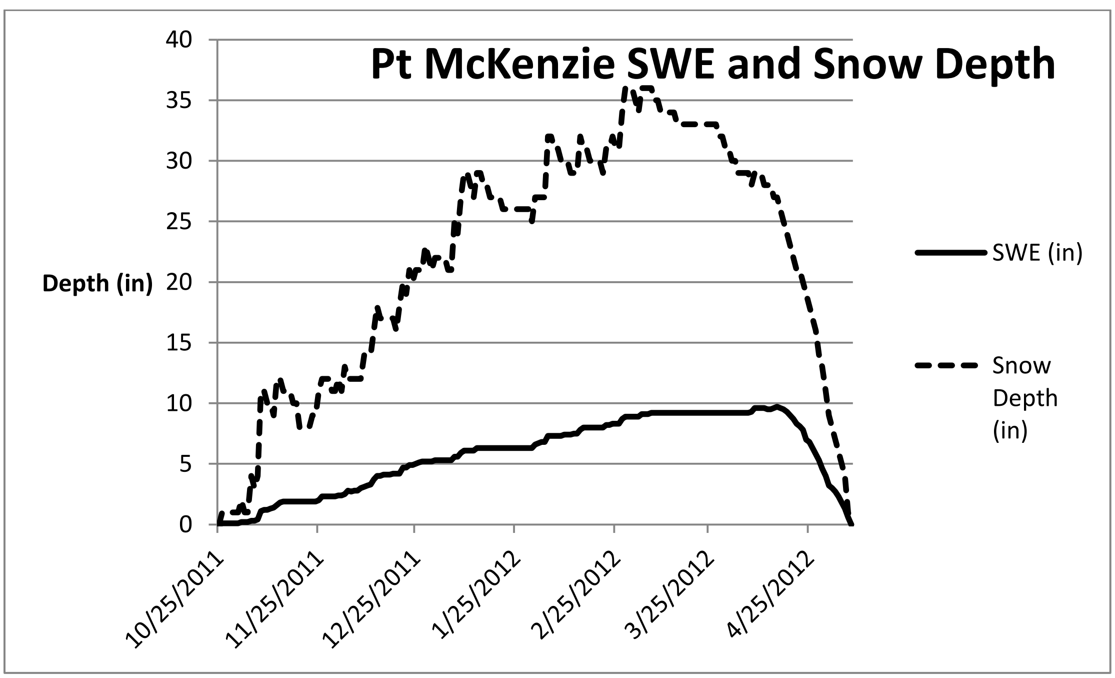
Bentalit Lodge SNOTEL Site Daily Measurements of Snow Depth and Snow Water Equivalent, 2011-2012. Compiled by the NRCS

Appendix A-4

Susitna Basin Snow Depth Measurements, 2011-2012 (continued)



Tokositna Valley SNOTEL Site Daily Measurements of Snow Depth and Snow Water Equivalent, 2011-2012. Compiled by the NRCS



Pt. McKenzie SNOTEL Site Daily Measurements of Snow Depth and Snow Water Equivalent, 2011-2012. Compiled by the NRCS

Appendix A-4

Susitna Basin Snow Depth Measurements, 2011-2012 (continued)

Snow Course Data for the Susitna Basin, 2011-2012

Compiled by the NRCS

Snow Course	Elevation (ft)	Date Reported	Snow Depth (in)	Water Content (%)	Depth Last Year (2011)	Depth Average (1971-2000)
Alexander Lake	160	---	---	---	---	---
		30 Jan 2012	41	10.9	8.3	8.6
		29 Feb 2012	62	14.3	11.3	10.7
		28 Mar 2012	51	15.2	12.0	12.0
		---	---	---	---	9.8
Archangel Road	2200	---	---	---	---	---
		---	---	---	5.8	12.1
		01 Mar 2012	60	17.6	7.6	13.5
		02 Apr 2012	57	18.4E	9.5	16.3
		01 May 2012	39	15.6	10.7	14.9
Bentalit Lodge	150	01 Jan 2012	---	5.2	5.2	---
		01 Feb 2012	---	6.4	6	---
		01 Mar 2012	---	8.3	7.8	---
		01 Apr 2012	44	12.1	7.8	---
		01 May 2012	5	1.9	4.2	---
Blueberry Hill	1200	---	---	---	---	---
		01 Feb 2012	50	13.4	12.6	11.5
		29 Feb 2012	58	15.8	13.5	13.8
		29 Mar 2012	52	16.4	13.6	16.0
		01 May 2012	34	13.2	14.9	17.4
Chelatna Lake	1450	---	---	---	---	---
		---	---	---	5.8	8.3
		28 Feb 2012	59	13.8	---	10
		29 Mar 2012	50	14	9.1	11.6
		02 May 2012	35	13	8.1	10.9
Curtis Lake	2850	---	---	---	---	---
		---	---	---	3.2	3.2
		29 Feb 2012	30	5.5	3.5	3.9
		02 Apr 2012	29	5.8	4.2	4.3
		---	---	---	---	---

Snow Course	Elevation (ft)	Date Reported	Snow Depth (in)	Water Content (%)	Depth Last Year (2011)	Depth Average (1971-2000)
Denali View	700	---	---	---	---	---
		01 Feb 2012	47	11.5	9.9	9.6
		29 Feb 2012	54	13.4	11.7	11.4
		29 Mar 2012	46	14	11.4	13.4
		01 May 2012	22	8.7	11.1	12.3
Dunkle Hills	2700	---	---	---	---	---
		---	---	---	---	---
		28 Feb 2012	33	7.6	---	---
		29 Mar 2012	32	8.8	8.5	---
		---	---	---	8.5	---
Dutch Hills	3100	---	---	---	---	---
		---	---	---	---	19.6
		28 Feb 2012	90	27.9E	---	23
		29 Mar 2012	69	25	13.5	27.5
		02 May 2012	69	27	17.5	28.7
E. Fork Chulitna	1800	---	---	---	---	---
		01 Feb 2012	48	12.2	8.9	10.5
		29 Feb 2012	53	14	10.8	12.7
		29 Mar 2012	51	15.4	10.7	14
		01 May 2012	35	13.3	12.3	15.7
Fishhook Basin	3300	---	---	---	---	---
		01 Feb 2012	77	20.8	10.2	15.4
		01 Mar 2012	75	23.2	10.9	17.7
		02 Apr 2012	70	24.2	12.1	20.5
		01 May 2012	58	23.6	15.6	22.1
Fog Lakes	2120	---	---	---	---	---
		30 Jan 2012	27	5	4.2	4.4
		29 Feb 2012	31	5.1	4.6	5.3
		02 Apr 2012	30	5.8	5	6.2
		01 May 2012	---	5.8	4.5	5.3
Halfway Slough	3500	---	---	---	---	---
		01 Feb 2012	36	7.9	6.4	---
		29 Feb 2012	42	9.2	6.4	---
		29 Mar 2012	34	9.3	6.2	---
		01 May 2012	0	0	---	---
Independence Mine	3550	---	---	---	9	13.9
		01 Feb 2012	81	21.2	10.6	18.1
		01 Mar 2012	85	27.1	12.5	21.2

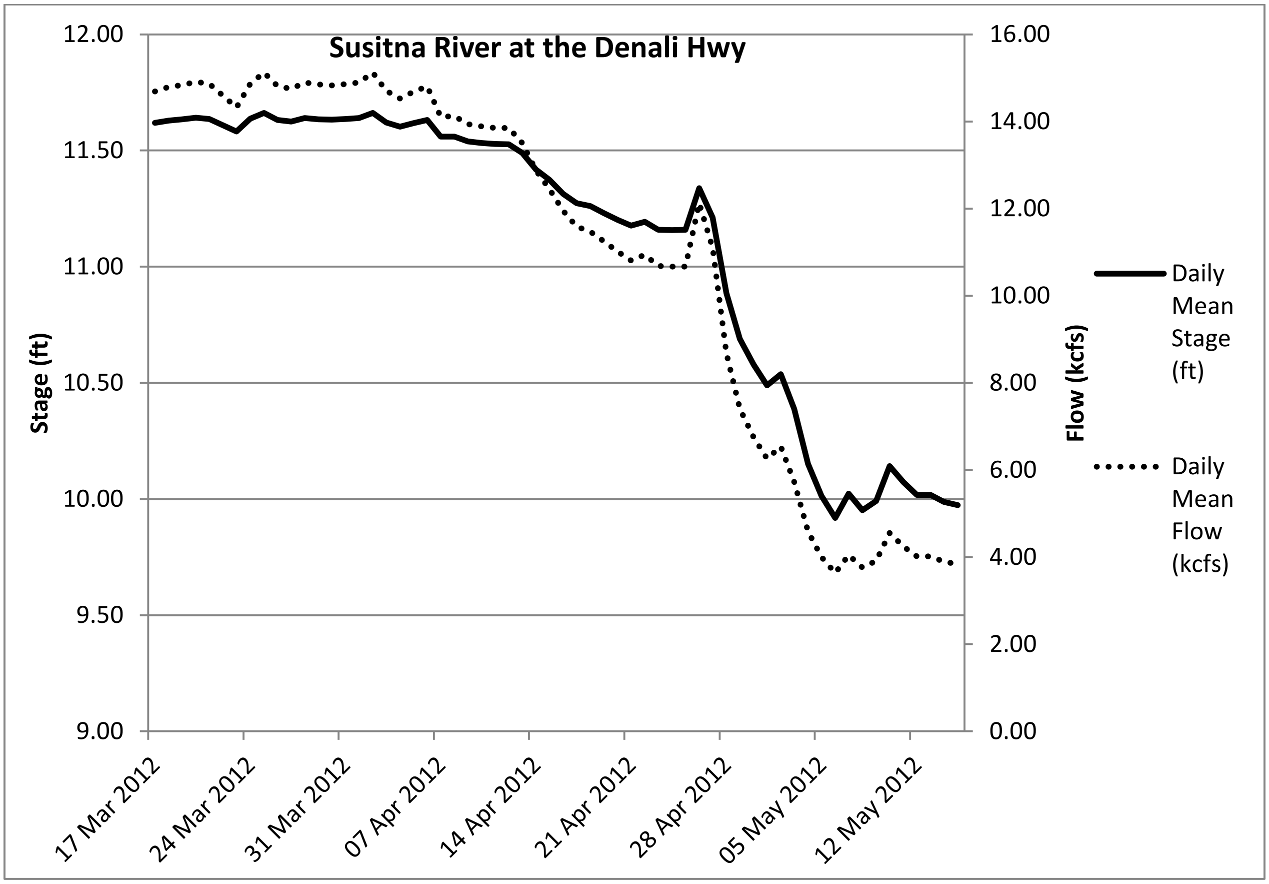
Snow Course	Elevation (ft)	Date Reported	Snow Depth (in)	Water Content (%)	Depth Last Year (2011)	Depth Average (1971-2000)
		02 Apr 2012	77	28.2	13.1	24.2
		01 May 2012	69	28.9	18.5	27.1
Independence Mine	3550	01 Jan 2012	53	14.2	---	11.1
		01 Feb 2012	68	14.8	---	14.1
		01 Mar 2012	70	17.8	9.9	16.5
		01 Apr 2012	67	19	10.5	18.9
		---	---	---	15.2	21.1
Lake Louise	2400	---	---	---	---	2.8
		30 Jan 2012	23	4.2	2.4	3.3
		27 Feb 2012	26	5.2	4.1	4
		30 Mar 2012	30	6.6	4.2	4.6
		02 May 2012	13	4.5	3.9	2.9
Little Susitna	1700	---	---	---	---	---
		01 Feb 2012	54	13	5.2	9.6
		01 Mar 2012	54	14.5	6.3	11.6
		02 Apr 2012	50	15.1	---	13.3
		01 May 2012	24	9.4	6.4	9.2
Moose Creek	4500	---	---	---	---	---
		30 Jan 2012	22	5.1	1.9	---
		27 Feb 2012	30	7.1	2	---
		30 Mar 2012	28	7.7	1.2	---
		02 May 2012	0	0	0	---
Nugget Bench	2010	---	---	---	---	---
		---	---	---	---	10.9
		28 Feb 2012	58	14.8	---	12.9
		29 Mar 2012	45	14.5	9	15.5
		02 May 2012	31	12	10.5	15.3
Ramsdyke Creek	2220	---	---	---	---	---
		---	---	---	---	16.3
		28 Feb 2012	81	23.5	---	18.9
		29 Mar 2012	68	22.5	13	22
		02 May 2012	45	18.8	15	21.9
Sheep Mountain	2900	---	---	---	---	---
		30 Jan 2012	31	7.2	4.3	4.5
		27 Feb 2012	38	9.4	4.7	5.4
		30 Mar 2012	37	10.3	4.8	6
		02 May 2012	16	6.6	0	3.9

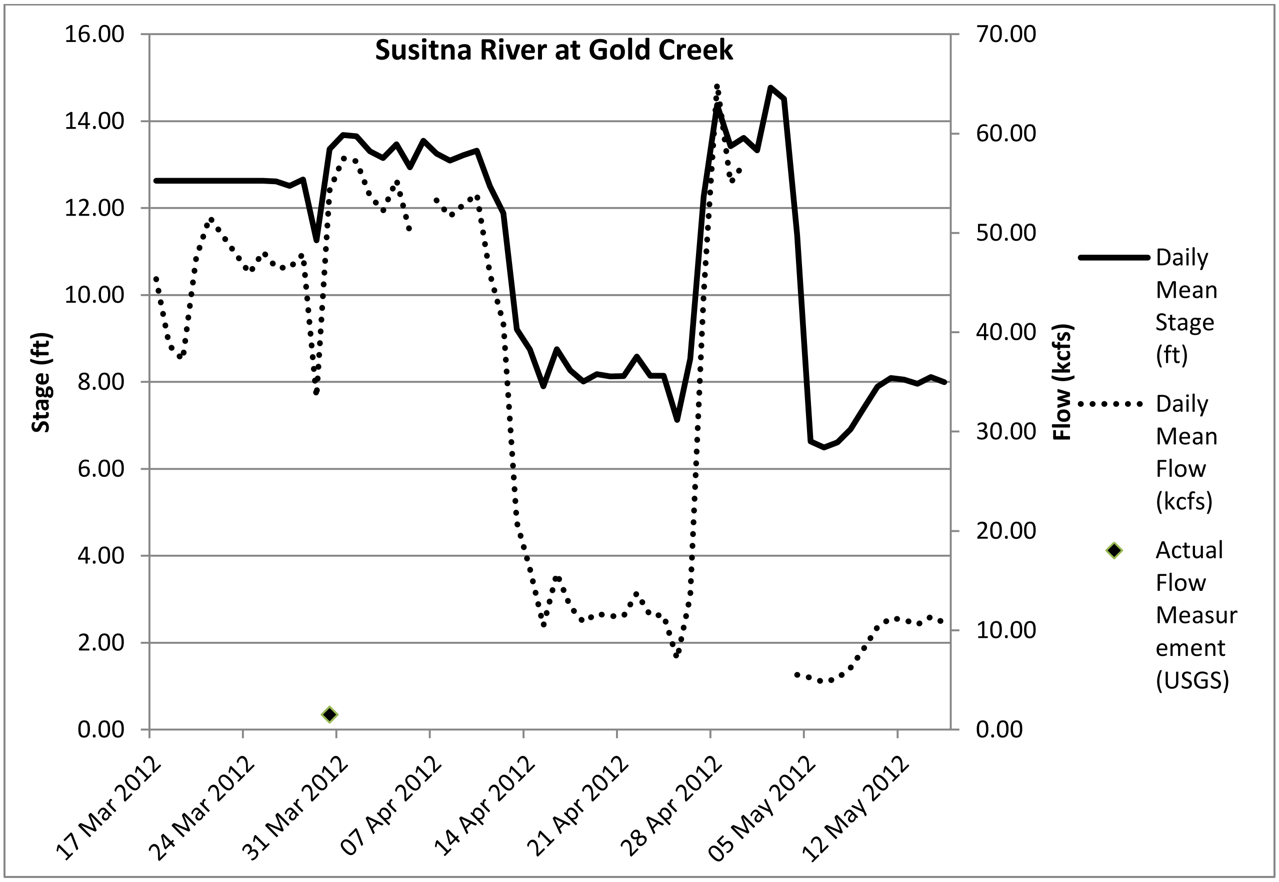
Snow Course	Elevation (ft)	Date Reported	Snow Depth (in)	Water Content (%)	Depth Last Year (2011)	Depth Average (1971-2000)
Skwentna	160	---	---	---	---	---
		30 Jan 2012	41	10.8	8.3	8.5
		29 Feb 2012	59	14.2	12	10.5
		28 Mar 2012	48	14.5	11.8	11.6
		---	---	---	---	---
Square Lake	2950	---	---	---	---	---
		30 Jan 2012	19	3.5	3.5	3.2
		29 Feb 2012	32	5.2	---	3.8
		02 Apr 2012	29	5.8	3.2	4.2
		---	---	---	---	---
Susitna Valley High	380	01 Jan 2012	30	7.4	4.4	5.7
		01 Feb 2012	41	9	5.5	7.5
		01 Mar 2012	48	10.9	6.2	9.4
		01 Apr 2012	38	11.2	6.2	10.2
		01 May 2012	13	4.5	3.2	5.6
Talkeetna	350	---	---	---	---	---
		01 Feb 2012	36	7.5	6.3	6.2
		29 Feb 2012	42	9.2	6.5	7.6
		29 Mar 2012	34	9.6	6.3	8.7
		01 May 2012	8	3.1	4.1	5.4
Tokositna Valley	850	---	---	---	---	---
		---	---	---	---	13.6
		28 Feb 2012	67	15.6	---	15.7
		29 Mar 2012	57	16.4	12.9	18.7
		02 May 2012	39	14.2	14.1	17
Tokositna Valley	850	01 Jan 2012	59	10.3	9.3	9.6
		01 Feb 2012	54	12.5	10.7	13.6
		01 Mar 2012	67	15.7	12.4	16.2
		01 Apr 2012	59	16.4	12	18.7
		01 May 2012	39	14.3	14.1	17
Upper Oshetna River	3150	---	---	---	---	---
		30 Jan 2012	24	4.3	3.7	3.4
		29 Feb 2012	36	6.5	4.1	3.9
		02 Apr 2012	30	7.5	4.1	4.9
		---	---	---	---	---

Snow Course	Elevation (ft)	Date Reported	Snow Depth (in)	Water Content (%)	Depth Last Year (2011)	Depth Average (1971-2000)
Upper Sanona Creek	3100	---	---	---	---	---
		30 Jan 2012	31	5.9	4.2	4
		29 Feb 2012	39	7.4	4.3	4.4
		02 Apr 2012	37	9	5.5	5.2
		---	---	---	---	---
Willow Airstrip	200	---	---	---	---	---
		01 Feb 2012	38	9.1	5.1	5.7
		29 Feb 2012	53	11.3	6	6.9
		29 Mar 2012	42	11.6	---	8.1
		01 May 2012	19	6.5	4.6	4.1

Appendix A-5

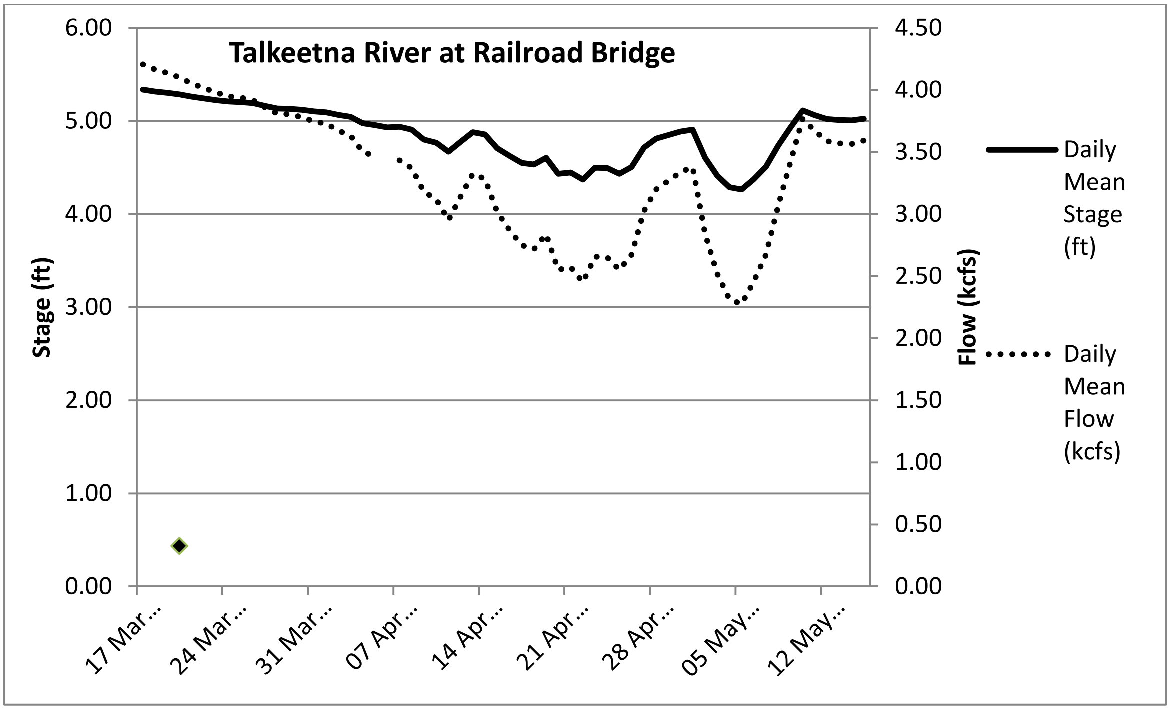
Preliminary Recorded Stream Stage, Stage Equivalent Discharge and Measured Discharge Data

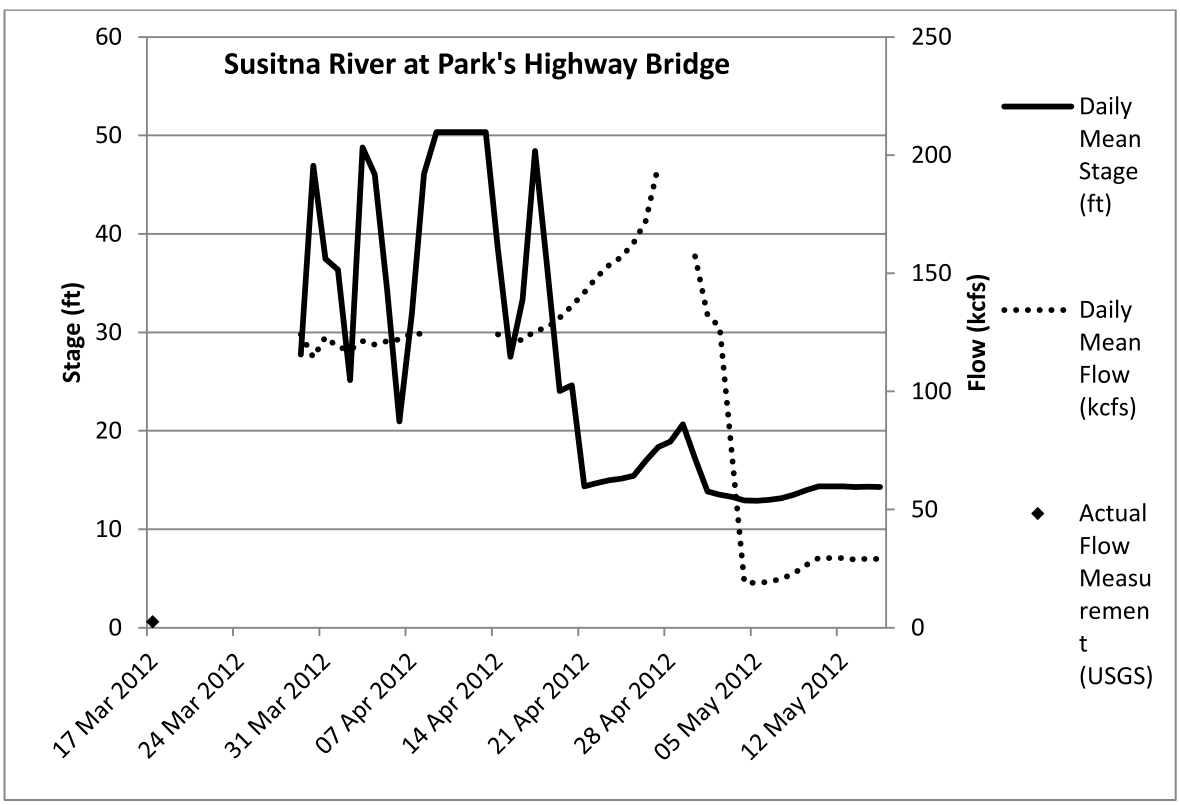


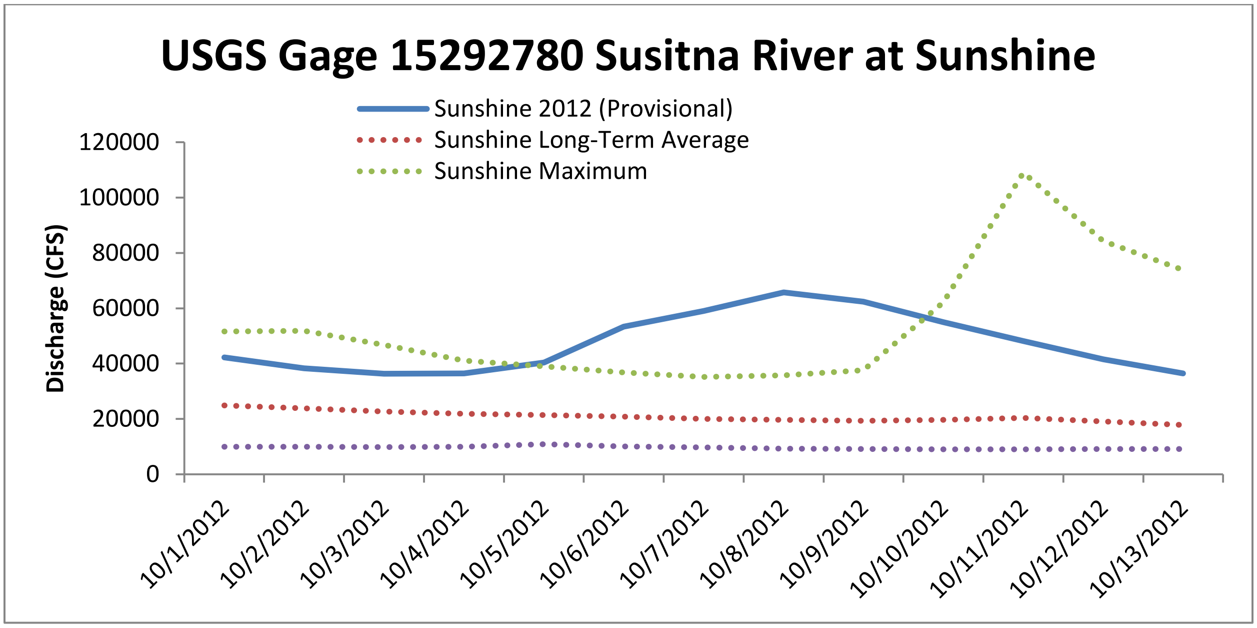

Susitna River at Gold Creek
Stage (ft)
Flow (kcfs)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
17 Mar 2012
24 Mar 2012
31 Mar 2012
07 Apr 2012
14 Apr 2012
21 Apr 2012
28 Apr 2012
05 May 2012
12 May 2012
Daily Mean Stage (ft)
Daily Mean Flow (kcfs)
Actual Flow Measurement (USGS)

Appendix A-5

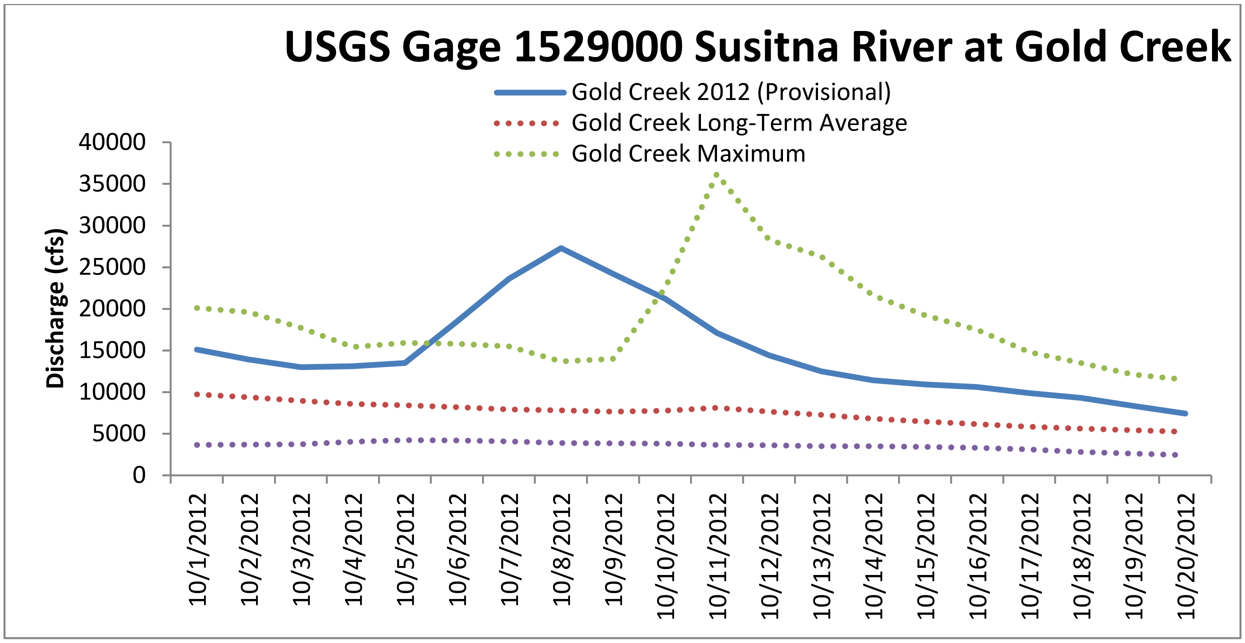
Preliminary Recorded Stream Stage, Stage Equivalent Discharge and Measured Discharge Data (continued)







Susitna River at Sunshine discharge during freeze-up, 2012. Gage stopped reporting on 10/13.



Susitna River at Gold Creek discharge during freeze-up, 2012. Gage stopped reporting on 10/20.