Susitna-Watana Hydroelectric Project Document
ARLIS Uniform Cover Page

Title: Glacier and runoff changes study, Study plan Section 7.7 : Final study plan	**SuWa 200**
Author(s) – Personal:	
Author(s) – Corporate: Alaska Energy Authority	
AEA-identified category, if specified: Final study plan	
AEA-identified series, if specified:	
Series (ARLIS-assigned report number): Susitna-Watana Hydroelectric Project document number 200	**Existing numbers on document:**
Published by: [Anchorage : Alaska Energy Authority, 2013]	**Date published:** July 2013
Published for:	**Date or date range of report:**
Volume and/or Part numbers: Study plan Section 7.7	**Final or Draft status, as indicated:**
Document type:	**Pagination:** 10 p.
Related work(s):	**Pages added/changed by ARLIS:**
Notes:	

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Glacier and Runoff Changes Study
Study Plan Section 7.7

Final Study Plan

Alaska Energy Authority

July 2013

7.7. Glacier and Runoff Changes Study

On December 14, 2012, Alaska Energy Authority (AEA) filed with the Federal Energy Regulatory Commission (FERC or Commission) its Revised Study Plan (RSP), which included 58 individual study plans (AEA 2012). Included within the RSP was the Glacier and Runoff Changes Study, Section 7.7. RSP Section 7.7 focuses on understanding how changes to the Upper Susitna basin hydrology due to glacial retreat and climate change can affect Project operations and environmental resources.

On February 1, 2013, FERC staff issued its study determination (February 1 SPD) for 44 of the 58 studies, approving 31 studies as filed and 13 with modifications. RSP Section 7.7 was one of the 13 approved with modifications.

On February 21, 2013, the National Marine Fisheries Service (NMFS) filed a notice of study dispute pursuant to section 5.14(a) of the Commission's regulations regarding FERC's failure to require AEA to implement the three study components related to glacier runoff and climate change that AEA proposed in the RSP. A Dispute Resolution Panel Meeting and Technical Conference was held on April 3, 2013 to discuss NMFS' modification requests.

On April 26, 2013 FERC provided its Study Dispute Determination, requesting the following modification;

> "*We recommend that AEA review existing literature relevant to glacial retreat and summarize the understanding of potential future changes in runoff associated with glacier wastage and retreat, as described in RSP section 7.7.4.1*"

On May 28, 2013, NMFS and the Center for Water Advocacy (Center) filed requests for rehearing of the formal study dispute determination issued on April 26, 2013. NMFS and the Center sought rehearing of the Director's finding that studies proposed by the potential applicant, AEA, and NMFS related to global climate change are unnecessary to conduct the Commission's environmental analysis and therefore will not be required to be conducted by AEA. On July 18, 2013, FERC rejected the Center's request for rehearing and denied NMFS' request for rehearing.

AEA has included RSP section 7.7.4.1 in this Final Study Plan, as approved by FERC. Importantly, AEA is carrying out other components of the Glacier and Runoff Changes Study as proposed in the RSP and is intending to publish the results of this larger study effort along with documentation of methodology in 2014.

7.7.1. General Description of the Proposed Study

Glaciers have generally retreated during the last century (Kaser et al. 2006; Meier et al. 2007), and glaciers in Alaska are currently subject to some of the highest glacial wastage rates on Earth (Arendt et al. 2002; Hock et al. 2009). Projections indicate that Alaskan glaciers may lose up to 60 percent of their current volume within the next 100 years (Radic and Hock 2011). Figure 7.7-1 provides an example of a glacier within the Upper Susitna basin that has recently retreated.

Such changes will alter stream flow both in quantity and timing (Hock and Jansson 2005a). This is because glaciers temporarily store water as snow and ice during varying time scales with the release controlled by both climate and internal drainage (Jansson et al. 2003).

Typical characteristics of discharge from glacier-dominated drainages include pronounced diurnal patterns and mid- to late summer high flows due to the dominance of glacier meltwater over precipitation. Annual runoff from a glaciered basin strongly depends on glacier mass balance. During years of positive glacier net, balance water is withdrawn from the annual hydrological cycle into glacier storage, and total stream flow is reduced. During years of negative glacier mass, balance water is released from storage and total stream flow increases.

Glaciers also tend to dampen interannual streamflow variations, where melting variations tend to offset precipitation variations. As little as 10 percent glacierization in a hydrologic basin reduces year-to-year variability in precipitation to a minimum (Huber 2005). As glaciers retreat, total glacier runoff will initially increase but then be followed by a reduction in runoff as the mass of the glacier dwindles (Figure 7.7-2).

With a high fraction of ice cover in the drainage basin, the increases in runoff during glacial mass wasting events can temporarily exceed any other component of the water budget. Nevertheless, glaciers tend to be only crudely represented in hydrological modeling (Hock et al. 2005b). Hence, the watershed runoff response due to glacier retreat is not well understood.

The primary goal of this study is to identify potential impacts and trends related to glacier wastage and retreat on the Susitna-Watana Hydroelectric Project (Project). Specifically, how will glacier wastage and retreat, along with associated changes to the climate, affect the flow of water into the proposed reservoir? Currently several glaciers flow down the southern flanks of the Alaska Range near 13,832-foot Mount Hayes to form the three forks of the Upper Susitna River (Figure 7.7-3).

Glaciers in this area provide a significant portion of the total runoff within the Upper Susitna drainage, and it is well documented that these glaciers are currently retreating (Molnia 2008). Given this trend, changes to the runoff represented by glacial melting may occur in the future, and may affect the Project. Therefore, it is important to understand how changes to the upper basin hydrology due to glacial retreat and climate change can affect Project operations and environmental resources.

Specific objectives of the literature review study are as follows:

1) Review existing literature relevant to glacier retreat in Southcentral Alaska and the Upper Susitna watershed. This review will summarize the current understanding of potential future changes in runoff associated with glacier wastage and retreat.

2) Summarize the results in a technical report.

7.7.2. Existing Information

Approximately 5 percent of the Upper Susitna River basin is covered by glaciers. Permafrost is generally discontinuous, although seasonal freeze and thaw cycles affect the entire basin. Long-term, discontinuous (~60 years) stream flow observations from the U.S. Geological Survey (USGS) are available at five locations in the basin: Denali, Cantwell, Gold Creek, Sunshine, and Susitna Station.

7.7.2.1. Existing information on Glacier Retreat in Alaska

There has been extensive melting of glaciers in Alaska in recent decades (Molnia 2008). Statewide, Alaskan glaciers lost 10.1 mi^3 (41.9 km^3) of water per year, plus or minus 2.1 mi^3 (8.6 km^3) of water per year, between 1962 and 2006 (Berthier et al. 2010). However, like temperature and precipitation, glacier ice loss is not uniform across wide areas; even while most glaciers in Alaska are losing mass, a small number have been advancing (e.g., Hubbard Glacier in Southeast Alaska). Alaska glaciers with the most rapid mass loss are those terminating in sea water or lakes (Markon et al, 2012).

7.7.2.2. Documented Changes in Climate

Scenarios Network for Alaska and Arctic Planning (SNAP) (2011) reported that Alaska has seen a statewide increase in temperatures of 2.69 degrees Fahrenheit (°F) since 1971. This has not been equal across the state. Statewide, Barrow displayed the greatest increase (4.16°F) and Kodiak showed the least (0.87°F). The U.S. Global Change Research Program (2009) reported that Alaska has experienced a 3.4°F rise in average annual temperatures over the past 50 years, with an increase in winter temperatures of 6.4°F. These increases in temperatures have led to other related changes in climate. For example, the average snow-free days have increased across Alaska by 10 days, and the number of frost-free days has steadily increased in Fairbanks, Alaska (Figure 7.7-4).

Precipitation rates are generally increasing across the state. On the whole, Alaska saw a 10 percent increase in precipitation from 1949 to 2005, with the greatest increases recorded during winters (U.S. Global Change Research Program 2009). However, this trend is very location-specific across Alaska. Figure 7.7-5 shows that while temperatures have increased in Talkeetna, mean annual precipitation has remained relatively constant (Alaska Climate Research Center 2012).

7.7.2.3. Projections of the Future

For any hydropower project it is important to understand the variability of the discharge as it directly affects power generation.

The observed trends in temperature, precipitation, and snowpack are largely consistent with climate model projections for Alaska (Christensen et al. 2007; Karl et al. 2009). The magnitude of projected changes depends on many factors and will vary seasonally. Projected changes in climate will translate into hydrologic changes through alteration of rain and snowfall timing and intensity, evapotranspiration, and groundwater and surface flows. For example, precipitation is predicted to increase in the Susitna basin, but this may be offset by an increase in evapotranspiration from warmer temperatures. Milder winters could result in reductions in snowpack because a higher percentage of precipitation would occur as rain. But given the elevation of the Upper Susitna basin, increases in precipitation may simply result in increased seasonal snow storage, resulting in greater spring runoff.

Both air temperature and precipitation are currently predicted to increase over time in Alaska, including the southcentral region (SNAP 2011). Temperatures in this region are projected to increase over the coming decades at an average rate of about 1°F (~0.6 °C) per decade (SNAP 2011).

7.7.3. Study Area

The proposed study area for the literature review is generally Southcentral Alaska including the Upper Susitna watershed, but includes relevant literature related to glacial retreat in northern latitudes.

7.7.4. Study Methods

The study components to be conducted as part of the FERC formal studies include the following:

- Review existing literature relevant to Southcentral Alaska, the Susitna watershed, and glacier retreat, and document trends in the historic record.
- Summarize results in the Initial Study Report.

7.7.4.1. Review Existing Literature

Existing literature will be reviewed to summarize the current understanding of the rate and trend of glacier retreat and the contribution of glacial mass wasting to the overall flow of the Upper Susitna watershed. This will include trend analyses of glacier retreat, temperature, and precipitation.

7.7.4.2. Summarize Results in Initial Study Report

The technical report will a summary of the results of the literature review regarding the state of knowledge regarding glacial melt in the Upper Susitna River basin along with a list of bibliographic references used in the background research. Consistency with Generally Accepted Scientific Practice

The review of existing literature relevant to glacial retreat is a commonly accepted practice to provide further insight into possible future trends that can be considered in other studies using hydrologic information.

7.7.5. Schedule

The study will be completed in 2013. Updates on the study progress will be provided during Technical Workgroup meetings which will be held quarterly in 2013.

7.7.6. Relationship with Other Studies

In Climate change studies providing parameters for anticipated precipitation and temperature changes are potentially relevant to the hydrologic-driven studies being conducted by AEA. The results of this study will be considered in several studies that rely on hydrologic modeling including water quality modeling for the reservoir and downstream areas.

7.7.7. Level of Effort and Cost

The total estimated cost of the literature review study is $40,000.

7.7.8. Literature Cited

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7.7.10. Figures

Figure 7.7-1. September 1999 oblique aerial photograph of the terminus of an unnamed glacier that drains to the East Fork of the Susitna River, looking northeast. The western end of the lake corresponds to the 1955 position of the terminus. The large trimline suggests that the glacier has recently thinned significantly more than 50 meters (164 feet) and retreated more than 2 kilometers (1.2 miles). From Molnia 2008.

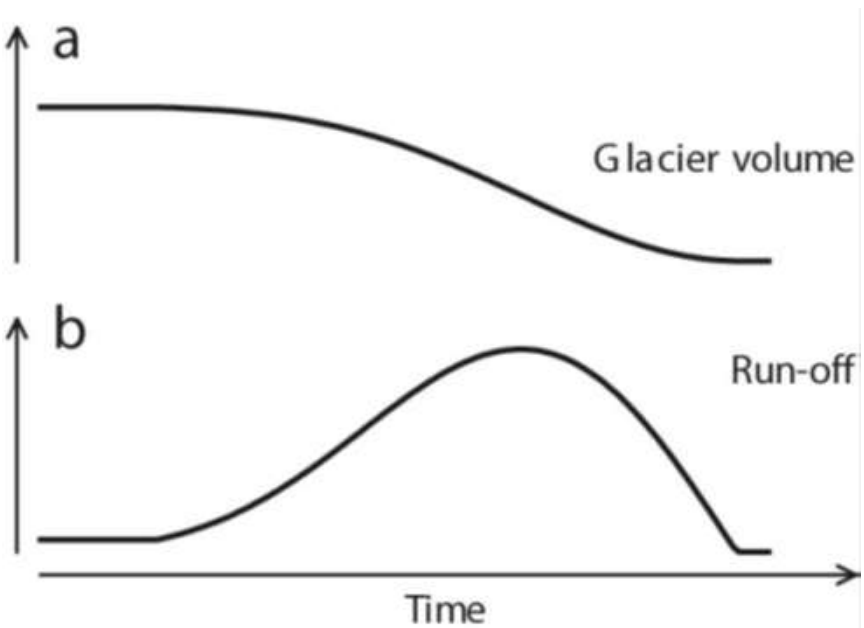


Figure 7.7-2. Schematic representation of the long-term effects of negative glacier mass balances on a) glacier volume and b) glacier runoff. Note that runoff is initially larger during prolonged mass wasting until the glacier is small enough to reduce excess runoff (Jansson et al. 2003).

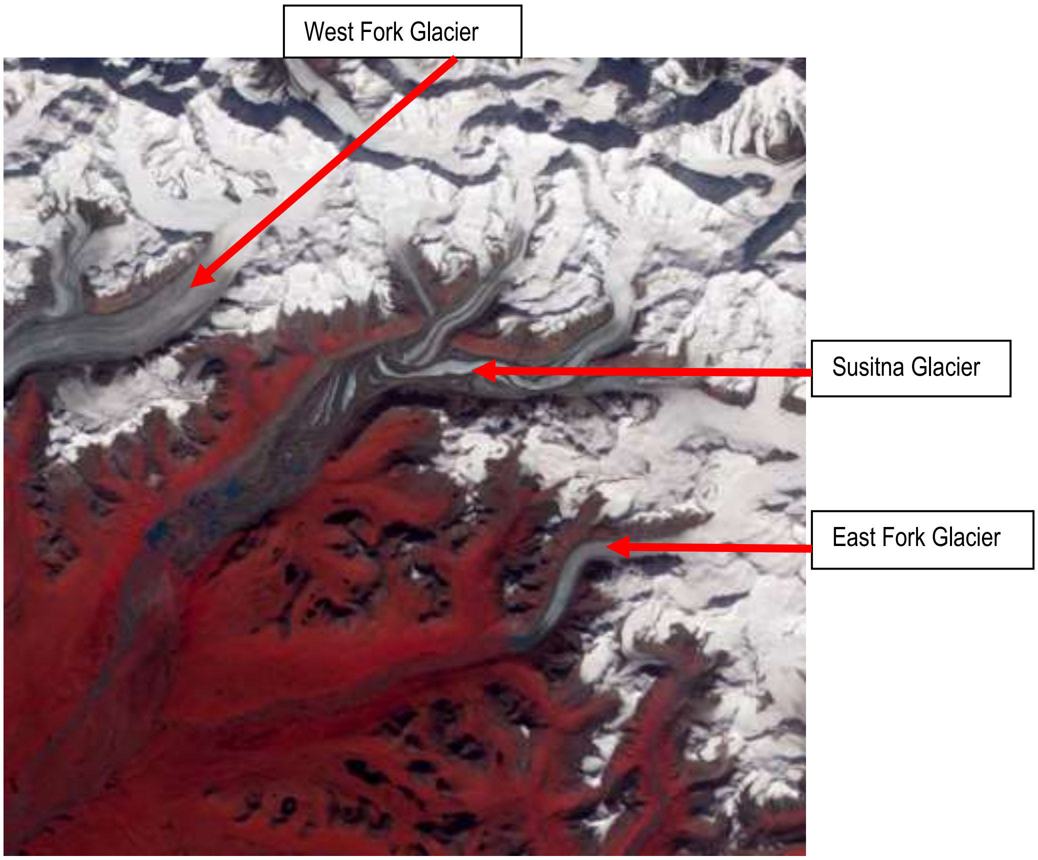


Figure 7.7-3. Susitna Glacier and other unnamed glaciers contributing to Upper Susitna River drainage.

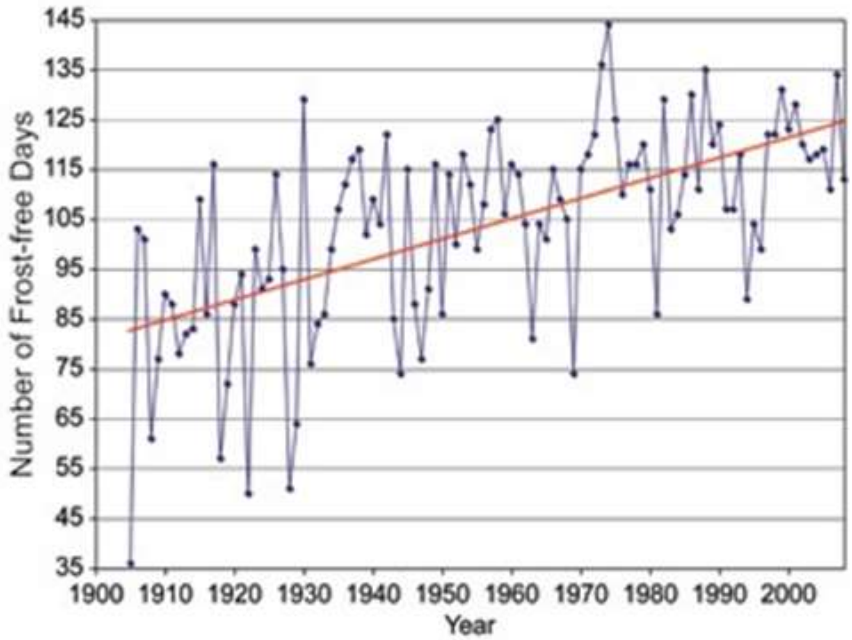
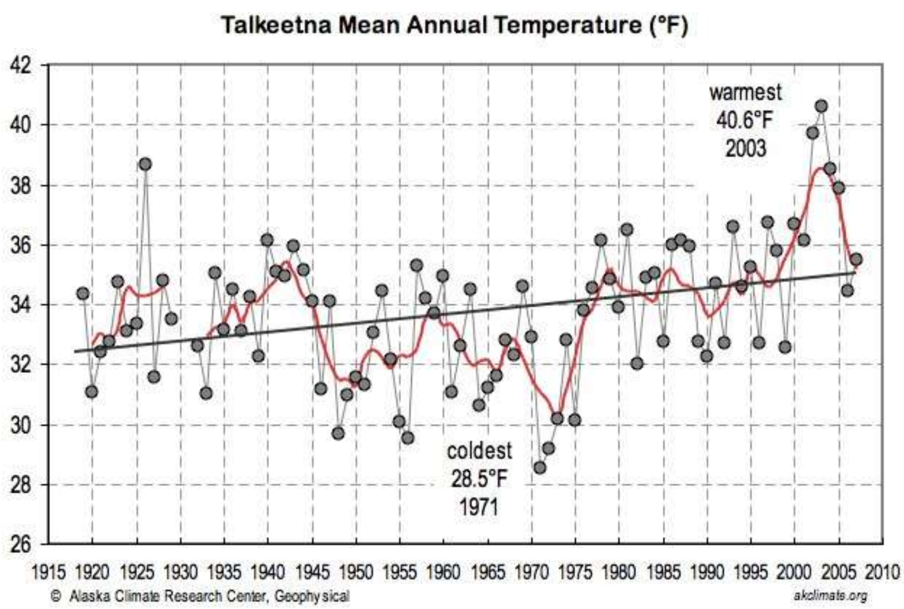


Figure 7.7-4. Fairbanks Frost-Free Season, 1904 to 2008. Over the past 100 years, the length of the frost-free season in Fairbanks, Alaska, has increased by 50 percent. U.S. Global Change Research Program (2009).



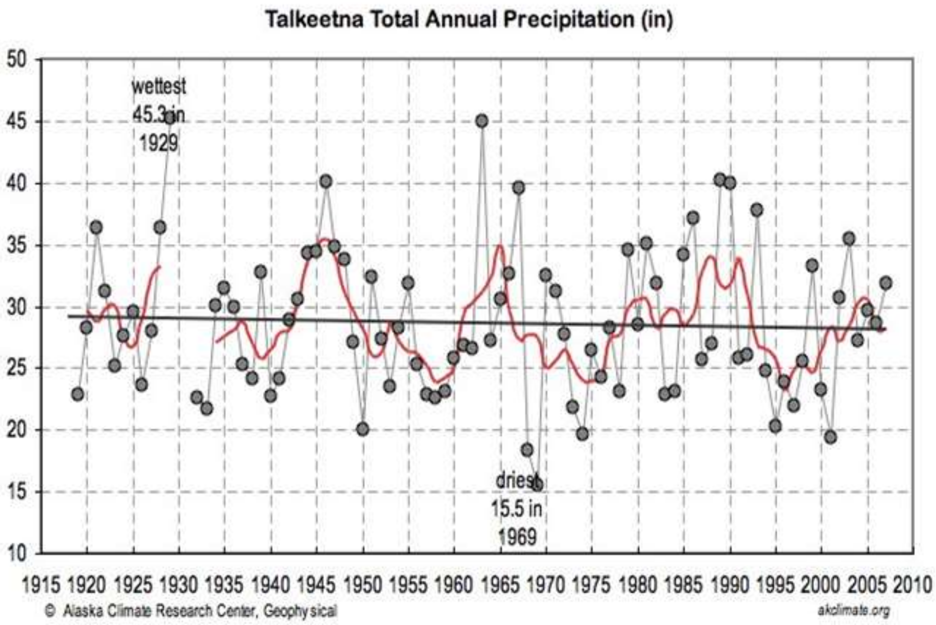


Figure 7.7-5. Mean annual temperature and total annual precipitation at Talkeetna, Alaska 1915–2010 showing the trend line. From Alaska Climate Research Center, http://climate.gi.alaska.edu/Climate/Location/TimeSeries/Talkeetna.html.

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