Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Probable Maximum Flood (PMF) Study
Study Plan Section 16.5

Initial Study Report
Part A: Sections 1-6, 8-10

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

MWH

June 2014

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

Abbreviation	Definition
AEA	Alaska Energy Authority
BOC	Board of Consultants
DAD	Depth-Area-Duration
FERC	Federal Energy Regulatory Commission
GLOF	glacial lake outburst floods
HMR	hydrometeorological reports
ILP	Integrated Licensing Process
ISR	Initial Study Report
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
Project	Susitna-Watana Hydroelectric Project
RSP	Revised Study Plan
SPAS	Storm Precipitation Analysis System
SSARR	Streamflow Synthesis and Reservoir Routing
SST	Sea Surface Temperature
SPD	study plan determination
WMO	World Meteorological Organization

1. INTRODUCTION

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). Section 16.5 of the RSP described the Probable Maximum Flood (PMF) Study. This study focuses on developing a site-specific Probable Maximum Precipitation (PMP) and modeling the PMF. RSP 16.5 provided goals, objectives, and proposed methods for data collection regarding PMF.

On February 1, 2013, FERC staff issued its study plan determination (February 1 SPD) for 44 of the 58 studies, approving 31 studies as filed and 13 with modifications. RSP Section 16.5 was one of the 31 studies approved with no modifications.

Following the first study season, FERC's regulations for the Integrated Licensing Process (ILP) require AEA to "prepare and file with the Commission an initial study report describing its overall progress in implementing the study plan and schedule and the data collected, including an explanation of any variance from the study plan and schedule." (18 CFR 5.15(c)(1)) This Initial Study Report (ISR) on the Probable Maximum Flood (PMF) Study has been prepared in accordance with FERC's ILP regulations and details AEA's status in implementing the study, as set forth in the FERC-approved RSP (referred to herein as the "Study Plan").

2. STUDY OBJECTIVES

The general goals and objectives of the PMF study are as follows:

- Develop a site-specific PMP to be used for the derivation of the PMF including both a temporal and spatial distribution of rainfall;
- Model the runoff through the project drainage basin to produce the PMF inflow, including snowmelt considerations for the Project reservoir;
- Route the PMF inflow through the Project to obtain the PMF outflow and maximum flood elevation at the dam;
- Determine the required outlet capacity to safely route the PMF through the reservoir;
- Determine the freeboard allowance; and
- Use the Board of Consultants (BOC) for technical review during development and performance of the site-specific studies.

3. STUDY AREA

As established by RSP Section 16.5.3, the study area is the entire watershed tributary to the Watana Dam site, plus the additional drainage area between Watana Dam and the USGS gaging station at Gold Creek. The watershed drainage area is 5,180 square miles at the Watana Dam site and 6,160 square miles at the Gold Creek USGS gage.

4. METHODS AND VARIANCES

The following sections describe the study methods and major tasks necessary to develop the PMP and PMF for Watana Dam, including variances from the original study plan.

4.1. Board of Consultants Review

During the 2013 study season, AEA implemented the methods for the Board of Consultants (BOC) as set forth in RSP Section 16.5.4.1, with no variances.

A BOC has been established for technical review of many aspects of the dam design. The BOC review of the studies described herein has been primarily focused on the development of the site-specific PMP but has also included other aspects of the PMF study. The BOC has met and will continue to meet and review design progress at appropriate intervals and, when appropriate, can co-opt specialists for particular topic review. The PMP and PMF study methods and tasks described herein have been the subject of review by the BOC.

4.1.1. Variances

There are no variances to the BOC section of this study.

4.2. Data Acquisition

During the 2013 study season, AEA implemented the methods for data acquisition as set forth in RSP Section 16.5.4.2, with the exception of variances explained below in Section 4.2.1.

A variety of historical recorded meteorological and hydrologic data are necessary to develop the PMP and PMF. Data acquisition began at the earliest possible time as it was anticipated that some data (e.g., streamflow data on a time increment less than daily) could take months to retrieve.

Previous PMP and storm analysis work in the region were reviewed to identify storm events, available rainfall data and techniques applicable the basin. PMP-type storm events which have occurred in a region that were considered transpositionable to the basin were identified in the storm search. A comprehensive list of significant storm events and the characteristics of the PMP type storm(s) relevant to the basin was constructed. Storms identified included storms used in previous PMP and hydrologic studies in the region. Nine storms have been identified and are the short list storms. The resulting list of storms was used to derive the PMP values for the basin for the all season PMP and the seasonally adjusted PMP.

Data was acquired to develop meteorological time series for use in rain on snow PMF modeling. Information from six floods and the associated meteorological data was used in the runoff model calibration efforts. Daily and hourly time series were developed for meteorological parameters (i.e. temperature, dew point, wind) required for snow melt modeling using data from surrounding weather stations (e.g. NWS COOP, RAWS, SNOTEL, and various other networks).

Relevant watershed data was collected including the streamflow data, drainage area of sub-basins, the area within elevation bands for snowpack and snowmelt estimation, channel slopes, vegetation cover, lake area, and soil types.

4.2.1. Variances

Archived USGS hourly streamflow records for selected floods were requested but not received. USGS daily streamflow records are available at all gages in the watershed for the period of record, and 15-minute flow data is available for the September 2012 flood. Due to the large area of the watershed and the significant snowmelt component of most floods, flood hydrographs occur over periods of 10 to 20 days, or even longer. Instantaneous annual maximum peak flows are also available. This amount of streamflow data is considered adequate to fully meet the hydrograph calibration and verification objectives of the PMF study.

4.3. Historical Data Analysis

During the 2013 study season, AEA implemented the methods for the analysis of historical data as set forth in RSP Section 16.5.4.3, with no variances.

Historical data analysis forms the basis of the PMP and PMF analysis and consisted of the following.

- Previous PMP and storm analysis work were reviewed. Significant rainfall storm events that were previously identified were noted along with supporting data and techniques used in PMP determination. Additionally, procedures used in other site-specific studies were identified that could be used for the Susitna-Watana Dam site-specific PMP study.
- A search to identify the most significant rainfall storm events in and surrounding the basin was completed.
- Storm rainfall analyses using the Storm Precipitation Analysis System (SPAS) were completed for the nine identified extreme rainfall storm events.
- A maximum Sea Surface Temperature (SST) climatology was developed for storm atmospheric moisture source regions over the Gulf of Alaska and northern Pacific Ocean. This climatology is the mean SST plus 2-sigma (2 standard deviations) and provides maximum SSTs for the storm maximization and transpositioning procedures.
- Historic peak flows were summarized for selection of major flood events for model calibration and verification.
- Flood frequency analyses were performed for up to at least the 100-year flood from historical peak flow data.
- Antecedent watershed conditions prior to the PMP were developed.
- The 100-year snowpack and snow water equivalent was determined for various elevation bands.

- The 100-year and probable maximum snowpack was developed based on October through April average precipitation.

4.3.1. Variances

There are no variances to the historical data analysis section of this study.

4.4. Review of Previous PMF Study Report

During the 2013 study season, AEA implemented the methods for review of the previous PMF study report as set forth in RSP Section 16.5.4.4, with the exception of variances explained below in Section 4.4.1.

In support of the previous design and licensing effort for the APA Susitna Hydroelectric Project, two PMF studies were performed (Acres 1982, and Harza-Ebasco 1984). These PMF studies included developing a site-specific PMP and used generally accepted methods at the time. It is notable that although many new data have become available in the 30-year interim since the previous PMF study, all of the five largest floods of record at the Gold Creek USGS gaging station were available for calibration and verification studies in 1982 (subject to change by the June 2013 flood). Although few calculations and model input data, and no output are available, the two PMF studies do contain useful information regarding final results and conclusions of the analysis, including numerous tables and figures. The two PMF study reports were thoroughly reviewed to gain applicable insights to be used in the current PMF study.

4.4.1. Variances

Subsequent to the Commission's February 1 SPD, the 1984 Susitna PMF study became available. It was included in the review of previous PMF studies in the same manner as the 1982 Susitna PMF study so that a comprehensive background of PMF studies for the Susitna could be used to inform and verify the current study approach As a historical note, two of the largest seven floods of record at the USGS streamflow gaging station at Gold Creek have occurred (September 2012 and June 2013) since filing of the PMF study plan, although peak flow rates are preliminary and subject to change by the USGS. The June 2013 flood is not used in this study because it occurred after selection and meteorological data analysis began of the storms associated with the floods used for runoff model calibration and verification.

4.5. Field Visit

During the 2013 study season, AEA implemented the methods for the field season as set forth in RSP Section 16.5.4.5, with no variances.

In conformance with FERC's recommendations for PMF studies (FERC 2001), AEA conducted two field visits during the 2012 and 2013 study seasons. These occurred on September 27, 2012 and May 29, 2013. The site flyover on May 29, 2013 with the BOC included representatives from the study team. The site flyover of September 27, 2012 was specifically for the study team participants. The site visits were undertaken to observe significant topographical variations within and adjacent to the basin. Observations made during the field visits were oriented toward the following aspects:

- Manning's "n" and general hydrologic and hydraulic characteristics of river channels;
- Special features within the drainage basin such as marshes, lakes, and closed basins that may delay or reduce runoff;
- Constrictions such as bridge abutments that may influence flood routing characteristics, although none were observed;
- Areal extent of snow cover;
- Large natural constrictions that could act as hydraulic control structures, but none were observed; and
- Areas that could result in locally different infiltration rates, including rock exposures, dense forest, or high altitude meadows.

4.5.1. Variances

There are no variances to the field visit section of this study.

4.6. Flood Hydrology Model Selection

During the 2013 study season, AEA implemented the methods for flood hydrology model selection as set forth in RSP Section 16.5.4.6, with no variances.

At least three flood hydrology models are available, and a key task was to select which to use to develop the PMF. These models include:

- Streamflow Synthesis and Reservoir Routing (SSARR). This model was developed by the U.S. Army Corps of Engineers (USACE), North Pacific Division. The SSARR model was used for the 1982 Susitna PMF study. In addition to its use by the USACE, the SSARR model was used occasionally by consultants for flood simulation on major watersheds, particularly in the Pacific Northwest. The SSARR model is no longer in general use. The latest version of SSARR was modified in 1991 to run on IBM-compatible personal computers. The USACE has noted that there will be no further program updates or modifications to the SSARR files by the USACE, and no user support is available.
- Flood Hydrograph Package (HEC-1). This model was developed by the Hydrologic Engineering Center (HEC) of the USACE and was (possibly still is) the most widely used model in PMF studies. HEC-1 is one of the two rainfall-runoff models recommended for PMF studies (FERC 2001). Compared to other models, HEC-1 has the advantage of including the recommended energy budget snowmelt method as well as fully documented equations for calculating snowmelt in the model.
- Hydrologic Modeling System (HEC-HMS). This model was also developed by the HEC and is the Windows-based successor to HEC-1. HEC-HMS contains many of the same methods as HEC-1 and is the other model recommended for PMF studies (FERC 2001). Snowmelt in the HEC-HMS model is based on a method that uses temperature data only.

Flood hydrology model selection was reviewed with the BOC during the initial BOC meeting on November 2, 2012. With BOC input from that review, AEA has selected the HEC-1 Flood Hydrograph Package as the rainfall-runoff model for developing the PMF.

4.6.1. Variances

There are no variances to the flood hydrology model selection section of this study.

4.7. Flood Hydrology Model Initial Setup

During the 2013 study season, AEA implemented the methods for the initial setup of the flood hydrology model as set forth in RSP Section 16.5.4.7, with no variances.

The flood hydrology computer model initial setup includes sub-basin delineation, areas in elevation bands for use in snowmelt calculations, lake areas, areas in various soil groups, coincident base flow, and initial estimates of infiltration rates. Sub-basin delineation was aligned with USGS stream-gaging station locations whenever possible to facilitate model calibration and verification. River channel geometry was checked for areas that may warrant special consideration for storage-outflow routing. Topographic mapping was developed using ArcGIS software.

4.7.1. Variances

There are no variances to the flood hydrology model initial setup section of this study.

4.8. Flood Hydrology Model Calibration and Verification

During the 2013 study season, AEA implemented the methods for flood hydrology model calibration and verification as set forth in RSP Section 16.5.4.8, with the exception of variances explained below in Section 4.8.1.

This task includes calibration and verification of the sub-basin unit hydrographs to the extent that available recorded streamflow and meteorological data allow. Calibration provides the important adjustments to hydrograph parameters that are initially estimated from standard equations or based on experience in similar watersheds. Two of the largest floods on record were planned to be selected for calibration, with a third large historical flood used for verification. However, as work proceeded in reviewing floods, three floods were chosen each for rainfall and snowmelt flood events because it was not clear which flood type would be the dominant and critical condition for the PMF. More storms would also be available if further calibration/validation is required. The calibration points at the outlets of the sub-basins coincide with USGS stream-gaging stations to the extent possible. The selection of storm periods to use in model calibration and verification included the availability of data at multiple stream-gaging stations. Activities under this task would also include estimating ungaged local runoff as necessary, base flow separation, and a final estimate of infiltration loss rates.

4.8.1. Variances

The calibration and verification of hydrograph parameters normally involves the collection of meteorological and flow data for three flood periods. Analysis of flood records as the PMF study proceeded revealed that there have been two fundamentally different and seasonally separated flood generating scenarios, one resulting primarily from rainfall, the other primarily from snowmelt. It could not be determined in advance which of these flood generating scenarios would ultimately be the critical condition for the PMF. Therefore, three floods of each type (total of six) were selected for calibration and verification. This resulted in an initially unanticipated increase in data acquisition and calibration effort, although it was considered to be necessary for a reliable determination of the PMF.

4.9. Development of the Site-Specific PMP

During the 2013 study season, AEA implemented the methods for flood hydrology model calibration and verification as set forth in RSP Section 16.5.4.8, with the exception of variances explained below in Section 4.9.1.

The applicable available National Weather Service (formerly the U.S. Weather Bureau) PMP guidance document is *Probable Maximum Precipitation and Rainfall-Frequency Data for Alaska,* Technical Paper No. 47 (Miller 1963). Technical Paper No. 47 is applicable to areas up to 400 square miles and durations up to 24 hours. Because the drainage area at the Watana Dam site is 5,180 square miles and current standards call for the PMP to have a duration of at least 72 hours, development of a site-specific PMP is necessary. The existing PMP studies are being used to make comparisons to the 1982 Susitna site-specific PMP and the Technical Paper No. 47 PMP at the highest-intensity central 400-square-mile area and 24-hour duration of the new site-specific PMP. Development of the site-specific PMP for the watershed tributary to the proposed Watana Dam site required a substantially greater effort than is necessary for most other dams in the USA because of new storm analyses, sparse data availability and cool season considerations.

The site-specific PMP study follows many of the methods (e.g., a storm-based approach) used to develop the current National Weather Service PMP hydrometeorological reports (HMR). The basic techniques for storm maximization and transposition are well-established. An additional 30 years of data and more advanced models and recent adjustments to methods are now available for development of site-specific PMP (e.g. radar aided storm analyses, quantification of orographic affects). Results include both a temporal and spatial distribution of the PMP for durations appropriate to most accurately model the PMF. No predetermined maximum storm sequence length is set so that the critical PMP sequence could be 96 hours or more. Long duration, high volume events are among the candidate PMF cases evaluated to determine if they constitute the critical storm event for the determination of the PMF maximum reservoir elevation. In addition, guidance for alternative centerings of the PMP design storm are determined based on the patterns of the actual storm events used to derive the PMP values. NEXRAD data are used when available (generally after 1995) in all storm analyses.

A consultant with extensive experience in developing site-specific PMP was retained to perform this task. The initial storm search included all twelve months of the year, so the months that are potentially PMP drivers will naturally result from this process. Based on an analysis of historic flow frequency, peak annual flood data, and anticipated seasonal reservoir levels, the PMP development is expected to be focused on the months of May through October. The site-specific PMP task also includes development of the 100-year precipitation temporal and spatial distribution during a season coincident with the probable maximum snowpack.

4.9.1. Variances

While the development of the site-specific PMP is well underway, it was not completed in study year 2013. At the time the RSP was prepared, it was contemplated the development of the PMP could be fully accomplished in the first study year, however due to the complexity of the meteorology to capture both snowmelt and rainfall, and the need to accommodate the BOC schedules for meetings leading into 2014, the PMP work was not finalized, but will be finalized in 2014.. This will allow the study to meet the study objectives by allowing the BOC a full review of the PMP work.

4.10. Coincident Conditions for the PMF

Developing coincident conditions includes the 100-year snowpack, the probable maximum snowpack, necessary temperature, dew point, and wind speed sequences, and other data for energy budget method as necessary. The 100-year precipitation is also being developed, because one of the potential combinations of coincident conditions that can result in the PMF is the probable maximum snowpack combined with the seasonally appropriate 100-year precipitation. A determination of the maximum reservoir level during the 50-year flood may also be required, as this may become the starting reservoir elevation for spillway operation.

4.10.1. Variances

While the development of the coincident conditions for the PMF work efforts were mostly accomplished in 2013, the full effort was not completed in study year 2013. At time the RSP was prepared, it was contemplated the site-specific PMP and PMF study could be completed in 2013, however due to the complexity of the hydrology to capture both snowmelt and rainfall events, and the need to accommodate the BOC schedules for meetings leading into 2014, the PMF work was not finalized, but will be finalized in 2014. This will allow the study to be ensure it meets the study objectives by allowing the BOC a full review of the PMP work.

4.11. Development of the PMF Inflow Hydrograph

The PMF is being developed at the proposed Watana Dam site by combining sub-area runoff and performing channel and reservoir routings for various cases and months. The energy budget snowmelt method is being used. Routing of the PMF through the reservoir may account for use of the fixed-cone outlet valves for discharges up to the 50-year flood and use of the spillway only after the expected maximum level of the 50-year flood has been exceeded, but final flood operating procedures are not yet finalized. While the development of the PMF Inflow Hydrograph was initiated in 2013, work efforts will continue into 2014. This task also includes a sensitivity analysis to test the effects of variation in parameters with relatively high uncertainty that could potentially have more significant effects on the results. The PMF channel routing will use the selected flood hydrology model.

4.11.1. Variances

As noted above, the full effort was not completed in study year 2013. At the time the RSP was prepared, it was contemplated the site-specific PMP and PMF study could be completed in 2013, however due to the complexity of the hydrology to capture both snowmelt and rainfall events, and the need to accommodate the BOC schedules for meetings leading into 2014, the PMF work was not finalized, but will be finalized in 2014. This will allow the study to ensure it meets the study objectives by allowing the BOC a full review of the PMP work.

4.12. Reservoir Routing of the PMF

Spillway capacity should be determined as part of the economical combination of spillway capacity and surcharge storage. Surcharge storage is defined as the storage between the normal maximum pool level (still water) and the maximum design flood water storage level. Determining the economical combination of surcharge storage/spillway capacity requires evaluation of the cost of increasing spillway capacity versus the cost of raising the dam height to provide the required freeboard (routed maximum flood level plus any required allowance for wind setup and wave run-up). Reservoir flood routing is used to determine the temporal and water level variation of the hydrograph as the flood passes through the reservoir. Increasing the spillway capacity will reduce the necessary surcharge storage (determined by flood routing), thereby lowering the required height of the dam. Alternatives analysis are being performed to optimize spillway capacity and flood surcharge. The PMF reservoir routing will use the selected flood hydrology model. As outlined in the RSP, this task was expected to be part of the PMF study that would all be accomplished in 2013, however this specific study component is being deferred to 2014.

It is expected that the volume and distribution of potential future sedimentation in the reservoir will form a PMF routing sensitivity case. AEA is evaluating the potential for glacial lake outburst floods (GLOF). AEA will compare the potential for GLOF to the critical PMF inflow hydrograph and will route the GLOF to determine the peak reservoir level if the GLOF potentially forms the critical condition for spillway design.

4.12.1. Variances

As noted above, the full effort was not completed in study year 2013. At time the RSP was prepared, it was contemplated the site-specific PMP and PMF study could be completed in 2013, however due to the complexity of the hydrology to capture both snowmelt and rainfall events, and the need to accommodate the BOC schedules for meetings leading into 2014, the PMF work was not finalized, but will be finalized in 2014. This will allow the study to meet the study objectives by allowing the BOC a full review of the PMP work.

4.13. Freeboard Analysis

Freeboard provides a margin of safety against the potential for overtopping of dams. Freeboard and flood control storage are required to provide the capacity to store and/or route the design storm through the reservoir considering inflows, precipitation on the reservoir basin, and wind generated waves without hazardous overtopping of the dam. Although freeboard selection involves more than simply the PMF water level, the freeboard selection will be made as part of the subject study, based on wind setup, wave action, uncertainties in analytical procedures, and uncertainties in Project function in combination with the most critical pool elevation (USACE 1991). The freeboard determination will be based on site-specific conditions that can be reasonably expected to occur simultaneously. Design criteria will be developed for logical combinations of reservoir levels/precipitation and wind conditions for freeboard determination. Wind setup and wave run-up will be determined with standard methods (USACE 1984 and USACE 2003). As outlined in the RSP, this task was expected to be part of the PMF study that would all be accomplished in 2013, however this specific study component is being deferred to 2014.

Normal freeboard is defined as the difference in elevation between the top of the dam and the normal maximum pool elevation. Minimum freeboard is defined as the difference in pool elevation between the top of the dam and the maximum reservoir water surface that would result from routing the PMF through the reservoir. It is generally not necessary to prevent splashing or occasional overtopping of a dam by waves under extreme conditions particularly for a concrete dam. If studies demonstrate that the RCC dam can withstand wave overtopping without erosion of foundation or abutment material, then minimum (or no) freeboard will be selected for the PMF condition. In that case, only normal freeboard would be required. The study of freeboard will take into account unusual circumstances.

4.13.1. Variances

As noted above, the full effort was not completed in study year 2013. At time the RSP was prepared, it was contemplated the site-specific PMP and PMF study could be completed in 2013, however due to the complexity of the hydrology to capture both snowmelt and rainfall events, and the need to accommodate the BOC schedules for meetings leading into 2014, the PMF work was not finalized, but will be finalized in 2014. This will allow the study to meet the study objectives by allowing the BOC a full review of the PMP work.

4.14. Reporting

Two reports will be prepared, one covering the development of the site-specific PMP, the other an overall PMF report for all aspects of the PMF study, including a summary of the site-specific PMP. The PMF report will generally follow the outline suggested by FERC for PMF studies (FERC 2001).

5. RESULTS

This section summarizes results completed to date.

5.1. Board of Consultants

The BOC meetings to date with regards to the PMP and PMF are summarized as follows:

- November 1-2, 2012, Bellevue, WA – This was the initial meeting of the BOC. The PMP presentation included a comprehensive overview of the site-specific PMP study process, and a preliminary graphic analysis of selected historic storms, sea surface temperatures, meteorological data, and storm tracks. PMF discussion focused on the availability of USGS streamflow gaging data, historic seasonal flows and annual peak flows, data contained in previous Susitna PMF studies from the 1980s, PMF rainfall-runoff model selection, snowmelt method selection, seasonal limits of the PMF study, and a review of the PMF study plan.

- March 7-8, 2013, Bellevue, WA – This BOC meeting focused on Susitna-Watana aspects other than the PMP and PMF. Only a very brief update on the PMP and PMF studies was presented.
- April 3-4, 2013, Denver, CO – This meeting was exclusively a PMP and PMF workshop with only the PMP and PMF experts from the BOC attending. PMP topics covered included selection of the initial storm short list, initial historic storm analysis, the storm maximization process, the limits of storm transposition, the orographic transposition factor, and the meteorological time-series development process. PMF aspects discussed included sub-basin segmentation, data acquisition using GIS, the months of occurrence of annual peak flows, selection of floods for hydrograph parameter calibration and verification, and results of a reconstruction of the 1982 PMF.
- May 29-30, 2013, Anchorage, AK – This meeting was primarily a site visit for the full BOC, but PMP and PMF updates were also included on May 30. On May 29, the PMP and PMF BOC experts and consultants conducted a watershed over-flight in a single-engine airplane. The PMP status update included a summary of work completed on storm analysis, meteorological data for the runoff model, storm maximization and development of the proportionality constant. The PMF update included a discussion of alternative methods for required snowpack development, seasonal watershed precipitation and mapping, snowpack data availability, and a runoff volume frequency analysis.

5.2. Field Visit

A field visit is a recommended part of the PMF study (FERC 2001) and was performed on May 29, 2013 with the BOC. The PMP and PMF BOC experts and consultants conducted a watershed over-flight in a single-engine airplane, beginning and ending at Talkeetna airport. Numerous geo-referenced photographs were taken. All watershed observations were made from the air as no landings were made within the watershed area tributary to Watana Dam.

The field visit occurred at an opportune time because a flood flow that equaled the maximum flow of record occurred at the Gold Creek USGS gaging station on June 2, 2013. On May 29, the day of the site visit, the high temperature was 83 degrees at Talkeetna. A colder than average spring was followed by a rapid warming that resulted in a snowmelt flood without significant concurrent rainfall. Figure 5.2-1 shows remnants of a river ice cover following the breakup. Figure 5.2-2 shows the Susitna River in the vicinity of the Denali Highway crossing with remaining snow cover on May 29, 2013.

5.3. Basin Hydrologic Data

Table 5.3-1 lists the data availability at USGS streamflow gaging stations in or near the Susitna watershed. Figure 5.3-1 is a location map that shows the location of USGS gages and the Susitna River watershed boundaries to Watana Dam and to the most downstream USGS gaging station.

Determination of snowpack and the resulting snowmelt is a particularly important part of the PMF study. Figure 5.3-2 shows the locations of the snow course and SNOTEL stations in and near the Susitna River watershed. Table 5.3-2 provides the latitude-longitude location, elevation, and period of record for the snow course and SNOTEL stations. Data for the full period of record was gathered at all of the stations.

5.4. Sub-Basin Definition

Figure 5.4-1 outlines the 29 sub-basins tributary to Watana Dam and the 5 additional sub-basins between Watana Dam and the USGS gaging station at Gold Creek, which is the downstream limit of the PMF study. Table 5.4-1 provides a summary of elevation-band area data for the 29 sub-basins tributary to Watana Dam. The watershed area in elevation bands is depicted on Figure 5.4-2.

Figure 5.4-3 shows the type and distribution of watershed cover and Table 5.4-2 provides a data summary for the watershed cover types. Shrub and scrub is the dominant watershed cover type, totaling about 56% of the entire watershed. Forest covers about 18% of the watershed to the Gold Creek USGS gaging station. Barren land makes up about 15% of the watershed cover, while wetlands cover 3.9%, perennial snow/ice is 3.8% and open water covers 2.9% of the watershed.

5.5. Historic Flood Records

For the four USGS gages upstream or near the proposed Watana Dam site, the ranked highest ten peak flows of record for the Susitna River at Gold Creek, Cantwell, near Denali, and for the Maclaren River near Paxson have been summarized in Tables 5.5-1 through Table 5.5-4, respectively. Floods for the same date at different stations have been highlighted in the same color. Floods with the largest recorded peaks at the most gages are favored for selection as flood hydrograph calibration and verification floods. As would be expected, there is some variation in the flood rankings from gage to gage, in part due to the period of record available for each gage.

5.6. Seasonal Flood Distribution

The determination of a 100-year snowpack for every month of the year is unnecessary because of the highly seasonal nature of Susitna River flow. With 59 years of daily flow data available, the USGS streamflow gage at Gold Creek provides an excellent long-term record of the seasonality of Susitna River flow. Table 5.6-1 provides the maximum daily flow of record at Gold Creek for each month. During the coldest months of November through March, a daily flow of as much as 10,000 cfs has never been recorded, indicating that these five months can be eliminated as potentially maximum flood producing months.

Table 5.6-2 presents a summary of the month of occurrence of the annual peak flow at each of the four USGS gages in or near the watershed tributary to the Watana Dam site. For the gaging stations nearest the Watana Dam site, Gold Creek and Cantwell, June is the month during which the annual maximum flows most frequently occur and the same is true at the Maclaren gage. The Denali gage is most heavily influenced by glacier melt and annual peak flows occur most frequently at Denali during July or August. In 134 gage-years of daily flow data, an annual peak flow has never been recorded during the months of October through April.

Additional flow frequency data at Gold Creek is provided on Figure 5.6-1, and simulated maximum and median monthly Watana reservoir elevations are shown on Figure 5.6-2. Because April is the month with the lowest reservoir elevations, and April flows exceed 10,000 cfs less than 1 percent of the time, April can be eliminated from further consideration as the critical PMF month for Watana Dam. Although October has never had an annual maximum flow, the reservoir levels would be higher and it was therefore retained for further consideration as a potentially critical month for the PMF.

5.7. Snowpack Determination

5.7.1. Snowpack Distribution

Maximum snowpack distribution data was developed in proportion to the October through April average precipitation as has been previously suggested for the Yukon River (Weather Bureau 1966). GIS-based monthly precipitation was prepared using PRISM (Parameter-elevation Regressions on Independent Slopes Model) an analytical tool developed at Oregon State University that uses point data, a digital elevation model, and other spatial data sets to generate gridded estimates of monthly, yearly, and event-based climatic parameters, such as precipitation, temperature, and dew point.

Figure 5.7.1-1 graphically depicts the October through April average precipitation for the drainage area above the Gold Creek USGS gaging station. This figure clearly shows the wide variation in precipitation with lower total precipitation in the southeast part of the watershed and higher precipitation in the northern and western portions of the watershed.

Historic snowpack data at available SNOTEL and snow course stations can be used to develop the 100-year snowpack by season. The same ratio of the 100-year snowpack at a given snow course station (or stations) for a given month to the seasonal precipitation (Oct-April) is being used to develop the 100-year snowpack at all locations. Different ratios are used for different months. For example, if the 100-year SWE at a snow course station (or stations) for May was equal to 120 percent of the October through April average precipitation at the snow course station (or stations) as determined from GIS precipitation maps, then the 100-year SWE at all locations in the watershed for May would be equal to 120 percent of the Oct-Apr precipitation.

Table 5.7.1-1 provides the monthly average precipitation for each sub-basin and for the annual and October through April totals. Also shown is the area-weighted average precipitation to Watana Dam and to each of the four USGS gaging stations. The months of maximum precipitation are July through September with April being the month with the minimum precipitation. The average October through April precipitation varies from a maximum of almost 20 inches for the West Fork Susitna River (sub-basin 6) to a minimum of 4.32 inches in the area tributary to Susitna Lake and Tyone Lake (sub-basin) 14.

5.7.2. 100-Year Snowpack

PMF combined events criteria call for using a 100-year snowpack coincident with the PMP appropriate for the same month. The 100-year snow water equivalent was developed at several stations based on monthly snowpack statistics and the following equation:

$$SWE = M + KS$$

where: SWE is the 100-year snow water equivalent (inches)

M is the mean snow water equivalent for a month (inches)

S is the standard deviation of the monthly snow water equivalent (inches)

K is a factor corresponding to a 100-year return period and the calculated skew of the monthly snow water equivalent

Table 5.7.2-1 presents the calculated 100-year snow water equivalent values on or about the first of the month from February through May. Also shown is the October through April average total precipitation at the snow course locations as obtained from PRISM data. The last column of this Table shows the ratio of the calculated May 1, 100-year SWE values to the October through April total average precipitation. These are the key values used to distribute the 100-year snowpack over the watershed.

The last column ratios in Table 5.7.2-1 for snow courses in areas tributary to Watana Dam range from 1.51 to 1.94 and average 1.68. The data for the snow courses highlighted in red, which are all outside the area tributary to Watana Dam, are all outside the 1.51 to 1.94 range and have therefore been eliminated from further consideration. Therefore, the tributary area average factor of 1.68 times the average October through April total precipitation was selected and was used to develop the 100-year May and June snowpacks. Due to the potential for cold weather to persist from April up to the start of June, the May and June snowpacks were considered to be equal. The precipitation that falls during May would essentially offset any snowmelt that occurs. Table 5.7.2-2 presents the 100-year all season snowpack SWE averaged by sub-basin. The runoff model separates the 100-year SWE values within each sub-basin by 1000-foot elevation bands.

5.7.3. Probable Maximum Snowpack

The evaluation of a 100-year precipitation on a Probable Maximum Snowpack is required in areas where snowpack may make a significant contribution to the PMF (FERC 2001). In many cases, it can be enough to simply assume an unlimited snowpack and if the resulting PMF is less than for the PMP on 100-year snowpack case, then the Probable Maximum Snowpack scenario can be dismissed, which is the usual result. A more reasonable Probable Maximum Snowpack is developed for Watana Dam in this section.

The Yukon River watershed lies to the north and east of the Susitna River watershed and is in places adjacent to the Susitna River watershed. The Weather Bureau (1966) has prepared a hydrometeorological report (HMR 42) for the Yukon River and preparation of a Probable

Maximum Snowpack for the Yukon River was a major part of the report. Results of the HMR 42 are applicable to the Susitna River watershed.

The HMR 42 Yukon River final result was that the Probable Maximum Snowpack was equal to 3.0 times the October through April cumulative average precipitation, based on an enveloping analysis of historic October through April precipitation data. The Susitna River watershed tributary to Watana Dam lacks this type of long-term precipitation data. In terms of May 1 recorded snow course SWE as a ratio to October through April average precipitation, the maximum recorded year values for the area in or near the area tributary to Watana Dam are significantly less than 3.0. Although it is a very approximate comparison, a snowpack of 3.0 times the average snowpack on May 1 would be more rare than a calculated 10,000-year event at many of the snow course stations, which would be appropriately rare for a probable maximum event.

The adopted Probable Maximum Snowpack for the watershed tributary to Watana Dam will be 3.0 times the average October through April precipitation. The method of snowpack distribution over the watershed will be the same as for the 100-year snowpack. The average Probable Maximum Snowpack SWE for each sub-basin is presented on Table 5.7.3-1. The average Probable Maximum Snowpack SWE in the area tributary to Watana Dam is 27.9 inches, which compares to the Weather Bureau result of 15.7 inches Probable Maximum Snowpack for the upper Yukon River.

5.8. Runoff Model Calibration Floods

Preference for selection of historic floods for calibration and verification was based on:

- The largest floods of record;
- The floods with data at the most USGS gages
- The floods with the most complete flow data near the peak flow
- Distribution of floods in the May through October potential flood season
- Storms used for calibration in the 1980s PMF studies
- Storms used for PMP development

The flood periods selected for calibration and verification of hydrograph parameters are:

1. June 1964
2. August 1967
3. June 1971
4. August 1971
5. June 1972
6. September 2012

Consideration was given to the June 1964 flood because it has the largest peak flow and the largest daily average flow of record at Gold Creek and is the second largest flood of record at Cantwell. It was also the 10th largest flood of record on the Maclaren River, and the largest flow of the year at Denali. Because of the magnitude of the flood at Gold Creek and Cantwell and the availability of flow data at all four USGS gages, June 1964 was selected for use in the calibration and verification of hydrograph parameters.

The August 1967 period was used as a calibration flood in the 1982 Susitna PMF study and was also selected for PMP analysis. It had the 5th highest peak flows at Gold Creek and Cantwell, the 2nd highest peak flow of record at Denali, and the 3rd highest peak flow on the Maclaren River. Although a peak flow value is available at Denali, no daily flow data is available. Data availability and the magnitude of the flood are sufficient for selection of the August 1967 period as one of the floods for calibration and verification of hydrograph parameters.

June 1971 was used as a calibration flood in the 1982 Susitna PMF study. Data is available at all four USGS gages. It is the 7th largest partial duration flood of record at Gold Creek and has the 3rd highest partial duration flow of record at Cantwell. The shape of the hydrograph appears to be well-suited for calibration. Because of data availability and flood magnitude, June 1971 is selected. As an example of recorded flood data, the available flow data for June 1971 are shown on Figure 5.8-1.

August 1971 was used as a calibration flood in the 1982 Susitna PMF study. Data is available at all four USGS gages and it was also selected as a PMP evaluation storm. It is the maximum flood of record at Cantwell, Denali, and the Maclaren River, and the 2nd largest flood of record at Gold Creek. Because of data availability at all four USGS gages and because of the flood magnitude, August 1971 is selected for calibration and verification of flood hydrograph parameters.

June 1972 was one of the calibration floods in the 1982 Susitna PMF study. Data is available at all four USGS gages. It is the 3rd largest peak flow of record at Gold Creek, the 4th largest at Cantwell, and the 6th largest on the Maclaren River. Because of data availability and the magnitude of the flood, the June 1972 period is selected for calibration and verification of hydrograph parameters.

The September 2012 flood was selected for further PMP analysis. Data is currently available at the USGS gages at Gold Creek, Denali, and the new gage below Tsusena Creek. The September 2012 flood was the largest flood at Gold Creek in the past 40 years, the 6th largest on record, and by far the largest flow ever recorded in September. Because of the exceptional nature of this September flood, and because of the availability of more meteorological data than for other floods, the September 2012 flood is selected for calibration and verification of unit hydrograph parameters.

5.9. Probable Maximum Precipitation

Previous PMP and storm analysis work in the region were reviewed to identify storm events, available rainfall data and techniques applicable to the basin. Previous site-specific PMP studies were reviewed for procedures that are applicable. Discussions were drafted for inclusion in the final report to summarize the applicability of the previously used procedures.

PMP-type storm events which have occurred in a region that were considered transpositionable to the basin were identified in the storm search. Storms identified included storms used in previous PMP and hydrologic studies in the region. The resulting list of storms was used to derive the PMP values for the basin for the all season PMP and the seasonally adjusted PMP. Table 5.9-1 presents the short list of storms used to determine the PMP values in this analysis. A comprehensive list of significant storm events and the characteristics of the PMP type storm(s) relevant to the basin was constructed.

All storms on the short list were fully analyzed using the SPAS. The SPAS program allowed for the development of rainfall grids on a 1/3rd of a square mile resolution at hourly (or 5-minute with NEXRAD) temporal increments. Figure 5.9-1 shows an example of the total storm isohyetal pattern for a SPAS storm analysis. The program follows the same basic procedures used in the HMRs to develop Depth-Area-Duration (DAD) and mass curve information. These analysis results were used to develop the PMP values and provided the required information to calculate the orographic transposition factor. Nine new SPAS storm analyses were completed. Figure 5.9-2 shows the locations of rainfall centers associated with the nine storms.

Total adjustment factors were calculated for each of the storms on the short storm list. This included an update of the 2 sigma sea surface temperature climatology that was completed for other PMP studies along the West Coast. This update extended that climatology to include all of the Gulf of Alaska and northern Pacific Ocean to ensure all areas that could supply atmospheric moisture for extreme rainfall events were included. The total adjustment factor is a combination of the in-place maximization factor, the moisture transposition factor, and the orographic transposition factor. The in-place maximization factors for all short list storms were calculated. This procedure follows the standard procedures as outlined in the HMRs and the World Meteorological Organization (WMO) PMP manual. This procedure has been used during PMP studies completed over the previous 15 years. Trajectory model analyses were completed for each of the short list storms to provide guidance in determining the storm moisture inflow vector. Figure 5.9-3 shows an example of a trajectory model analysis. Each storm was transpositioned to the basin using standard procedures outlined in the HMRs and WMO manuals and previous PMP studies conducted by the consultant. Upwind and within basin mountainous regions are being analyzed to determine the effect on moisture availability and rainfall production within the basin. This process can either enhance storm dynamics or deplete available atmospheric moisture, thereby affecting the resulting rainfall. The orographic transposition factor is being calculated to quantify the difference in orographic effects from the in-place storm location and the Susitna-Watana drainage basin.

A meteorological time series was developed for use in rain on snow PMF modeling. Information from six storms was used in model calibration efforts. Daily and hourly time series were developed for meteorological parameters (i.e. temperature, dew point, wind) required for snow melt modeling using data from surrounding weather stations (e.g. NWS COOP, RAWS, SNOTEL, and various other networks). A data set was provided that represented the environment which occurred prior to, during, and immediately following the storm events used to derive the PMP values when rain on snow is a consideration. Storm dates associated with rain-on-snow rainfall events in the region were used to develop the meteorological input parameters for each hour of a period required for hydrologic modeling. The average thermal structure during extreme rainfall events was provided as input for PMF modeling to support snowmelt calculations. The meteorological variables associated with the pre-storm and storm environment starting prior to the beginning of rainfall and continuing through the rainfall period were analyzed for the storms on the short list. These parameters were supplied to the hydrologist for inclusion in the hydrologic model analyses and specifically for the energy budget equation used to calculate the rate and amount of snowmelt which would reasonably be expected to occur prior to and coincident with the PMP event. This allowed for an accurate representation of the conditions that could be expected during a rain-on-snow PMP scenario based on actual storm data and physically possible meteorological parameters.

The site-specific PMP values is being derived for the basin required for PMF calculations. These results are being provided on a gridded basis (.025DD x .025DD resolution) similar to the grid spacing used in several other PMP studies completed or in progress. Also, DAD tables were provided in the same format as given in the HMRs for comparison and sensitivity purposes. Results were also provided on a sub-basin level.

5.10. Review of Previous PMF Studies

A comparison of the current study snowpack results to those obtained during the 1980s Susitna PMF studies is instructive. The 1982 Acres June PMF had a 51 inch SWE in the area tributary to Watana Dam site, and a 49 inch SWE even after eliminating the glacier areas that were assigned an essentially unlimited 99 inch SWE. The Harza-Ebasco May (maximum) snowpack shown on Table 5.10-1 has an average SWE of 16.8 inches, which is comparable to the 15.7 inch May-June 100-year snowpack developed for the current study. The 1982 Acres PMF snowpack SWE appears to be the result of excessive conservatism as it is about 75 percent greater than the Probable Maximum Snowpack as determined in the current study and 5.5 times the average October through April precipitation.

A site-specific PMP is being prepared for the current PMF study, but a comparison of the PMPs from the 1980s studies with the snowpack SWE provides useful information on PMF runoff volume potential. The 1982 Acres June PMP was an average of 8.7 inches over the watershed tributary to Watana Dam, compared to the snowpack average SWE of 49 inches. The 1984 Harza-Ebasco July-August PMP was an average of 6.85 inches over the basin, the June PMP was 6.37 inches and the May PMP was an average of 5.00 inches, which combined with the average May SWE of 16.8 inches to form the critical PMF runoff in that study. These values indicate that snowmelt is likely to be the dominant factor in PMF runoff volume at Watana Dam.

6. DISCUSSION

Data gathering to develop the PMP has been completed and the available data was adequate. Development of the all-season and seasonal PMP values are ongoing. The seasonal PMP values and coincident meteorological conditions are expected to be available for review by the BOC in March 2014.

Data gathering to develop the rainfall-runoff model to develop and route the PMF has been completed and the available data was adequate. Development and distribution of the antecedent snowpack has been completed. Calibration and verification of hydrograph parameters is ongoing. Development of the monthly PMF inflow hydrographs and determination of the critical PMF inflow condition will logically follow development of the seasonal PMP values.

7. COMPLETING THE STUDY

[Section 7 appears in the Part C section of this ISR.]

8. LITERATURE CITED

Acres. 1982. *Feasibility Report, Susitna Hydroelectric Project*, Volume 4, Appendix A, Hydrological Studies, Final Draft.

AEA (Alaska Energy Authority). 2012. Revised Study Plan: Susitna-Watana Hydroelectric Project FERC Project No. 14241. December 2012. Prepared for the Federal Energy Regulatory Commission by the Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/study-plan.

FERC (Federal Energy Regulatory Commission). September 2001. *Engineering Guidelines for the Evaluation of Hydroelectric Projects*, Chapter VIII, Determination of the Probable Maximum Flood.

FERC (Federal Energy Regulatory Commission). May 31, 2012. "Request for Studies and Comments on Preliminary Study Plan", letter from Jennifer Hill, Chief, Northwest Branch, Division of Hydropower Licensing to Wayne Dyok, Project Manager, Alaska Energy Authority.

Harza-Ebasco Susitna Joint Venture. January 1984. *Probable Maximum Flood for Watana and Devil Canyon Sites, Susitna Hydroelectric Project*, Draft Report, Document No. 457.

Miller, John F., 1963. *Probable Maximum Precipitation and Rainfall-Frequency Data for Alaska*, Technical Paper No. 47, Weather Bureau, U.S. Department of Commerce.

U.S. Army Corps of Engineers (USACE), 1991, *Inflow Design Floods for Dams and Reservoirs*, ER 1110-8-2(FR), March 1, 1991.

U.S. Army Corps of Engineers (USACE), 1984. *Shore Protection Manual*, Coastal Engineering Research Center, Waterways Experiment Station, Second Printing.

U.S. Army Corps of Engineers (USACE), July 31, 2003. *Coastal Engineering Manual*, EM-1110-2-1100, Part II Coastal Hydrodynamics.

Weather Bureau. May 1966. *Hydrometeorological Report No. 42, Meteorological Conditions for the Probable Maximum Flood on the Yukon River Above Rampart, Alaska*, U.S. Department of Commerce, Environmental Science Services Administration, Office of Hydrology, Hydrometeorological Branch.

9. TABLES

Table 5.3- 1. USGS Streamflow Gages in the Susitna Watershed

USGS Gage Number	Gage Name	Drainage Area (sq.mi)	Latitude	Longitude	Gage Datum (feet)	Available Period of Record
15290000	Little Susitna River near Palmer	62	61°42'37"	149°13'47"	917	1948 - 2013
15291000	Susitna River near Denali	950	63°06'14"	147°30'57"	2,440	1957 - 1976; 1978 - 1986; 2012
15291200	Maclaren River near Paxson	280	63°07'10"	146°31'45"	2,866	1958 - 1986
15291500	Susitna River near Cantwell	4,140	62°41'55"	147°32'42"	1,900	1961 - 1972; 1980 - 1986
15291700	Susitna River above Tsusena Creek	5,160	62°49'24"	147°36'17"	1,500	2013
15292000	Susitna River at Gold Creek	6,160	62°46'04"	149°41'28"	677	1949 - 1996; 2001 - 2013
15292400	Chulitna River near Talkeetna	2,570	62°33'31"	150°14'02"	520	1958 - 1972; 1980 - 1986
15292700	Talkeetna River near Talkeetna	1,996	62°20'49"	150°01'01"	400	1964 - 1972; 1980 - 2013
15292780	Susitna River at Sunshine	11,100	62°10'42"	150°10'30"	270	1981 - 1986; 2012 - 2013
15292800	Montana Creek near Montana	164	62°06'19"	150°03'27"	250	2005 - 2006; 2008 - 2012
15294005	Willow Creek Near Willow	166	61°46'51"	149°53'04"	350	1978 - 1993; 2001 - 2013
15294010	Deception Creek near Willow	48	61°44'52"	149°56'14"	250	1978 - 1985
15294100	Deshka River near Willow	591	61°46'05"	150°20'13"	80	1978 - 1986; 1988 - 2001
15294300	Skwentna River near Skwentna	2,250	61°52'23"	151°22'01"	200	1959 - 1982
15294345	Yentna River near Susitna Station	6,180	61°41'55"	150°39'02	80	1980 - 1986
15294350	Susitna River at Susitna Station	19,400	61°32'41"	150°30'45	40	1974 - 1993

Table 5.3- 2. Snow Course and SNOTEL Stations In or Near the Susitna Watershed

Station Name	Station Number	Station Type	In Susitna R. Watershed (1)	Latitude (deg:min)	Longitude (deg:min)	Elevation (feet)	Years of Available Snowpack Data In the Period of Record
Anchorage Hillside	1070	SNOTEL	No	N 61:07	W 149:40	2,080	8 years: 2006 - 2013
Bentalit Lodge	1086	SNOTEL	Yes	N 61:56	W 150:59	150	8 years: 2006 - 2013
Fairbanks F.O.	1174	SNOTEL	No	N 64:51	W 147:48	450	31 years: 1983 - 2013
Granite Creek	963	SNOTEL	No	N 63:57	W 145:24	1,240	26 years: 1988 - 2013
Independence Mine	1091	SNOTEL	Border	N 61:48	W 149:17	3,550	16 years: 1998 - 2013
Indian Pass	946	SNOTEL	No	N 61:04	W 149:29	2,350	34 years: 1980 - 2013
Monohan Flat (4)	1094	SNOTEL	**Border**	N 63:18	W 147:39	2,710	6 years: 2008 - 2013
Mt. Alyeska	1103	SNOTEL	No	N 60:58	W 149:05	1,540	40 years: 1973 - 2013
Munson Ridge	950	SNOTEL	No	N 64:51	W 146:13	3,100	33 years: 1981 - 2013
Susitna Valley High	967	SNOTEL	Yes	N 62:08	W 150:02	375	27 years: 1988 - 2013
Tokositna Valley	1089	SNOTEL	Yes	N 62:38	W 150:47	850	8 years: 2006 - 2013
Blueberry Hill	49N07	Snow Course	Yes	N 62:48	W 149:59	1,200	26 years: 1988 - 2013
Clearwater Lake	46N01	Snow Course	**Yes**	N 62:56	W 146:57	2,650	47 years: 1964 - 2013
E. Fork Chulitna River	47N02	Snow Course	Yes	N 63:08	W 149:27	1,800	26 years: 1988 - 2013
Fog Lakes	48N02	Snow Course	**Yes**	N 62:47	W 148:28	2,120	50 years: 1964 - 2013
Horsepasture Pass	47N02	Snow Course	**Border**	N 62:08	W 147:38	4,300	46 years: 1968 - 2013
Independence Mine	49M26	Snow Course	Border	N 61:48	W 149:17	3,550	25 years: 1989 - 2013
Lake Louise	46N02	Snow Course	**Yes**	N 62:16	W 146:31	2,400	50 years: 1964 - 2013
Monohan Flat	47O01	Snow Course	**Border**	N 63:18	W 147:39	2,710	49 years: 1964 - 2013
Monsoon Lake	46N03	Snow Course	**Border**	N 62:50	W 146:37	3,100	29 years: 1985 - 2013
Square Lake	47N01	Snow Course	**Yes**	N 62:24	W 147:28	2,950	50 years: 1964 - 2013
Susitna Valley High	50N07	Snow Course	Yes	N 62:08	W 150:02	375	19 years: 1988 - 2012
Talkeetna	50N02	Snow Course	Yes	N 62:19	W 150:05	350	47 years: 1967 - 2013
Tyone River	47N03	Snow Course	**Yes**	N 62:40	W 147:08	2,500	21 years: 1981 - 2011

Notes:

(1) Items in bold indicate the location is tributary to Watana Dam. Border indicates the station is on or near the watershed border.

Table 5.4- 1. Area in Elevation Bands to Watana Dam

Basin	Area in Elevation Bands (sq.mi.) for Model with Reservoir												% of
No.	1-2000	2-3000	3-4000	4-5000	5-6000	6-7000	7-8000	8-9000	9-10000	10-11000	11-14000	Total	Total
1	0.0	0.0	8.7	19.7	8.9	11.3	3.9	0.2	0.0	0.0	0.0	52.7	1.02%
2	0.0	16.4	105.6	65.3	32.3	7.0	0.4	0.0	0.0	0.0	0.0	226.9	4.39%
3	0.0	145.7	139.5	9.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	295.2	5.71%
4	0.0	3.5	18.2	28.5	34.4	32.5	17.1	9.2	3.8	1.4	0.8	149.4	2.89%
5	0.0	90.7	93.0	99.8	48.5	18.5	3.6	0.0	0.0	0.0	0.0	354.2	6.85%
6	0.0	3.6	23.1	39.8	37.0	29.8	14.0	3.4	1.5	0.9	0.4	153.4	2.97%
7	0.0	55.2	9.4	2.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	67.5	1.31%
8	0.0	54.3	60.4	59.5	15.8	0.1	0.0	0.0	0.0	0.0	0.0	190.1	3.68%
9	0.0	38.5	91.3	52.5	5.3	0.0	0.0	0.0	0.0	0.0	0.0	187.6	3.63%
10	0.0	180.0	113.2	28.1	5.5	0.0	0.0	0.0	0.0	0.0	0.0	326.9	6.32%
11	0.0	72.4	130.2	57.0	13.7	0.4	0.0	0.0	0.0	0.0	0.0	273.6	5.29%
12	0.0	48.7	23.7	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	74.7	1.45%
13	0.0	202.6	20.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	222.6	4.30%
14	0.0	131.5	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	135.2	2.61%
15	0.0	68.0	87.9	29.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	185.2	3.58%
16	0.0	41.6	100.5	22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	164.4	3.18%
17	0.0	223.2	27.3	2.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	253.3	4.90%
18	0.0	0.1	28.7	48.2	21.2	1.8	0.0	0.0	0.0	0.0	0.0	100.0	1.93%
19	0.0	0.6	45.9	77.9	62.9	14.4	0.5	0.0	0.0	0.0	0.0	202.2	3.91%
20	0.0	16.5	19.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.3	0.70%
21	0.0	7.2	48.4	52.3	42.3	11.6	1.0	0.0	0.0	0.0	0.0	162.7	3.15%
22	0.0	76.3	14.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.0	1.78%
23	0.0	41.0	88.7	35.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0	168.9	3.27%
24	0.0	51.6	89.5	20.2	1.5	0.0	0.0	0.0	0.0	0.0	0.0	162.8	3.15%
25	0.0	5.3	42.0	72.4	54.0	10.2	0.1	0.0	0.0	0.0	0.0	184.0	3.56%
26	0.0	37.1	115.5	51.0	17.2	2.1	0.0	0.0	0.0	0.0	0.0	222.9	4.31%
27	0.0	141.0	92.5	33.3	2.8	0.1	0.0	0.0	0.0	0.0	0.0	269.6	5.21%
28	0.0	62.2	88.5	61.7	8.8	0.0	0.0	0.0	0.0	0.0	0.0	221.1	4.28%
29	0.0	36.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.8	0.71%
Total	0.0	1851.4	1729.1	972.2	417.6	139.8	40.6	12.8	5.3	2.3	1.3	5172.3	100.00%
	0.00%	35.79%	33.43%	18.80%	8.07%	2.70%	0.78%	0.25%	0.10%	0.04%	0.02%	100.00%	

Table 5.4- 2. Susitna Watershed Land Cover

Code	To Gold Creek without Reservoir Description	Area (sq. mi.)	% of Total
52	Shrub/Scrub	2784.0	45.3%
42	Evergreen Forest	996.4	16.2%
31	Barren Land (Rocks/Sand/Clay)	925.9	15.1%
51	Dwarf Scrub	652.9	10.6%
90	Woody Wetlands	238.9	3.9%
12	Perennial Ice/Snow	234.3	3.8%
11	Open Water	180.3	2.9%
43	Mixed Forest	56.4	0.9%
41	Deciduous Forest	54.2	0.9%
72	Sedge/Herbaceous	14.6	0.2%
95	Emergent Herbaceous Wetlands	2.9	0.0%
22	Developed, Low Intensity	1.7	0.0%
71	Grassland/Herbaceous	1.6	0.0%
21	Developed, Open Space	0.1	0.0%
23	Developed, Medium Intensity	0.01	0.0%
	Total	6144.1	100.0%

Table 5.5- 1. Recorded Peak Flows – Susitna River at Gold Creek – 59 Years of Record

Rank	Date	Peak Flow (cfs)	cfs/sq.mi.
1	June 7, 1964	90,700	14.7
2	August 10, 1971	87,400	14.2
3	June 17, 1972	82,600	13.4
4	June 15, 1962	80,600	13.1
5	August 15, 1967	80,200	13.0
6	September 21, 2012	72,900	11.8
7	July 12, 1981	64,900	10.5
8	June 6, 1966	63,600	10.3
9	August 25, 1959	62,300	10.1
10	August 20, 2006	59,800	9.7

Table 5.5- 2. Recorded Peak Flows – Susitna River at Cantwell – 18 Years of Record

Rank	Date	Peak Flow (cfs)	cfs/sq.mi.
1	August 10, 1971	55,000	13.3
2	June 8, 1964	51,200	12.4
3	June 15, 1962	46,800	11.3
4	June 17, 1972	44,700	10.8
5	August 14, 1967	38,800	9.4
6	June 16, 1984	33,400	8.1
7	July 18, 1963	32,000	7.7
8	August 14, 1981	30,900	7.5
9	June 23, 1961	30,400	7.3
10	July 29, 1980	28,500	6.9

Table 5.5- 3. Recorded Peak Flows – Susitna River near Denali – 28 Years of Record

Rank	Date	Peak Flow (cfs)	cfs/sq.mi.
1	August 10, 1971	38,200	40.2
2	August 14, 1967	28,200	29.7
3	July 28, 2003	27,800	29.3
4	September 21, 2012	25100	26.4
5	July 28, 1980	24,300	25.6
6	August 9, 1981	23,200	24.4
7	August 4, 1976	22,100	23.3
8	July 12, 1975	21,700	22.8
9	June 7, 1957	18,700	19.7
10	July 7, 1983	18,700	19.7

Table 5.5- 4. Recorded Peak Flows – Maclaren River near Paxson – 28 Years of Record

Rank	Date	Peak Flow (cfs)	cfs/sq.mi.
1	August 11, 1971	9,260	33.1
2	September 13, 1960	8,920	31.9
3	August 14, 1967	7,460	26.6
4	July 18, 1963	7,300	26.1
5	July 2, 1985	7,190	25.7
6	June 16, 1972	7,070	25.3
7	August 10, 1981	6,650	23.8
8	August 5, 1961	6,540	23.4
9	June 14, 1962	6,540	23.4
10	June 7, 1964	6,400	22.9

Table 5.6- 1. Maximum Daily Flows for Each Month for the USGS Gage at Gold Creek

Gold Creek USGS Gage Maximum Daily Flow (cfs)	
January	2,900
February	3,700
March	2,400
April	24,000
May	55,500
June	85,900
July	60,800
August	77,700
September	70,800
October	36,200
November	8,940
December	4,400

Table 5.6- 2. Monthly Distribution of Annual Peak Flows

Month	Gold Creek Gage		Cantwell Gage		Denali Gage		Maclaren Gage		Total of All Gages	
	Annual Peaks	% of Total	Annual Peaks	% of Total	Annual Peaks	% of Total	Annual Peaks	% of Total	Annual Peaks	% of Total
January	0	0%	0	0%	0	0%	0	0%	0	0%
February	0	0%	0	0%	0	0%	0	0%	0	0%
March	0	0%	0	0%	0	0%	0	0%	0	0%
April	0	0%	0	0%	0	0%	0	0%	0	0%
May	8	14%	1	6%	0	0%	1	4%	10	7%
June	28	47%	8	44%	3	10%	12	43%	51	38%
July	9	15%	5	28%	12	41%	6	21%	32	24%
August	10	17%	4	22%	12	41%	7	25%	33	25%
September	4	7%	0	0%	2	7%	2	7%	8	6%
October	0	0%	0	0%	0	0%	0	0%	0	0%
November	0	0%	0	0%	0	0%	0	0%	0	0%
December	0	0%	0	0%	0	0%	0	0%	0	0%
Total	59	100%	18	100%	29	100%	28	100%	134	100%

Table 5.7.1- 1. Monthly Precipitation by Month and Sub-Basin

Sub-Basin Number	Basin Area (sq.mi.)	Average Precipitation (inches)														Oct-Apr % of Year
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Oct-Apr	
1	52.6	1.73	2.61	2.07	1.54	1.67	3.46	4.36	5.85	5.61	4.32	2.01	2.64	37.88	16.92	44.7%
2	226.4	1.26	1.79	1.40	1.11	1.34	2.86	3.75	4.60	4.15	3.30	1.44	1.95	28.94	12.24	42.3%
3	295.4	0.81	0.71	0.61	0.59	1.10	2.34	2.93	2.85	2.19	1.92	0.84	1.18	18.08	6.66	36.8%
4	149.3	2.38	2.73	2.49	1.60	1.76	3.72	4.84	6.29	5.83	4.44	2.43	3.14	41.66	19.22	46.1%
5	354.0	1.61	1.97	1.55	1.14	1.37	3.04	4.10	4.73	4.21	3.29	1.62	2.26	30.91	13.45	43.5%
6	153.4	2.67	2.60	2.21	1.65	1.62	3.83	5.39	6.31	5.79	4.68	2.33	3.74	42.84	19.90	46.4%
7	67.5	1.43	1.24	0.92	0.81	1.11	2.93	3.98	3.59	2.78	2.35	1.14	1.65	23.93	9.54	39.9%
8	189.9	1.35	1.67	1.29	1.01	1.28	2.87	3.85	4.35	3.85	2.96	1.41	1.88	27.76	11.57	41.7%
9	187.7	1.42	1.32	1.00	0.97	1.30	3.11	4.20	4.24	3.57	2.75	1.34	1.72	26.93	10.50	39.0%
10	326.8	0.94	0.97	0.72	0.76	1.13	2.35	3.24	3.70	2.94	2.36	0.90	1.31	21.31	7.96	37.3%
11	273.5	1.02	1.06	0.87	0.84	1.17	2.57	3.33	3.71	3.18	2.62	1.07	1.47	22.91	8.95	39.1%
12	74.7	0.69	0.57	0.54	0.51	1.08	2.28	2.86	2.69	2.01	1.61	0.79	1.12	16.76	5.84	34.9%
13	222.5	0.54	0.45	0.44	0.32	1.04	2.31	2.68	1.82	1.55	1.22	0.77	1.05	14.20	4.79	33.7%
14	135.1	0.47	0.41	0.38	0.26	1.06	2.34	2.70	1.75	1.64	1.25	0.66	0.90	13.81	4.32	31.3%
15	185.1	0.61	0.56	0.60	0.44	1.14	2.48	2.94	2.18	1.68	1.32	0.95	1.28	16.17	5.75	35.6%
16	164.3	0.60	0.50	0.58	0.51	1.18	2.53	3.02	2.36	1.85	1.44	0.95	1.30	16.83	5.88	34.9%
17	253.2	0.57	0.47	0.51	0.35	1.05	2.24	2.71	2.17	1.71	1.32	0.79	1.08	14.97	5.09	34.0%
18	100.0	0.69	1.00	0.89	0.75	1.45	3.01	3.57	2.92	2.35	1.75	1.03	1.40	20.81	7.52	36.1%
19	202.2	0.77	1.01	0.91	1.15	1.99	3.30	3.84	3.35	3.19	2.33	1.12	1.55	24.52	8.85	36.1%
20	36.3	0.52	0.46	0.47	0.63	1.26	2.49	3.03	2.72	2.21	1.58	0.76	1.04	17.15	5.45	31.8%
21	162.7	0.79	0.81	0.78	1.29	1.87	2.94	3.84	3.71	4.08	2.70	1.21	1.57	25.59	9.15	35.8%
22	92.0	0.56	0.46	0.49	0.54	1.05	2.24	2.83	2.73	2.05	1.59	0.77	1.08	16.40	5.50	33.6%
23	174.2	0.67	0.58	0.57	0.86	1.39	2.57	3.34	3.57	3.02	2.21	0.90	1.22	20.91	7.02	33.6%
24	157.4	0.86	0.75	0.63	0.85	1.23	2.48	3.45	3.86	3.04	2.46	0.99	1.28	21.89	7.84	35.8%
25	184.0	1.16	1.02	0.80	1.66	1.76	3.50	4.72	5.59	5.76	3.96	1.72	1.92	33.57	12.24	36.5%
26	222.9	1.02	0.92	0.75	1.32	1.40	2.99	4.35	4.72	4.06	3.07	1.46	1.60	27.67	10.14	36.6%
27	269.6	1.08	1.04	0.84	0.94	1.18	2.62	3.66	4.00	3.19	2.28	1.39	1.42	23.63	8.99	38.0%
28	218.5	1.20	1.23	1.03	0.99	1.22	2.89	4.05	4.44	3.71	2.15	1.78	1.66	26.35	10.04	38.1%
29	36.8	0.76	0.73	0.60	0.75	0.99	2.19	2.99	3.25	2.58	1.78	1.03	1.06	18.70	6.71	35.9%
30	146.4	1.32	1.42	1.23	1.20	1.36	2.91	4.22	4.79	4.12	2.19	2.16	1.88	28.78	11.40	39.6%
31	181.9	1.03	1.08	0.87	1.29	1.30	3.05	4.05	4.77	4.14	2.27	1.64	1.37	26.87	9.55	35.6%
32	208.1	1.02	1.48	1.39	1.53	1.52	2.86	3.85	4.69	4.10	1.75	2.59	1.72	28.49	11.47	40.3%
33	273.4	1.57	1.67	1.59	1.49	1.48	2.97	4.13	5.04	4.40	2.16	2.57	2.21	31.29	13.26	42.4%
34	164.8	2.07	1.98	1.87	1.48	1.21	3.04	4.57	6.27	5.45	3.69	2.28	2.69	36.60	16.06	43.9%
To Gold Creek Gage	6,143	1.11	1.17	1.01	0.99	1.32	2.80	3.70	3.97	3.45	2.46	1.40	1.67	25.04	9.80	39.1%
To Watana Dam	5,168	1.05	1.10	0.93	0.91	1.31	2.77	3.61	3.76	3.26	2.48	1.24	1.61	24.03	9.32	38.8%
To Denali Gage	914	1.85	2.08	1.71	1.25	1.44	3.24	4.37	5.09	4.56	3.57	1.79	2.53	33.50	14.79	44.2%
To Maclaren Gage	279	1.35	1.94	1.52	1.19	1.40	2.97	3.86	4.84	4.42	3.49	1.55	2.08	30.62	13.12	42.8%
To Cantwell Gage	4,079	1.05	1.13	0.96	0.85	1.30	2.74	3.51	3.58	3.10	2.42	1.17	1.62	23.44	9.20	39.3%

Table 5.7.2- 1. 100-Year Snowpack at Snow Course Stations

Station Name	Is Station Area Tributary to Watana Dam (1)	Elevation (feet)	100-Year Snow Water Equivalent				Oct-Apr Avg. Total Precip. (inches)	Ratio May 1 100-Year / Oct-Apr (2)
			Feb. 1 (inches)	Mar. 1 (inches)	Apr. 1 (inches)	May 1 (inches)		
Blueberry Hill	No	1,200	24.0	32.8	36.5	33.8	16.9	2.01
Clearwater Lake	Yes	2,650	8.1	8.2	9.8	11.6	6.0	1.94
E. Fork Chulitna River	No	1,800	23.6	28.8	31.5	34.3	11.8	2.90
Fog Lakes	Yes	2,120	11.6	12.1	12.9	11.9	6.7	1.78
Horsepasture Pass	Yes/Border	4,300	9.4	11.8	12.5	12.8	7.0	1.82
Independence Mine	No	3,550	39.6	48.1	50.1	50.1	24.5	2.05
Lake Louise	Yes	2,400	6.7	7.1	8.2	7.2	4.4	1.63
Monohan Flat	Yes/Border	2,710	12.7	13.8	14.7	12.0	8.5	1.40
Monsoon Lake	Yes/Border	3,100	8.3	9.6	10.8	-----	6.0	1.79
Square Lake	Yes	2,950	6.0	6.5	7.4	7.2	4.8	1.51
Susitna Valley High	No	375	13.6	15.5	16.5	19.0	13.3	1.43
Talkeetna	No	350	11.3	15.9	18.4	16.7	12.0	1.39
Tyone River	Yes	2,500	5.7	6.2	7.3	-----	4.8	1.53
							Average of non-red values	1.68

Notes:

(1) Border indicates that the stations are on or near the watershed boundary.

(2) Where May 1 data is missing, April 1 data was used.

Values in the red boxes were not used to determine the 100-year snowpack.

Table 5.7.2- 2. 100-Year All-Season Snowpack SWE

Sub-Basin Number	Basin Area (sq.mi.)	Annual Precip. (inches)	Oct-Apr Precip. (inches)	100-Year SWE (inches)
1	52.6	37.9	16.9	28.4
2	226.4	28.9	12.2	20.6
3	295.4	18.1	6.7	11.2
4	149.3	41.7	19.2	32.3
5	354.0	30.9	13.5	22.6
6	153.4	42.8	19.9	33.4
7	67.5	23.9	9.5	16.0
8	189.9	27.8	11.6	19.4
9	187.7	26.9	10.5	17.6
10	326.8	21.3	8.0	13.4
11	273.5	22.9	9.0	15.0
12	74.7	16.8	5.8	9.8
13	222.5	14.2	4.8	8.0
14	135.1	13.8	4.3	7.3
15	185.1	16.2	5.8	9.7
16	164.3	16.8	5.9	9.9
17	253.2	15.0	5.1	8.5
18	100.0	20.8	7.5	12.6
19	202.2	24.5	8.8	14.9
20	36.3	17.1	5.4	9.2
21	162.7	25.6	9.2	15.4
22	92.0	16.4	5.5	9.2
23	174.2	20.9	7.0	11.8
24	157.4	21.9	7.8	13.2
25	184.0	33.6	12.2	20.6
26	222.9	27.7	10.1	17.0
27	269.6	23.6	9.0	15.1
28	218.5	26.3	10.0	16.9
29	36.8	18.7	6.7	11.3
30	146.4	28.8	11.4	19.1
31	181.9	26.9	9.6	16.1
32	208.1	28.5	11.5	19.3
33	273.4	31.3	13.3	22.3
34	164.8	36.6	16.1	27.0
To Gold Creek Gage	6,143	25.0	9.8	16.5
To Watana Dam	5,168	24.0	9.3	15.7
To Denali Gage	914	33.5	14.8	24.9
To Maclaren Gage	279	30.6	13.1	22.0
To Cantwell Gage	4,079	23.4	9.2	15.5

Table 5.7.3- 1. Probable Maximum Snowpack SWE

Sub-Basin Number	Basin Area (sq.mi.)	Annual Precip. (inches)	Oct-Apr Precip. (inches)	PMS SWE (inches)
1	52.6	37.9	16.9	50.8
2	226.4	28.9	12.2	36.7
3	295.4	18.1	6.7	20.0
4	149.3	41.7	19.2	57.7
5	354.0	30.9	13.5	40.4
6	153.4	42.8	19.9	59.7
7	67.5	23.9	9.5	28.6
8	189.9	27.8	11.6	34.7
9	187.7	26.9	10.5	31.5
10	326.8	21.3	8.0	23.9
11	273.5	22.9	9.0	26.9
12	74.7	16.8	5.8	17.5
13	222.5	14.2	4.8	14.4
14	135.1	13.8	4.3	13.0
15	185.1	16.2	5.8	17.3
16	164.3	16.8	5.9	17.6
17	253.2	15.0	5.1	15.3
18	100.0	20.8	7.5	22.6
19	202.2	24.5	8.8	26.5
20	36.3	17.1	5.4	16.3
21	162.7	25.6	9.2	27.5
22	92.0	16.4	5.5	16.5
23	174.2	20.9	7.0	21.1
24	157.4	21.9	7.8	23.5
25	184.0	33.6	12.2	36.7
26	222.9	27.7	10.1	30.4
27	269.6	23.6	9.0	27.0
28	218.5	26.3	10.0	30.1
29	36.8	18.7	6.7	20.1
30	146.4	28.8	11.4	34.2
31	181.9	26.9	9.6	28.7
32	208.1	28.5	11.5	34.4
33	273.4	31.3	13.3	39.8
34	164.8	36.6	16.1	48.2
To Gold Creek Gage	6,143	25.0	9.8	29.4
To Watana Dam	5,168	24.0	9.3	27.9
To Denali Gage	914	33.5	14.8	44.4
To Maclaren Gage	279	30.6	13.1	39.4
To Cantwell Gage	4,079	23.4	9.2	27.6

Table 5.9- 1. Short List of Storms

Location Name	State	Lat	Lon	Year	Mon	Day	Total Rainfall	Precipitation Source
OLD TYONEK	AK	61.260	-151.860	2012	9	15	15.91	SPAS 1256 Zone 1
DENALI NP	AK	62.829	-151.138	1986	10	8	11.01	SPAS 1267 Zone 1
SEWARD	AK	60.113	-149.513	1986	10	8	20.80	SPAS 1267 Zone 2
MT GEIST	AK	63.638	-146.971	1980	7	24	5.26	SPAS 1268 Zone 2
DENALI NP	AK	62.954	-150.079	1980	7	24	7.33	SPAS 1268 Zone 1
BLACK RAPIDS	AK	63.471	-145.479	1971	8	5	12.17	SPAS 1269 Zone 2
SUTTON	AK	61.904	-148.863	1971	8	5	11.39	SPAS 1269 Zone 1
DENALI NP	AK	62.846	-150.513	1967	8	2	12.45	SPAS 1270 Zone 2
FAIRBANKS	AK	65.521	-147.329	1967	8	2	12.45	SPAS 1270 Zone 1
LITTLE SUSITNA	AK	61.854	-149.229	1959	8	18	13.05	SPAS 1271 Zone 1
DONNELLY	AK	63.496	-145.629	1958	7	25	7.06	SPAS 1273 Zone 1
DENALI NP	AK	63.038	-150.471	1955	8	22	13.75	SPAS 1272 Zone 1
DENALI NP	AK	63.029	-150.371	2006	8	17		SPAS 1303 Zone 1

Table 5.10- 1. Harza-Ebasco PMF Snowpack Estimate

Harza-Ebasco Sub-basin Number	Drainage Area (sq.mi.)	Sub-Basin Vicinity	Wtd. Avg. SWE (inches)
2	460	Watnana Creek	15.8
3	580	Kosina Creek	17.1
4	725	Black River	18.1
5	1,060	Tyone River	14.6
6	790	Coal Creek	15.7
7	188	W. Fork Susitna to Denali	17.0
8	762	Susitna R. above Denali	19.7
9	335	Maclaren R. below USGS gage	14.9
10	280	Maclaren R. above USGS gage	19.6
Total	5,180	Weighted Average	16.8

10. FIGURES

Figure 5.2-1. Susitna River near Deadman Creek on May 29, 2013

Figure 5.2-2. Susitna River near the Denali Highway Crossing on May 29, 2013

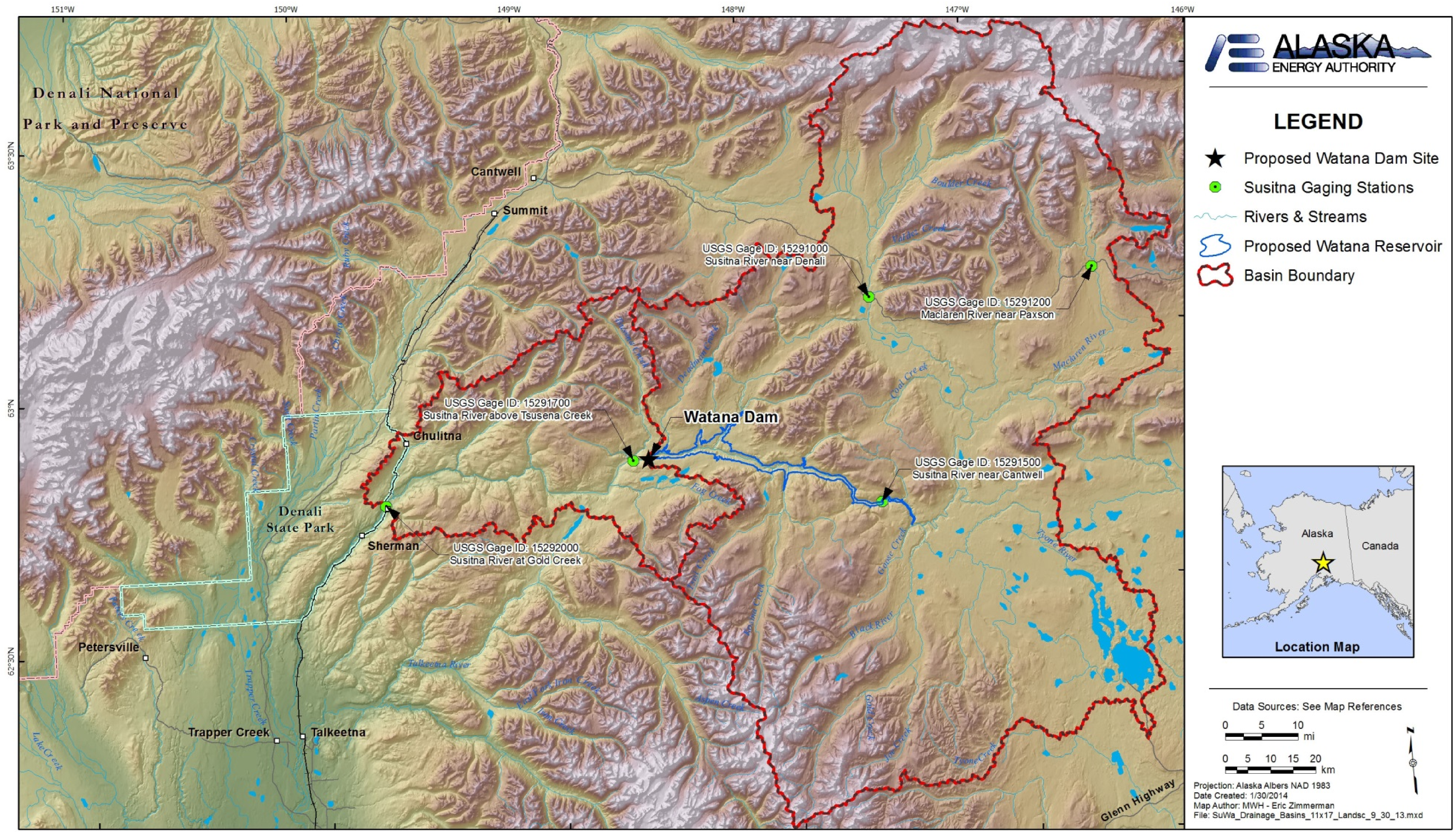


Figure 5.3- 1. Susitna Watershed Boundary and USGS Gage Locations

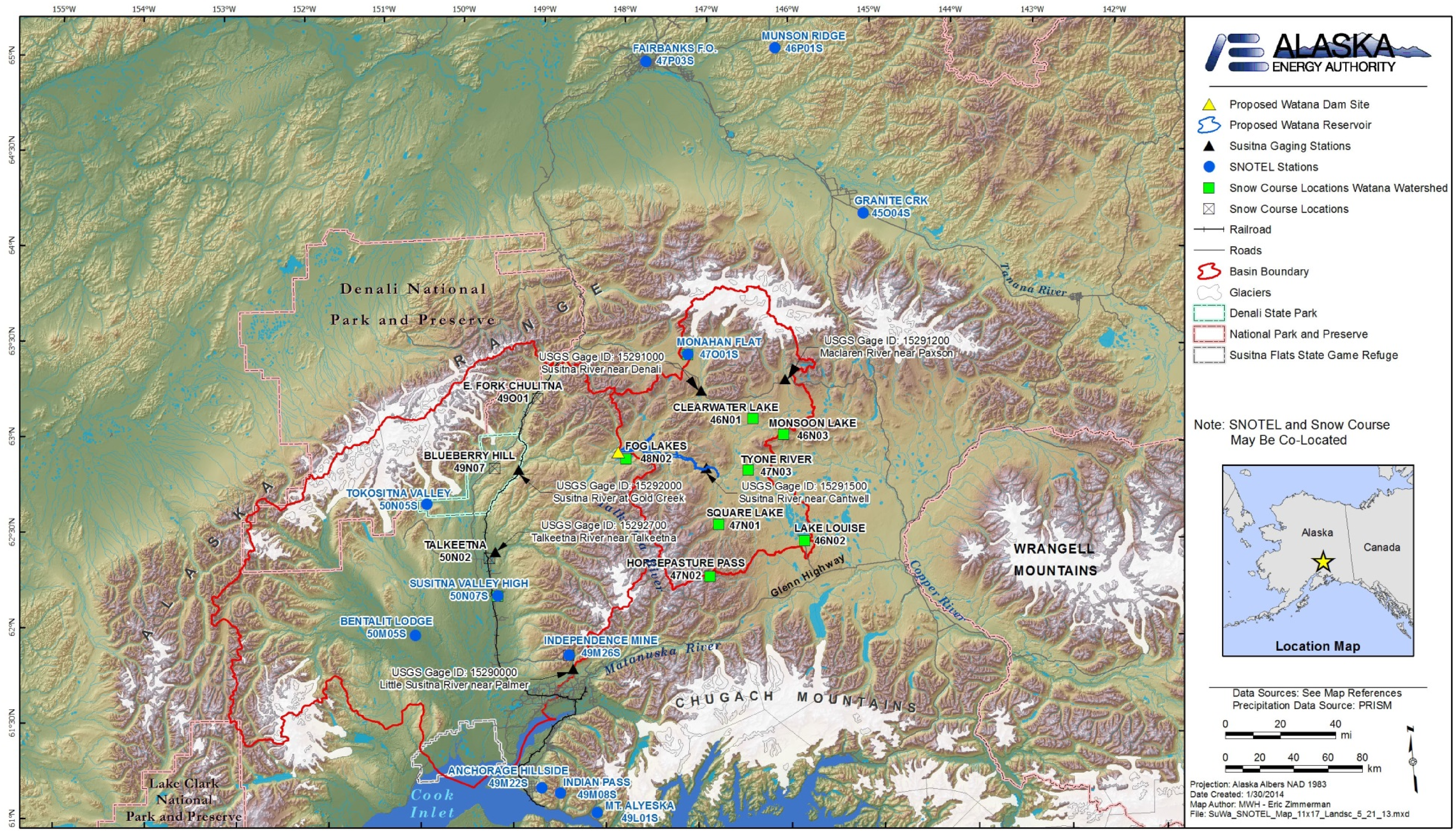
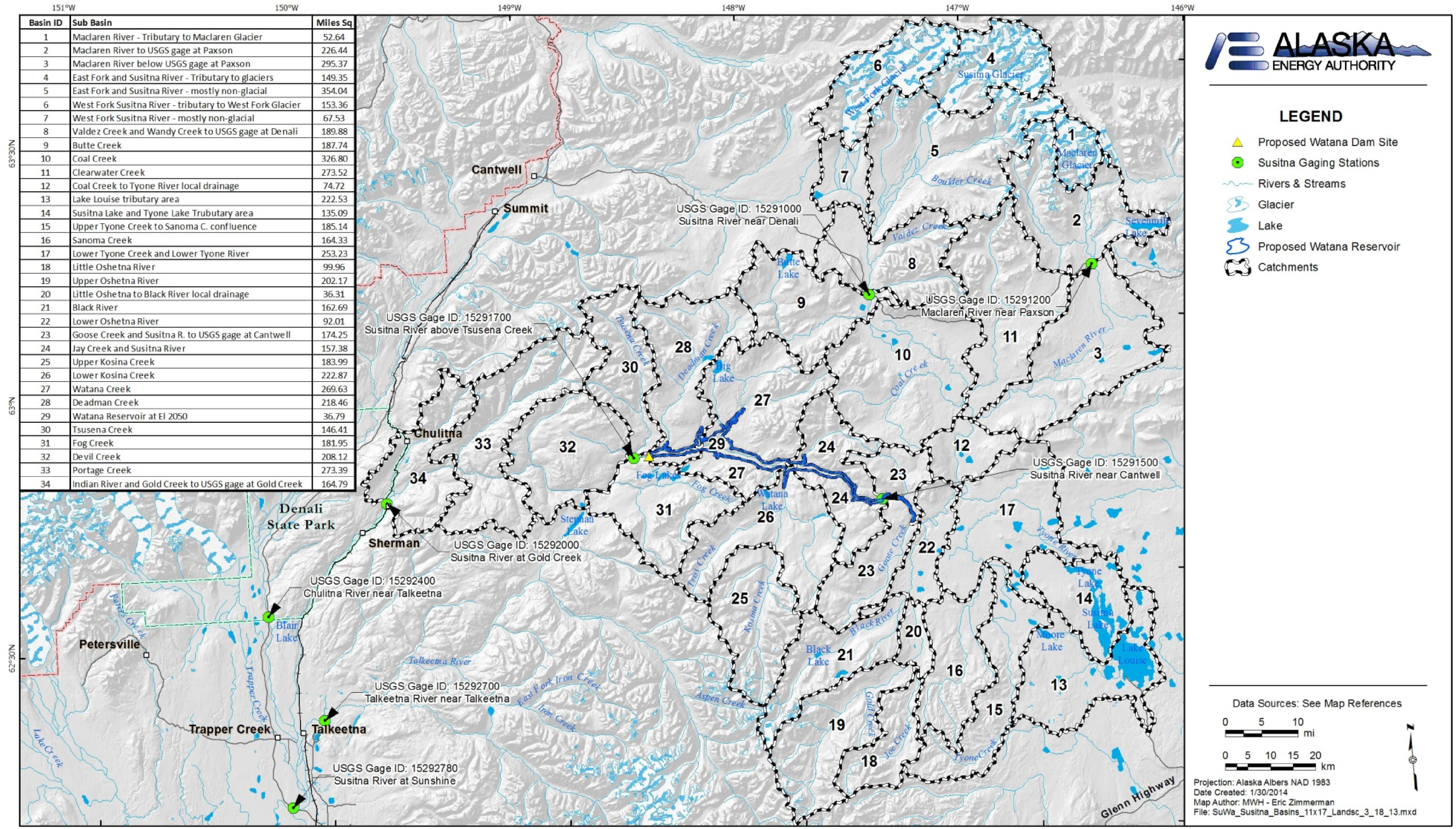
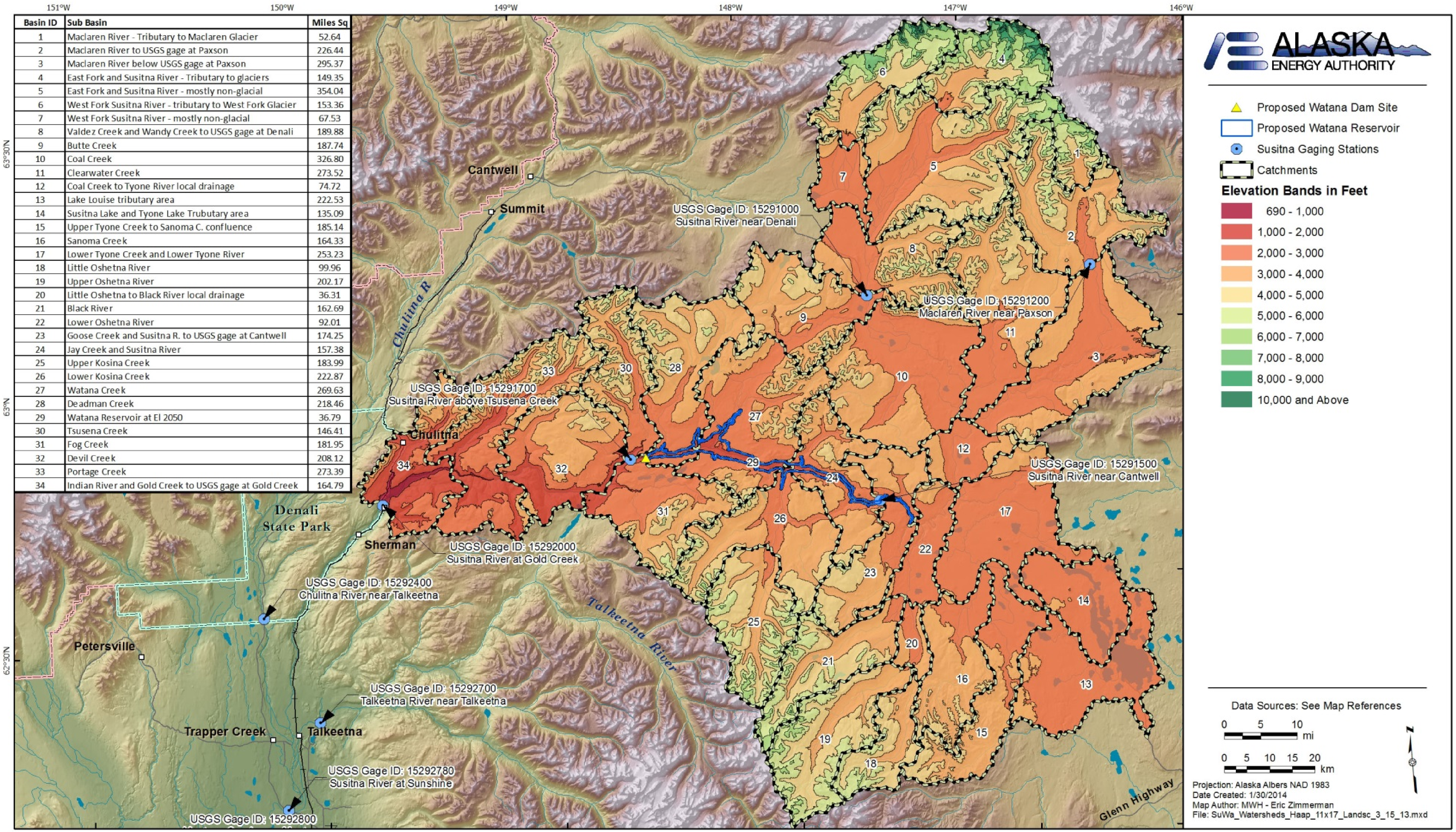


Figure 5.3- 2. Location of Snow Course and SNOTEL Stations



Basin ID	Sub Basin	Miles Sq
1	Maclaren River - Tributary to Maclaren Glacier	52.64
2	Maclaren River to USGS gage at Paxson	226.44
3	Maclaren River below USGS gage at Paxson	295.37
4	East Fork and Susitna River - Tributary to glaciers	149.35
5	East Fork and Susitna River - mostly non-glacial	354.04
6	West Fork Susitna River - tributary to West Fork Glacier	153.36
7	West Fork Susitna River - mostly non-glacial	67.53
8	Valdez Creek and Wandy Creek to USGS gage at Denali	189.88
9	Butte Creek	187.74
10	Coal Creek	326.80
11	Clearwater Creek	273.52
12	Coal Creek to Tyone River local drainage	74.72
13	Lake Louise tributary area	222.53
14	Susitna Lake and Tyone Lake Trubutary area	135.09
15	Upper Tyone Creek to Sanoma C. confluence	185.14
16	Sanoma Creek	164.33
17	Lower Tyone Creek and Lower Tyone River	253.23
18	Little Oshetna River	99.96
19	Upper Oshetna River	202.17
20	Little Oshetna to Black River local drainage	36.31
21	Black River	162.69
22	Lower Oshetna River	92.01
23	Goose Creek and Susitna R. to USGS gage at Cantwell	174.25
24	Jay Creek and Susitna River	157.38
25	Upper Kosina Creek	183.99
26	Lower Kosina Creek	222.87
27	Watana Creek	269.63
28	Deadman Creek	218.46
29	Watana Reservoir at El 2050	36.79
30	Tsusena Creek	146.41
31	Fog Creek	181.95
32	Devil Creek	208.12
33	Portage Creek	273.39
34	Indian River and Gold Creek to USGS gage at Gold Creek	164.79

Figure 5.4- 1. Susitna Watershed Sub-Basins



Basin ID	Sub Basin	Miles Sq
1	Maclaren River - Tributary to Maclaren Glacier	52.64
2	Maclaren River to USGS gage at Paxson	226.44
3	Maclaren River below USGS gage at Paxson	295.37
4	East Fork and Susitna River - Tributary to glaciers	149.35
5	East Fork and Susitna River - mostly non-glacial	354.04
6	West Fork Susitna River - tributary to West Fork Glacier	153.36
7	West Fork Susitna River - mostly non-glacial	67.53
8	Valdez Creek and Wandy Creek to USGS gage at Denali	189.88
9	Butte Creek	187.74
10	Coal Creek	326.80
11	Clearwater Creek	273.52
12	Coal Creek to Tyone River local drainage	74.72
13	Lake Louise tributary area	222.53
14	Susitna Lake and Tyone Lake Trubutary area	135.09
15	Upper Tyone Creek to Sanoma C. confluence	185.14
16	Sanoma Creek	164.33
17	Lower Tyone Creek and Lower Tyone River	253.23
18	Little Oshetna River	99.96
19	Upper Oshetna River	202.17
20	Little Oshetna to Black River local drainage	36.31
21	Black River	162.69
22	Lower Oshetna River	92.01
23	Goose Creek and Susitna R. to USGS gage at Cantwell	174.25
24	Jay Creek and Susitna River	157.38
25	Upper Kosina Creek	183.99
26	Lower Kosina Creek	222.87
27	Watana Creek	269.63
28	Deadman Creek	218.46
29	Watana Reservoir at El 2050	36.79
30	Tsusena Creek	146.41
31	Fog Creek	181.95
32	Devil Creek	208.12
33	Portage Creek	273.39
34	Indian River and Gold Creek to USGS gage at Gold Creek	164.79

Figure 5.4- 2. Susitna Watershed Elevation Bands

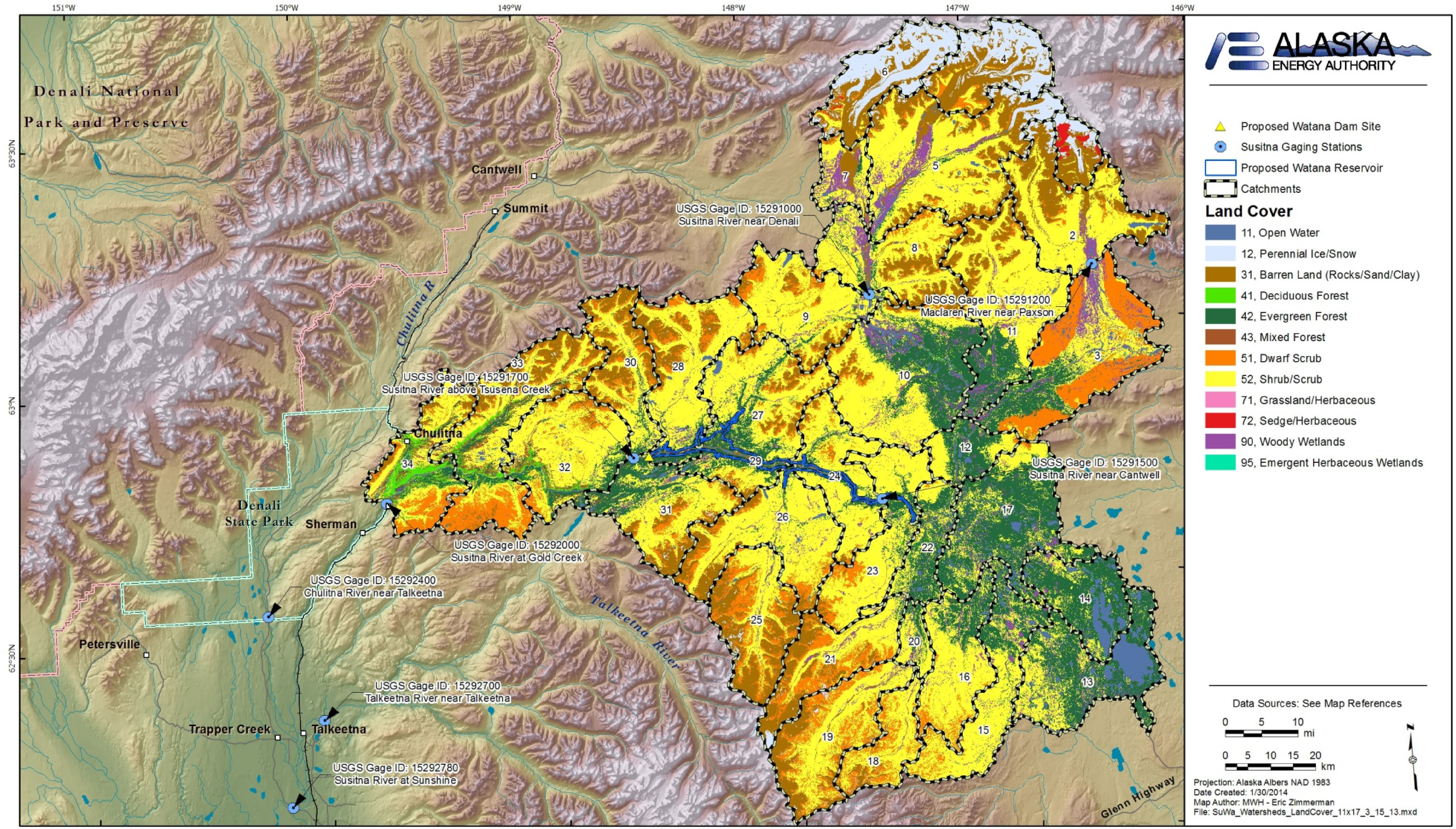


Figure 5.4- 3. Susitna Watershed Land Cover

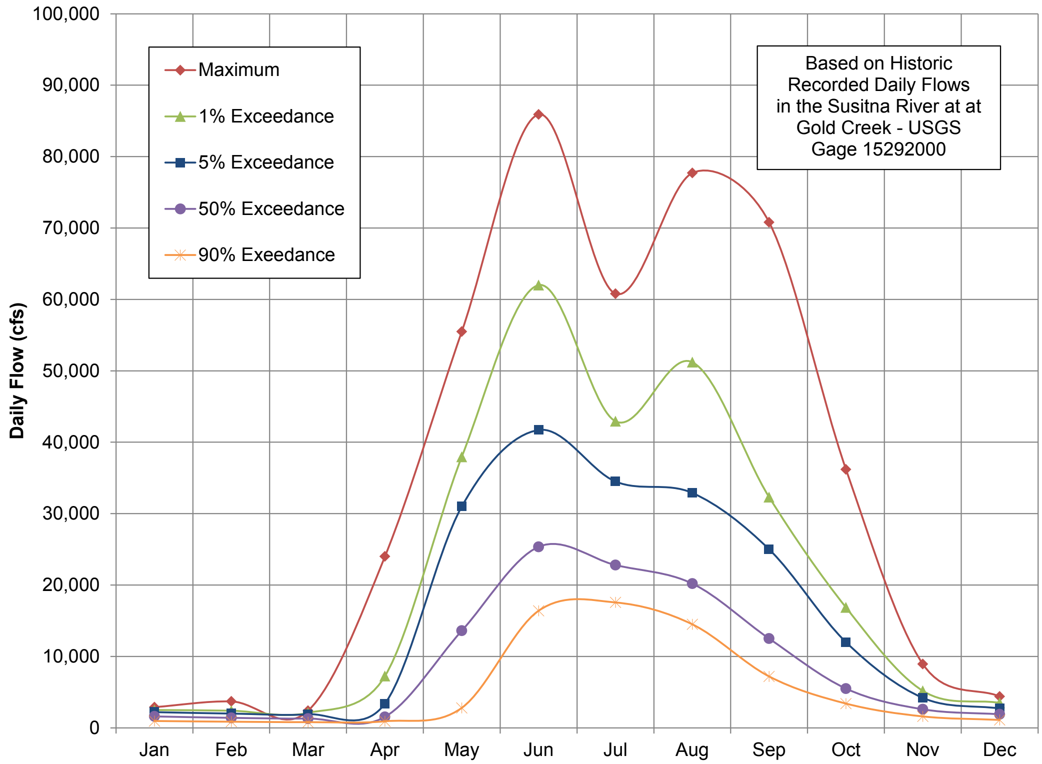


Figure 5.6- 1. Historic Flow Frequency at the USGS Gold Creek Gage

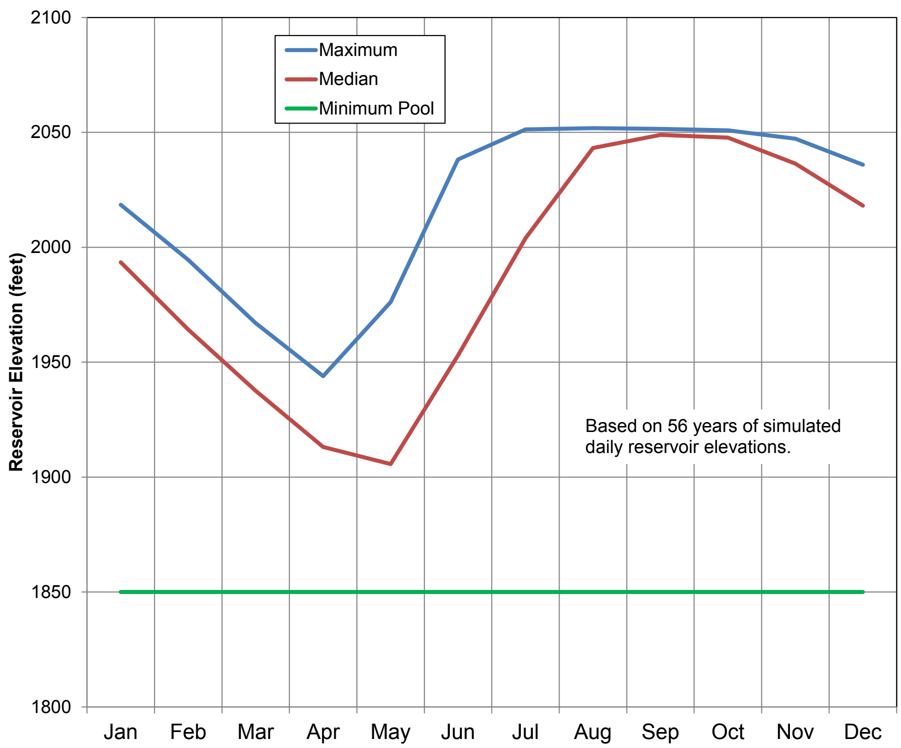
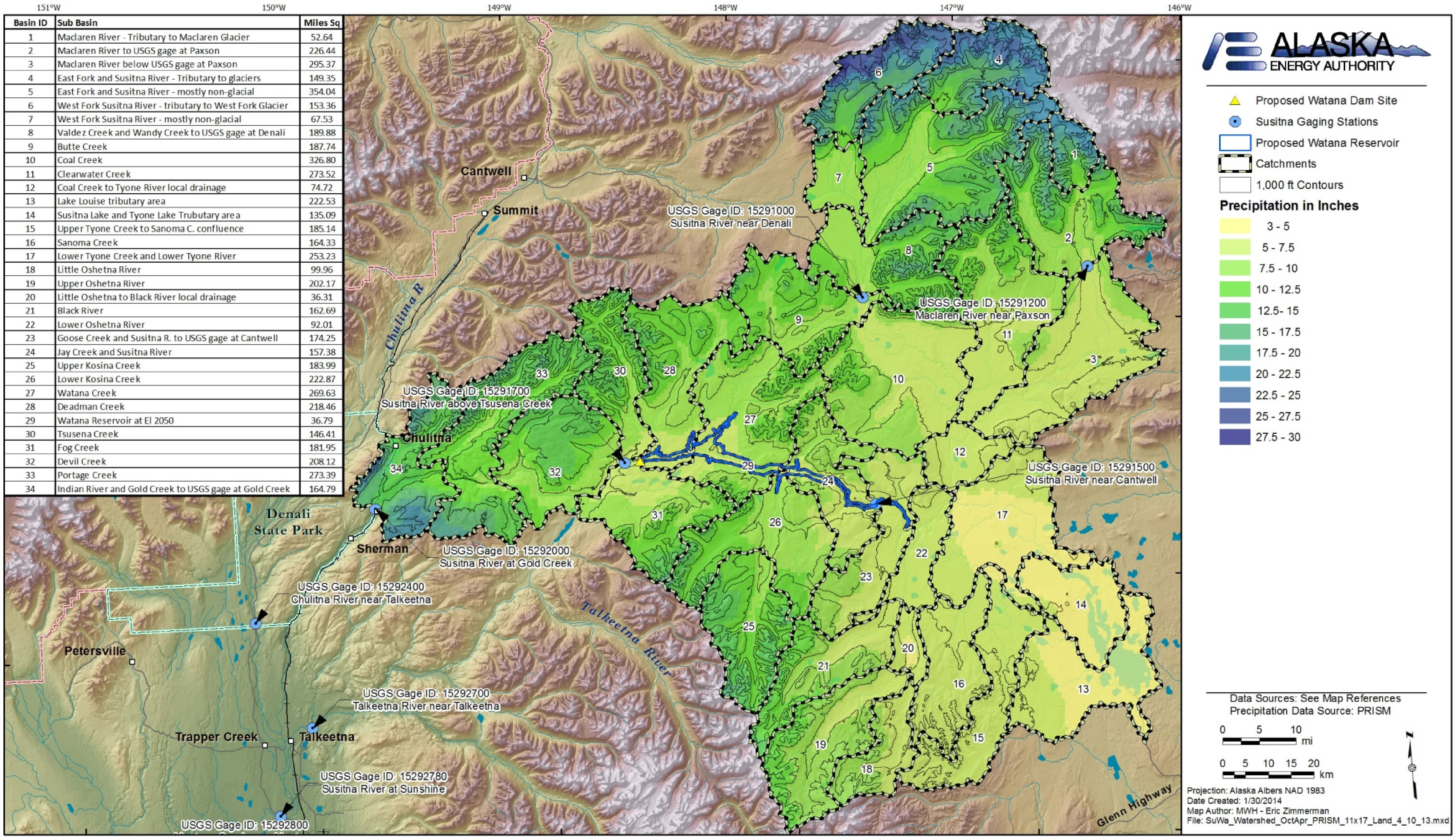


Figure 5.6- 2. Watana Reservoir Simulated Elevations



Basin ID	Sub Basin	Miles Sq
1	Maclaren River - Tributary to Maclaren Glacier	52.64
2	Maclaren River to USGS gage at Paxson	226.44
3	Maclaren River below USGS gage at Paxson	295.37
4	East Fork and Susitna River - Tributary to glaciers	149.35
5	East Fork and Susitna River - mostly non-glacial	354.04
6	West Fork Susitna River - tributary to West Fork Glacier	153.36
7	West Fork Susitna River - mostly non-glacial	67.53
8	Valdez Creek and Wandy Creek to USGS gage at Denali	189.88
9	Butte Creek	187.74
10	Coal Creek	326.80
11	Clearwater Creek	273.52
12	Coal Creek to Tyone River local drainage	74.72
13	Lake Louise tributary area	222.53
14	Susitna Lake and Tyone Lake Trubutary area	135.09
15	Upper Tyone Creek to Sanoma C. confluence	185.14
16	Sanoma Creek	164.33
17	Lower Tyone Creek and Lower Tyone River	253.23
18	Little Oshetna River	99.96
19	Upper Oshetna River	202.17
20	Little Oshetna to Black River local drainage	36.31
21	Black River	162.69
22	Lower Oshetna River	92.01
23	Goose Creek and Susitna R. to USGS gage at Cantwell	174.25
24	Jay Creek and Susitna River	157.38
25	Upper Kosina Creek	183.99
26	Lower Kosina Creek	222.87
27	Watana Creek	269.63
28	Deadman Creek	218.46
29	Watana Reservoir at El 2050	36.79
30	Tsusena Creek	146.41
31	Fog Creek	181.95
32	Devil Creek	208.12
33	Portage Creek	273.39
34	Indian River and Gold Creek to USGS gage at Gold Creek	164.79

Figure 5.7.1- 1. Average October through April Precipitation

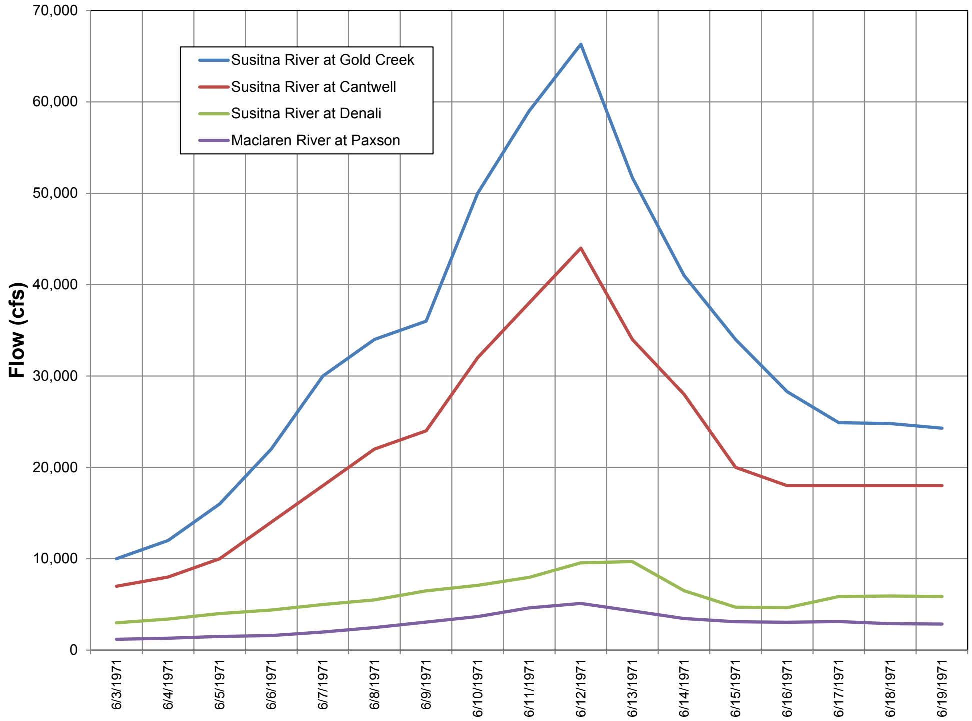


Figure 5.8- 1. Recorded Flows at USGS Streamflow Gaging stations for June 1971

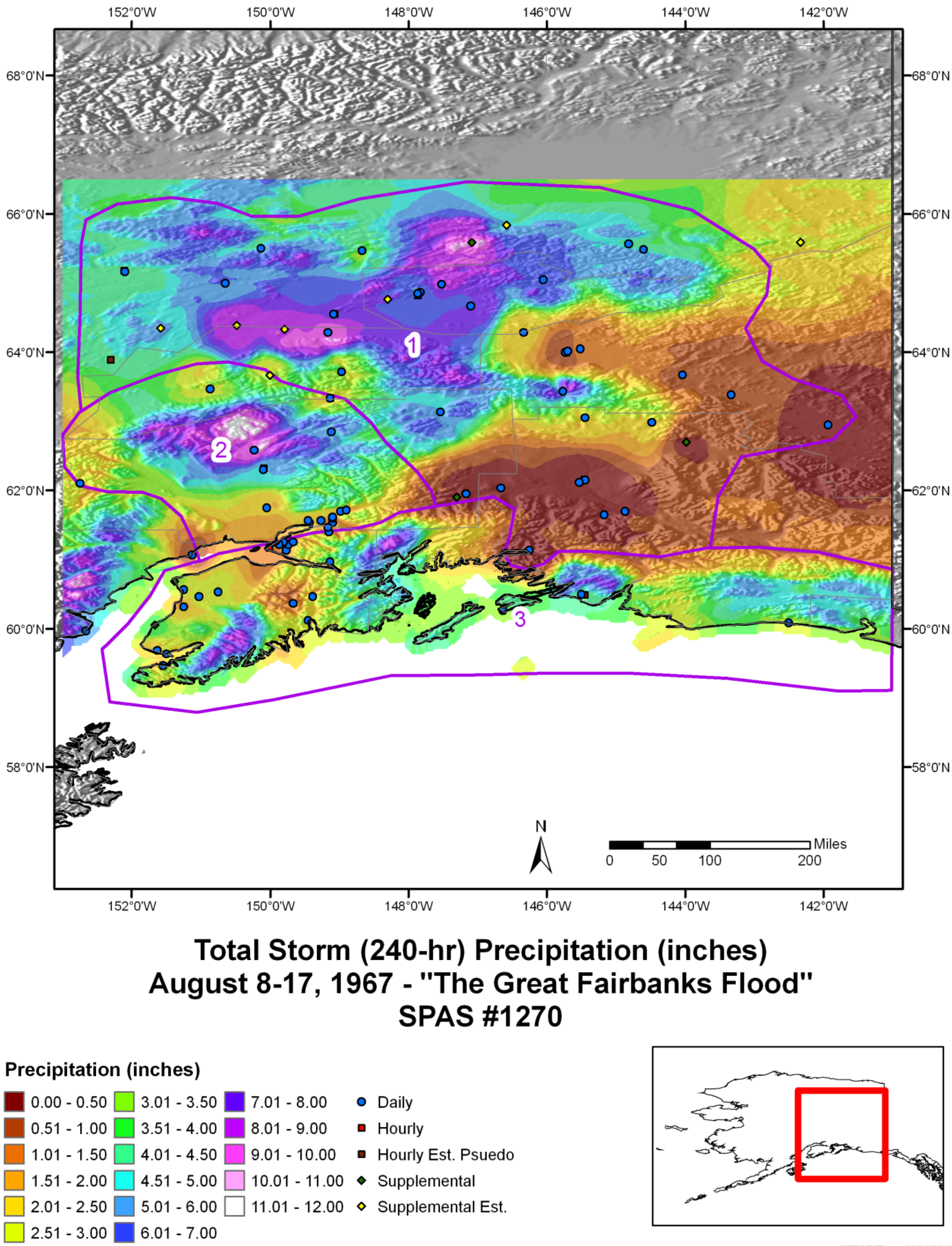


Figure 5.9- 1. SPAS Storm Analysis Results for the August 1967 Storm

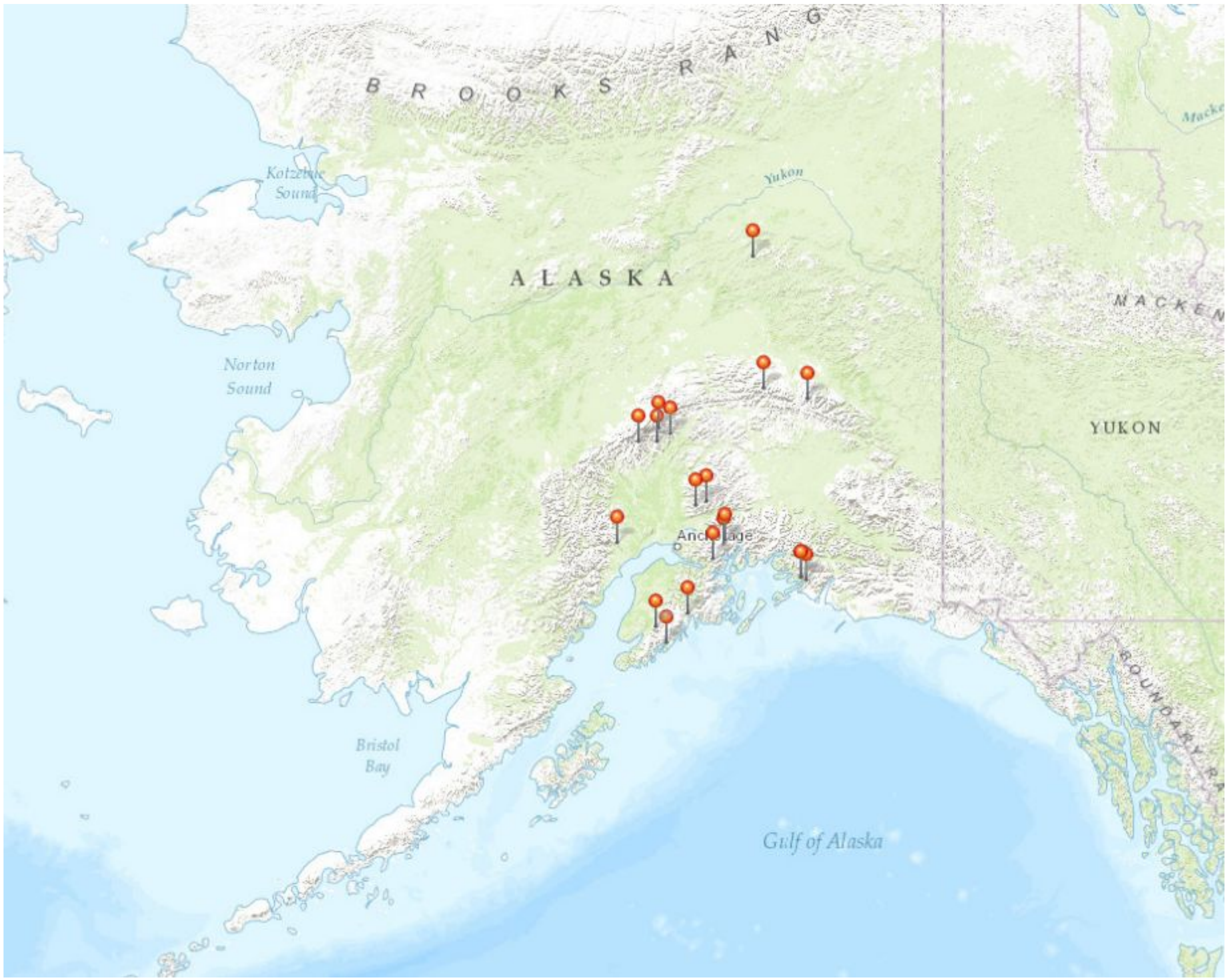


Figure 5.9- 2. Rainfall Center Locations for the Short List Storms

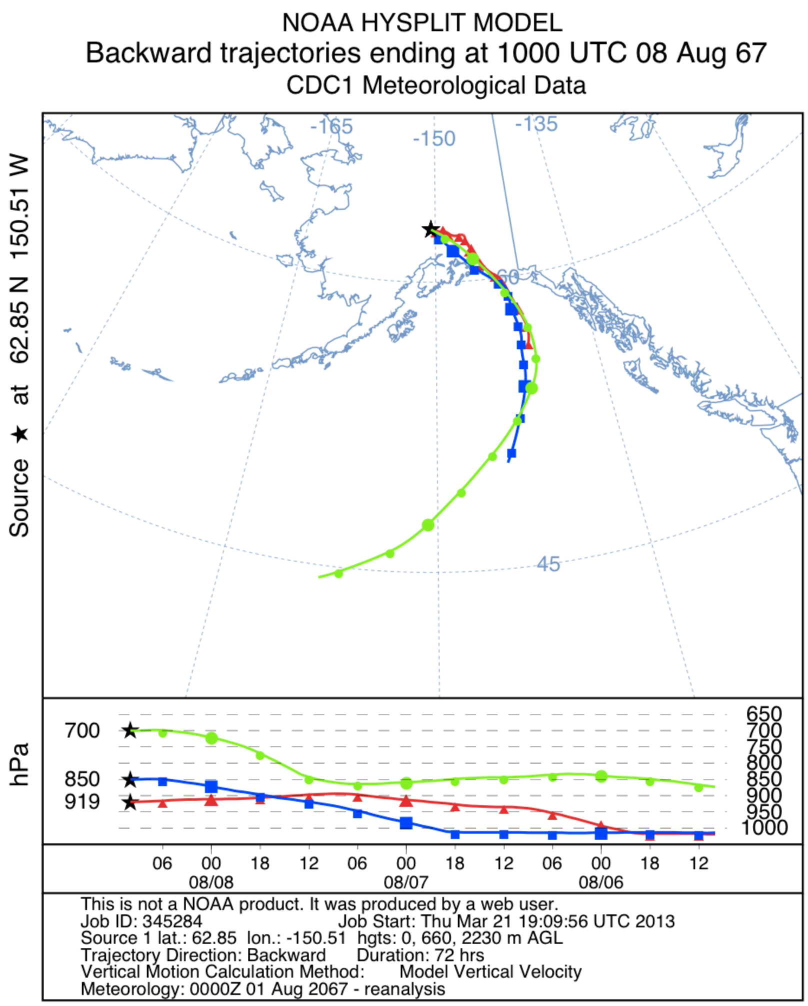


Figure 5.9- 3. Example of a Trajectory Model Analysis