BAKER RIVER PROJECT RELICENSE

Aquatic Resources Working Group

March 13, 2003

8:30 a.m. – 3:00 p.m.
U.S. Forest Service
Conference Room A/B (425-775-9702)
21905 64th Avenue West, Mountlake Terrace, WA

AGENDA

1. Review Agenda, Minutes, Schedule	8:30 – 8:45
2. Settlement Process-Update from Cross Resource Workshop, PME Status (2nd Draft PMEs)	8:45 – 9:15
3. Report from Instream Flow Technical Working Group (A09a,c,d)	9:15 – 10:30
Break	10:30 – 10:45
4. Review Study Plans/Requests: updates on A01a/b (A26b), A14, A16, A17, A24	10:45 – 12:00
Lunch (meeting snacks or bring your own)	12:00 – 12:30
5. Review Study Plans/Requests: updates on A25, A26a, A29, A36, A37, A38, A39 Others?	12:30 – 1:45
6. Action Items	1:45 - 2:00
7. Update from Solution Team Meeting	2:00 - 2:15
8. Additional Issues	2:15 - 2:30
9. Set Agenda for April 10th 2003 (WA DOE, Bellevue)	2:30 - 2:40
10. Evaluate Meeting	2:40 – 3:00

March 13, 2003

Driving Directions to US Forest Service Office:

1) Driving North from Seattle (or South from Everett) on I-5, take the 220th St. SW exit (exit 179).
2) Turn west (right if from southbound I-5, left if from northbound I-5) onto 220th St. SW.
3) Drive west about a block and turn right onto 64th Ave W.
4) The office building is about ¼ block down the street on the right side of the road.

BAKER RIVER PROJECT RELICENSE

Aquatic Resources Working Group

March 13, 2003
8:30 a.m. - 3: 00 p.m.
USFS Building, Mountlake Terrace, WA

MEETING NOTES

Aquatics Working Group Mission: *"To identify issues and develop solutions and recommendations addressing fish and aquatic resource interests related to the Baker River Project and its operations, leading to a settlement agreement."*

Fish Team Leader: Arnie Aspelund, 425-462-3442, arnie.aspelund@pse.com

PRESENT: Arnie Aspelund, Nick Verretto, Cary Feldmann (PSE), Arn Thoreen (Skagit Fisheries Enhancement Group), Sue Madsen (R2), Bill Reinard (Wildcat Steelhead Club), Steve Fransen (NMFS), Bob Wright and Rod Sakrison (DOE), Gary Sprague (WDFW), Gene Stagner (USFWS), Ruth Mathews (The Nature Conservancy), Stan Walsh (Skagit System Cooperative), Brady Green and Scott Lentz (USFS), Marc Daily (Meridian Environmental, Inc. for The Louis Berger Group), Dee Endelman (Agreements Dynamics), Lyn Wiltse, facilitator and Mary Jean Bullock (PDSA Consulting, Inc.).

AQUATICS WORKSHOP AT BAKER LODGE
April 1, beginning at 9:00 and lasting until 5-ish on April 2. Dress casually and bring musical instruments! See the draft retreat agenda under the Settlement Process discussion below.

FUTURE WORKING GROUP DATES AND LOCATIONS (2nd Thursday of each month):
April 10 (WA Ecology, Bellevue-Eastgate), May 8 (WA Ecology, Bellevue-Eastgate), June 12, July 10 (WA Ecology, Bellevue-Eastgate), August 14, September 11 (TBD), October 9, November 13, December 11, 2003 from 8:30-3:00 at USFS Office in Mountlake Terrace.

March 13, 2003 Agenda
8:30 – 3:00 p.m. at USFS Building in Mountlake Terrace

1. Review Agenda and Minutes

2. Review Relicensing Schedule
3. Settlement Process – Workshop debrief
4. Fish Passage Technical Working Group Report
5. Instream Flows Update (A9)
6. Studies:
   - A9d - Skagit River Flow & Habitat Assessment
   - A14 - Reservoir Shoreline Erosion
   - A16 - Lower Baker Delta/Channelization
   - A17 - Tributaries Surveys Upstream of Barriers
   - A25 – Inventory of Unnatural Predation Opportunity
   - A26 - Reservoir Production Potential
   - A29 - Sockeye Smolt Incubation Origin Otolith
   - A36 - Native & Wild Inland Fish Population Assessments
   - A37 - Evaluation of Aquatic and Riparian Habitat under Without Project Alternative
   - A38 - Bull Trout Population Assessment
   - A39 – Native Non-Salmonid Fish
   - A40 (?) – Chinook-related Study
7. Action Items
8. Update from Solution Team Meeting
9. Additional Issues?
10. Set agenda for April 10, 2003 meeting (@ WA Ecology, Bellevue-Eastgate)
11. Location for May 8 meeting (@ WA Ecology, Bellevue-Eastgate)
12. Evaluate meeting

INTRODUCTIONS

Brady Green of the U.S. Forest Service introduced Scott Lentz who will be his replacement as Brady will be retiring soon.

NEW ACTION ITEMS

- ALL: Consider additional data needs for April 1,2 retreat and let Arnie know ASAP
- Cary: Get HYDROPS runs (Stage, 6”, Amplitude, cycling) out to Working Groups by week of March 24th)
- Arnie: Send out list of all requested HYDROPS runs to Working Group members along with a recommendation of how to prioritize the runs by March 14 *(completed list of initial runs March 26th*)
- Brady: Bring Forest Service mosaic of aerial photos of low reservoir levels
- ALL: Bring musical instruments
- ALL: Let Sue know how you prefer to get the reports (hard copy, CD, etc.)
- Arnie: Check with Asit re: incorporating Resident trout into his analysis (*in reference to studies A26a/b*)
- Sue: Work on producing map including above barriers habitat in time for the retreat (*in reference to studies A37 and A17*).
- ALL: Review A24 report and get comments to Sue by end of April.

- ALL: Sent Stan comments on E03 (Examination of Spawning and Incubation Flows in the Skagit River below the Baker confluence in the Brood Year 2000) by January 31. The Economic Working Group will discuss this in April.
- Mark: Send out the revised Study Request on A36: Native & Wild Inland Fish Population Assessments (prior to our February meeting) for discussion at our March meeting.
- Mark: Send out the revised Study Request R-A38: Bull Trout Population Assessment & Risk Analysis
- Mark: Get Emily juvenile density for multiple age classes in the Sauk.
- ALL: Get comments on Large Woody Debris report *(A20)* to Phil by April 1st .

REPORT ON OLD ACTION ITEMS
- Nick: Talked with Stan re: A29.
- Nick: Sent Ruth downstream passage option criteria.
- Phil: Emailed Large Woody Debris report to Arnie to distribute by February 14 (including a cover letter identifying opportunities).
- Phil: Created a matrix of non-salmonids with relation to project effects and distributed by next meeting.

REVIEW RELICENSE SCHEDULE
There were no substantive changes to the schedule since our last meeting. We are on the critical path. Time is of the essence and FERC has announced that they won't be granting extensions.

SETTLEMENT PROCESS – UPDATE
At the cross-resource workshop last week, we learned that FERC is requiring us to submit the Settlement Agreement along with the license application on April 30, 2004. They are talking no extensions.

We will do a retreat at the Baker Lodge, April 1 and 2 to work on creating a second draft of proposed actions. The aim of this retreat would be: fleshing out the details of proposed actions that are a high priority for evaluation in the PDEA. This would include identifying a range of alternatives that would meet the interest of Working Group members. It would also be helpful to note areas of potentially high agreement along the way (at least areas where there doesn't appear to be a lot of conflict).

We would leave with a prioritized list of areas to address/conflicts to work through.
Materials and Supplies for Retreat:

- Input from other Working Groups
- GIS maps
- A37 maps
- Study results
- Photos
- HYDROPS model and output form model
- Projector and electronic version of draft proposed actions

DRAFT AGENDAS FOR BAKER LODGE RETREAT

April 1, 2003

8:30-9:00 Arrive/Get settled/Continental breakfast
9:00-11:00 Finish walking through draft proposed actions
11:00- 11:15 BREAK
11:15-12:15 HYDROPS runs/output/discussion
Instream Flows – Update on A9a
Ramping, cycling, amplitude
Identify additional model runs?
12:15-1:00 LUNCH
1:00-3:00 Complete HYDROPS discussions
3:00-3:15 BREAK
3:15-4:15 Connectivity (IntraBasin movement)
4:15-5:15 Water Quality- Stream and Reservoir
5:15-6:15 p.m. DINNER (with PDB)
7:00-8:30 p.m. Continue Water Quality discussions

April 2, 2003

7:30-8:00 Hot Breakfast
8:00-9:30 Fish Propagation
9:30 – noon Downstream Fish Passage
12-12:45 LUNCH
1:00-3:00 Habitat- Large Woody Debris/Sediment

INSTREAM FLOWS UPDATE (A-9)

R2 reports they should have A9c *report done* in next week *(A09a field work may supercede deadline). Will try to get* A9d out by March 24. Phil is in the field now, waiting for flows to come down so he can get the remaining transect data over the weekend.

FISH PASSAGE TECHNICAL WORKING GROUP REPORT

The group is continuing to rank various options according to set criteria. There is a high degree of uncertainty about the biological implications of the current system and various alternatives being considered. The potential cost exposure is also very high (from $20 Million to $220 Million)

Our Settlement Agreement could contain performance standards along with a process to achieve them. Absent a Settlement Agreement, we would have prescriptions that speak only to facilities. They will meet next week to continue discussions.

UPDATE FROM SOLUTION TEAM

The Solution Team spent most of their meeting discussing a draft outline of what our settlement agreement process might look like. They also reviewed the goals of the cross-resource workshop March 4-6. During the FERC conference call, the issues of schedule (no extensions granted) and flood control were raised.

STUDY REQUEST SUBMITTALS/STUDY PLAN DEVELOPMENT

Study #	Title	Notes/Next Steps
A01.A	Reservoir Tributary Habitat Surveys	Emily's tributary, habitat and biological report is

	being reviewed by Phil. Sue will try to see that we get to see this before our April 1 and 2 retreat. She will bring GIS maps to the retreat.
A01.B Reservoir Tributary Biological Surveys	See report for 101.A. ACTIVE
A01.C Reservoir Tributary Delta Surveys	See report for 101.A. ACTIVE
A02 LB River Habitat Mapping	Sue reported that this existing conditions report will be out before the end of the month.
A03 Reservoir Fish Population Characteristics	Not discussed. No action yet. PSE will review existing information for the PDEA.
A04 LB/Skagit River Flow, Gaging	Not discussed. Last meeting Phil reported that they downloaded pressure sensors last and are still in the process of collecting data. Links to A9. ACTIVE
A05 Water Quality Sampling	Not discussed. Data collection underway as per Study Plan. This study will be ongoing through Spring, 2004. Hoping to have all requirements fulfilled for Water Quality Certification.
A06 UB Passage Design Baffle Modification	Complete.
A07 Lower Baker Forebay Bathymetry	Complete.
A08 UB Passage System Evaluation	Complete.
A09A Skagit River Flow and Habitat Assessment	Sue reported that Phil is currently out in the field waiting for flows to subside so he can try to get the rest of the transect data we are missing. We will get an update at our April retreat.
A09B Salmonid Redd Selection and Maintenance in the Middle Skagit in Response to River Fluctuation from Hydropower Peaking	Not discussed. Adam is researching what type of spike in flow over what window of time is required to influence spawning behavior. R2 will continue to look at this when PSE resumes a regular operating schedule.
A09C Distribution, Timing and Depth of Salmonid Redds	Not discussed. PDEA contractors have requested a description of life history and timing of spawning for all species. These data will be out prior to our March meeting for discussion. *(we are expecting draft report for distribution by April 1)*
A09D Distribution, Timing of Salmonid Fry	Not discussed. After our January meeting, Phil got 2001 and 2002 WDFW Mt. Vernon screw trap data. They are integrating this into a report to be out in the next couple of weeks (including scoop trap and Baker trap data).
A10 Baker River Delta Habitat Assessment-Char	Complete. Note: USFWS is concerned with impacts to char and indirectly to bald eagles through chum and also to cutthroat.
A11 Nutrient Addition	Tie to A26.
A12 Instream Flows for Bio-diversity	Split between R-A21 & R-A09.
A13A Water Quality Impacts of Human Uses	Not discussed. Removed from list of studies this

of the Reservoir and Adjacent Shorelines.	group will address, reported by Brady in September. Greta reported the USFS will pursue this in the recreation working group.
A13B Water Quality Impacts on Aquatic Habitat	Removed from list of studies we will address. Tabled for now. Awaiting results of A14a.
A14A Reservoir Shoreline Erosion	Arnie reported that the draft report for this will be out in the next week so we have time to review it prior to our April 1 meeting. (*we are expecting draft report by April 1*)
A15 UB Delta Scour	Not discussed. Field work is complete. Hope to have the report in March 2003.
A16 Lower Baker River Alluvial Fan Assessment	Sue *and Devin Smith of SSC* met with folks working on the Little Baker *Side Channel Restoration* Project to identify synergies. By April 10, she'll get us a draft of the Study Plan including potential PME alternatives and a description of what type of analysis we'll be doing for each and what outputs we might expect.
A17 Tributaries Surveys Upstream of Barriers	We agreed that as a first step, we could use existing GIS maps to get at resident trout habitat. A37 will include what trout production would be without the project. We could extend it to have Asit do some analysis of existing reservoir production potential of resident trout. This means doing steps 1-7, and 9 now (according to the March 11 handout from R2: Effects of the Baker River Project on Resident Trout Potential Analysis Procedure). Based upon these data we could discuss what next steps are appropriate for the future. Brady appreciates R2's effort on this..
A18 Baker River Survey Upstream of 1 km.	Merged into A01a and A01b. ACTIVE.
A19 Review Limnological Information	This study has been combined with A26.
A20 Large Woody Debris Management	Sue asked members to review suggestions in Phil's cover letter for discussions at the April 1, 2 retreat.
A21 Skagit Wild & Scenic River Values	This is being addressed by A9 and A24.
A22 Baker Lake Trout Impacts Evaluation	No longer necessary due to change in management direction in favor of cancellation of non-native trout stocking in the reservoirs. Removed from list of studies we will consider.
A23 Baker River Wild & Scenic River Values	This is being addressed through A15.
A24 Hydrologic and Geomorphic Analysis	Sue distributed the Hydrology (IHA) portion of this report. It compares current project operations with unregulated flows. This is an effects analysis. It is not predictive. This provides a good place to start

	identifying what we might want to explore through the HYDROPS model. We can *assess various HYDROPS using the IHA model to compare various alternatives.* Note: Time periods and parameters are flexible. Let Sue know if you want to see something else to run through the IHA model. This *report* will be shared with the Economic Working Group, the County, etc. Please give your comments to Sue by the end of April, 2003. Part 2 of this report.- Sediment Transport and Channel Response will be out by end of April.
A25 Unnatural Predation	Nick reported that we are currently investigating unnatural opportunities for predation in four sites. Ten samplings have been completed of fry releases (March-May is the time frame for these releases). These samplings are taken every four days through out the time frame. We are also sampling smolt migration. This study is being combined with resident trout and bull trout surveys. We are fin clipping everything but the sculpin. It looks like a few sculpin will have to be sacrificed.
A26A Reservoir Limnology-Production Potential	The draft report is due out by the end of March. The Water Quality analysis is complete. Some data (phytoplankton) gaps have been identified. This will be reflected in the reports along with specific recommendations for future studies (may need to be included in adaptive management).
A26B Tributary Production Potential	Results combined in the report for A01a and A01b and expected by the April 10 meeting.
A27 Middle Skagit Incubation Flows	Addressed in A9.
A28 Fish Passage-Reservoir Management	Now addressed in Fish Passage Studies A30 to A34. ACTIVE
A29 Estimate Sockeye Production from Different Incubation Sources	This year, we have sockeye emerging out of Beach 3 and 4. For now, we have agreed to collect and preserve 100 samples. We can determine what to do with them latter on (otolith analysis).
R-A30 Near-Field Smolt Behavior	Completed. Coordinated through Fish Passage Tech. Group.
R-A31 Fish Passage-Far Field Smolt Migration	Completed. Coordinated through Fish Passage Tech. Group.
R-A32 Fish Passage-Kelt Radio telemetry	Completed. Coordinated through Fish Passage Tech. Group.
R-A33 Fish Passage-PIT Tag Migration	Completed. Coordinated through Fish Passage

	Tech. Group.
R-A34 Fish Passage-Downstream Run-Timing Correlation	Completed. Coordinated through Fish Passage Tech. Group.
R-A35 Fish Passage-Upstream Run-Timing	Completed. Coordinated through Fish Passage Tech. Group.
R-A36 Native & Wild Inland Fish Population Assessments	As part of the bull trout and resident trout studies, we are taking tissue samples. We will also be taking samples from the fish traps. Nick will follow up with Mark re: the number of samples needed. Tissue sampling continues…
R-A37 Without Project Alternative (evaluation of Aquatic & Riparian Habitat)	Sue walked us through a presentation of the where we are with this study. The emphasis was using data on historic aquatic habits to predict future potential aquatic habitats. It also provides a semi-quantitative description of aquatic habitats that would be present under various future operating scenarios: ongoing operations, dam decommissioning, and ongoing flood control without project. Members seemed reasonably comfortable with the assumptions as introduced that R2 is making for this study. She will bring tables/maps to our April 1st.
R-A38 Bull Trout Population Assessment & Risk Analysis	This is underway. We will discuss April 10th. .
R-39 Native Non Salmonid	Phil prepared a paper on what species are in the Baker River Project basin and what their habitat is. We will look at linking this to A1, 2, 9, 15, 16, 24, 37, 17, 26b and fish passage. Sue and Phil will follow up with Ruth on how to handle this. *(Brady emailed that the USFS has comments to make on this paper)*

HANDOUTS

- Agenda for 3-13-03 meeting
- Final Minutes from 2-13-03 meeting
- Long-term Aquatics Schedule
- Updated Aquatics Study Request Index
- Updates Aquatics Study Index
- Effects of the Baker River Project on Resident Trout Potential Analysis Procedure – Prepared by R2 Consultants, March 11, 2003
- Effects of Baker River Project on Native Non-Salmonid Fishes, Aquatic Study Request – A39---Reconnaissance level Analysis – R2 Resource Consultants, March 10, 2003
- Hydrology and Geomorphology of the Baker and Lower Skagit Rivers (Study A-24) – Part 1 of 2), PART 1 – Hydrology –draft report

- A37 *Power Point Presentation/Report*: Future Potential Aquatics Habitats within the Baker Project Area

PARKING LOT

- State agency presentations re: mandates (agency direction)
- Create a master list of possible studies across all working groups and share with all
- Access to the Baker River Project hourly operational model (Charles Howard)
- Participate in Lower Skagit Work Group for native char
- Create Overall "Study Plan" for Studies that will drive the Relicensing Process
- Address Trap & Haul – other species
- *PSE agreed to take over the Little Park Creek smolt trapping effort this year. Implementation is underway.*

EVALUATION OF MEETING
Well-Dones

- Gary and Steve actually remembered to pick up Gene today!
- Sue's A37 presentation
- Great progress on studies/results
- Arnie's food-
    - Predation opportunities
- Got a plan for 2-day Retreat (April 1 and 2)
- Lyn's joke
- Sue's "Blowing past" dam removal

What Needs to Be Changed

- Too much time planning for 2-day Retreat
- Lyn's joke

What's Hot?

- In-stream flows
- Planning for 2-day Retreat: April 1 and 2
- Downstream Passage

Studies Update for Solution Team

Made progress on:

- A17 – Tributary surveys above barriers
- A39 – Native Non-Salmonids
- A24 – Hydrologic part of Hydrologic and Geomorphic Analysis is out
- A37 – Evaluation of Aquatic and Riparian Habitat under Without Project Alternative
- A9 – We hope to get the remainder of the instream flow data soon!

Tentative April 10, 2003 Agenda
8:30 – 3:00 p.m. at WA Dept. of Ecology, Bellevue – Eastgate

1. Review Agenda and Minutes

2. Review Relicensing Schedule
3. Settlement Process – Status of 2nd draft proposed actions after April 1, 2 Retreat
4. Fish Passage Technical Working Group Report
5. Instream Flows Update (A9)
6. Studies:
   - A01(a,b)/A26 (b) – Reservoir Tributary Surveys
   - A2 – LB Habitat Mapping
   - A5 – Water Quality Sampling
   - A9 (a,b,c,d) - Skagit River Flow & Habitat Assessment
   - A14 - Reservoir Shoreline Erosion
   - A15 - UB Delta Scour
   - A16 - Lower Baker Alluvial Fan Assessment
   - *A17 – Tributaries Surveys Upstream of Barriers*
   - A20 – Large Woody Debris Management
   - A24 - Hydrologic & Geomorphic Analysis
   - A25 – Inventory of Unnatural Predation Opportunity
   - A26 (a) - Reservoir Production Potential
   - A36 - Native & Wild Inland Fish Population Assessments
   - *A37 – Evaluation of Aquatic/Riparian Habitats (Without Project Alternative)*
   - A38 - Bull Trout Population Assessment
7. Action Items
8. Update from Solution Team Meeting
9. Additional Issues?
10. Set agenda for May 8, 2003 meeting @ WA Ecology, Bellevue-Eastgate
11. Evaluate meeting

Baker River Hydroelectric Project

(FERC No. 2150)

HYDROLOGY AND GEOMORPHOLOGY OF THE BAKER AND LOWER SKAGIT RIVERS

(STUDY A-24)

Part 1 of 2

PART 1: HYDROLOGY

DRAFT REPORT

Prepared by:

R2 Resource Consultants, Inc.

15250 NE 95th Street

Redmond, Washington 98052-2518

Puget Sound Energy, Inc.

March 2003

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ACRONYMS AND ABREVIATIONS

ARWG	Aquatic Resources Working Group
cfs	cubic feet per second
GIS	Geographic Information System
GLO	General Land Office
GPS	Global Positioning System
IHA	Indicators of Hydrologic Alteration
LWD	Large woody debris
MBSNF	Mount Baker Snoqualmie National Forest
msl	Mean Sea Level
PSE	Puget Sound Energy
R2	R2 Resource Consultants
RM	river mile
RVA	Range of Variability Analysis
SSC	Skagit System Cooperative
SCL	Seattle City Light
USACE	U.S. Army Corps of Engineers
USFS	United States Forest Service
USGS	United States Geological Survey
WY	Water Year

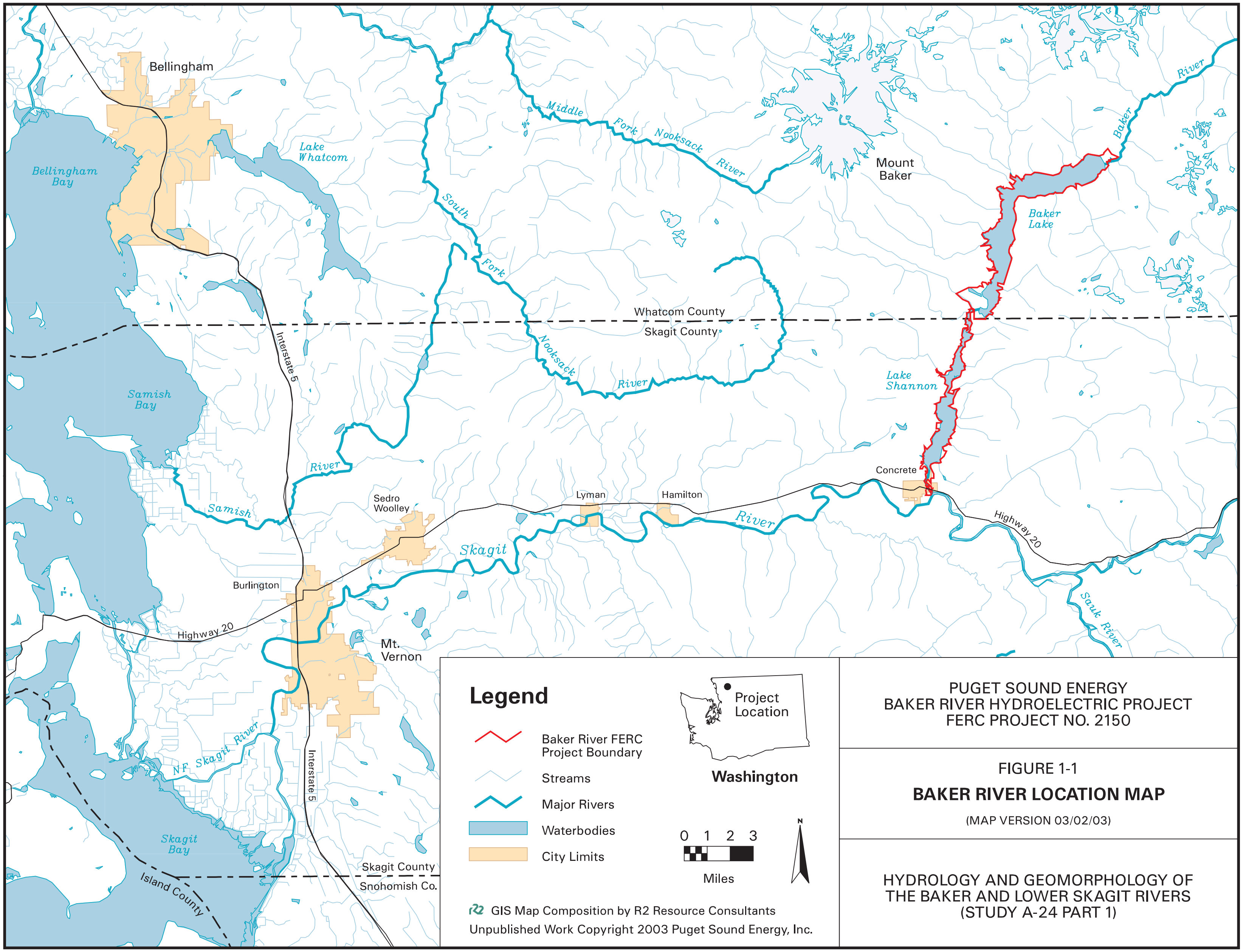
1. INTRODUCTION

The Baker River Hydroelectric Project is owned and operated by Puget Sound Energy, Inc. (PSE). The Baker River Project (FERC No. 2150; hereafter referred to as the Baker Project) consists of the Lower Baker Development (constructed in 1925) and the Upper Baker Development (constructed in 1959). The Baker Project is located in Skagit County, Washington, about 50 miles north of the city of Seattle, and 50 miles south of the Canadian border (Figure 1-1). The Project was licensed for 50 years, effective May 1, 1956, by the Federal Power Commission, now known as the Federal Energy Regulatory Commission (FERC). The Project's current license expires on May 1, 2006, and PSE has filed its notice of intent to seek relicense of the Project.

As a prerequisite to filing a new license, the applicant must consult with federal, state and local agencies, affected Indian Tribes, non-governmental agencies and the general public. The FERC allows an applicant for a new license to engage in a "traditional" or "alternative" pre-filing process. In March 2000, PSE began efforts to engage all potentially interested parties, including resource agencies and tribes, in a collaborative approach to relicensing. Under the Alternative Licensing Procedures (ALP) established by FERC in 1997, the licensee consults with the agencies, tribes and other interested parties from the outset of the process and seeks to obtain agreement on licensing issues to be addressed in the new license. Participants cooperatively examine environmental issues and design scientific studies as needed. As part of this process, PSE established five primary working groups focusing on the following resource areas: aquatic resources; terrestrial/wildlife; recreation/aesthetics; cultural/historical; and economics and operation. The purpose of these working groups is to identify issues and review available information, select studies that need to be completed, and make recommendations about the resource area.

The goal of the Aquatic Resources Working Group (ARWG) is identify issues and develop solutions and recommendations addressing fish and aquatic resource interests related to the Baker Project and its operations, leading to a settlement agreement. The ARWG has requested a series of studies to be undertaken in support of the relicensing process, and has numbered those studies consecutively. One of the issues identified is the ongoing effect of Project operations on the hydrology and geomorphology of the Baker and middle Skagit rivers. Flow regulation can alter geomorphic processes including the hydrologic and sediment transport regime of a river, causing changes in channel morphology that alter habitat conditions, riparian communities and aquatic ecology. Study A-24 describes project effects on the hydrologic regime, sediment transport and the responsiveness of channels downstream of the Project Area to inputs of water, wood and sediment.

Our analyses utilized available hydrologic records and measurement of channel conditions to describe the effects of the Baker Project under current operating conditions. The results of the analyses may be used to identify and develop protection, mitigation and enhancement measures (PMEs) that would be implemented under the new license. We also used various hydrologic statistics to describe channel and flow conditions under an assumed unregulated scenario; that is, without the influence of the Baker River Project. This information provides one of several potential standards to assess the effects of alternate



PUGET SOUND ENERGY
BAKER RIVER HYDROELECTRIC PROJECT
FERC PROJECT NO. 2150

FIGURE 1-1
BAKER RIVER LOCATION MAP
(MAP VERSION 03/02/03)

HYDROLOGY AND GEOMORPHOLOGY OF THE BAKER AND LOWER SKAGIT RIVERS (STUDY A-24 PART 1) operating scenarios. Alternative operating scenarios will be developed during the Settlement Agreement process and will reflect efforts to balance potentially competing resources. Hydrologic statistics used in this report can be calculated for potential operating regimes to support comparison of different scenarios. Part 1 of Study A-24 contains the results of our analyses of the hydrology of the Baker and Skagit rivers. Part 2 describes the results of our analyses that focused on Sediment Transport and Channel Response. The draft study results are presented in two documents to allow a more efficient review of the material.

1.1 GEOLOGIC AND CLIMATIC SETTING

The hydrologic regime of the Baker and Skagit rivers is strongly influenced by climate and geology. The Baker River basin is located on the western flank of the North Cascades Physiographic province in western Washington, extending from the glaciated peaks of Mount Baker and Mount Shuksan through a deeply entrenched valley carved by glaciers. The Baker River is the second largest tributary to the Skagit River system, contributing flows from a basin area of approximately 297 square miles. Streamflows in the Baker River are driven by runoff from fall rain events, spring snowmelt and, in the case of the larger tributaries in the northwestern portion of the Baker River basin, by glacial melt. Although average monthly flows are typically highest from May through July as a result of snowmelt, peak flows generally occur during the late fall and winter in response to heavy precipitation or rain-on-snow events.

The bedrock geology of the Baker River basin is complex. The western two-thirds of the basin is underlain by slates, limestones, phyllites and metavolcanic rocks of the Chilliwack Group dating from the late Paleozoic era. Superimposed on this older material are the much younger volcanic rocks originating from the Mount Baker volcano. The eastern third of the basin consists of greenschists and phyllites of the Shuksan Metamorphic Suite, dating from the mid-Cretaceous. These geologic formations represent episodes of mountain building over millions of years through uplift, folding and volcanism. The landforms of the basin have been sculpted by repeated glaciation and fluvial erosion. Alpine glaciation produced sharp peaks and ridges as well as cutting deep valleys. Continental glaciation rounded many of the landforms at lower elevations and scoured the pre-existing drainages. The glaciers also created ice dams behind which large lakes were formed, trapping alluvium carried by sediment-laden streams. After the glaciers had largely retreated, a series of volcanic events sent a sequence of mudflows, pyroclastic flows and lava flows down the tributary streams draining the southern flank of Mount Baker.

1.2 PROJECT OVERVIEW

The Baker Project consists of the Upper Baker and Lower Baker Developments. The Lower Baker Development consists of the Lower Baker Dam, a powerhouse, reservoir and associated facilities. Lower Baker Dam is located on the Baker River approximately 1.2-miles mile north of the confluence of the Baker and Skagit rivers. The present powerhouse contains a single generating unit (Unit 3). The single turbine was replaced in the spring of 2001 and the new unit has a maximum machine flow of approximately 4,700-cfs and is capable of producing 77 megawatts (MW) of electricity. However, the maximum generating flow is currently limited to 4,200-cfs due to limitations of the transformer. Unit 3 efficiently operates at flows between 3,700 cfs to 4,100 cfs at a net head of 253 feet, and has a minimum machine flown of approximately 3,200 cfs (Figure 1-2).

Under current operations, water in the lower Baker River either passes through the single power-generating unit at Lower Baker Dam, through a 24-inch bypass pipe (80 cfs), leakage through pressure relief holes in dam abutments, or is spilled through the Lower Baker Dam over the spillway crest at elevation 425-feet. When Lower Baker Unit 3 shuts down, an 80-cfs flow is continually released below Lower Baker Dam through the 24-inch bypass valve off the penstock to allow operation of the adult trap-and-haul facility. During periods of peak sockeye adult migration (i.e., late June through July), PSE has typically generated for 4 hours beginning at daylight into the Lower Baker River to provide additional attraction for adult fish staging at the confluence of the Baker and Skagit rivers.

Lake Shannon, the reservoir formed by Lower Baker Dam, is approximately seven miles long and covers an area of about 2,218 acres at normal full pool (elevation 438.6 feet). Approximately 159,465 acre-feet of water are stored in Lake Shannon at full pool, including about 122,565 acre-feet of active storage above the minimum generating pool. The top of Lower Baker Dam is at elevation 446.87 feet, and water is released through the turbine intake (elevation 350 feet) or through the dam spillway (spillway crest elevation 424.8 feet). Under normal operating conditions, Lake Shannon is held at full pool during the summer months. Minimum reservoir elevations are typically attained from November through March or early April. Lake Shannon can be operated in coordination with Baker Lake to provide flood control protection, but there is no formal agreement governing Lake Shannon operations for storage of winter storm runoff.

The Upper Baker Development consists of the Upper Baker Dam, a powerhouse, reservoir and associated facilities. The Upper Baker powerhouse contains two generating units (Units 1 and 2) with a combined authorized installed capacity of 90.7 MW and a collective maximum machine flow of approximately 5,050 cfs. Baker Lake, the reservoir formed by Upper Baker Dam, is approximately nine miles long and covers an area of about 4,985 acres at normal full pool (elevation 724.0 feet). Roughly 285,472 acre-feet of water are stored in Baker Lake at full pool, of which approximately 184,796 acre-feet is active storage above the minimum generating pool. The top of Upper Baker Dam is at elevation 732 feet and water is released through the turbine intakes (elevation 654 feet) or through the spillway (spillway crest elevation 694 feet) (Figure 1-3). Under normal operating conditions, Baker Lake is held near full pool during the summer months. Minimum reservoir elevations are typically attained from November through March or early April. PSE’s license obligates PSE to operate the Upper Baker Development to provide the U.S. Army Corps of Engineers (USACE) with 16,000 acre-feet of flood control storage between November 1 and March 1. In addition, PSE is obligated to provide up to 84,000 acre-feet of flood control storage if requested by the USACE (for a total of up to 100,000 acre-feet of flood control storage). Under the current agreement between PSE and the USACE, PSE must maintain Baker Lake elevations at or below 720.25 feet by November 1 to provide 16,000 acre-feet of flood control storage at the Upper Baker Development, and at or below elevation 707.8 feet under normal operating conditions from November 15 to March 1 (to provide a total of 74,000 acre-feet of flood control storage at the Upper Baker Development).

Lower Baker Dam

Section View - Not to Scale

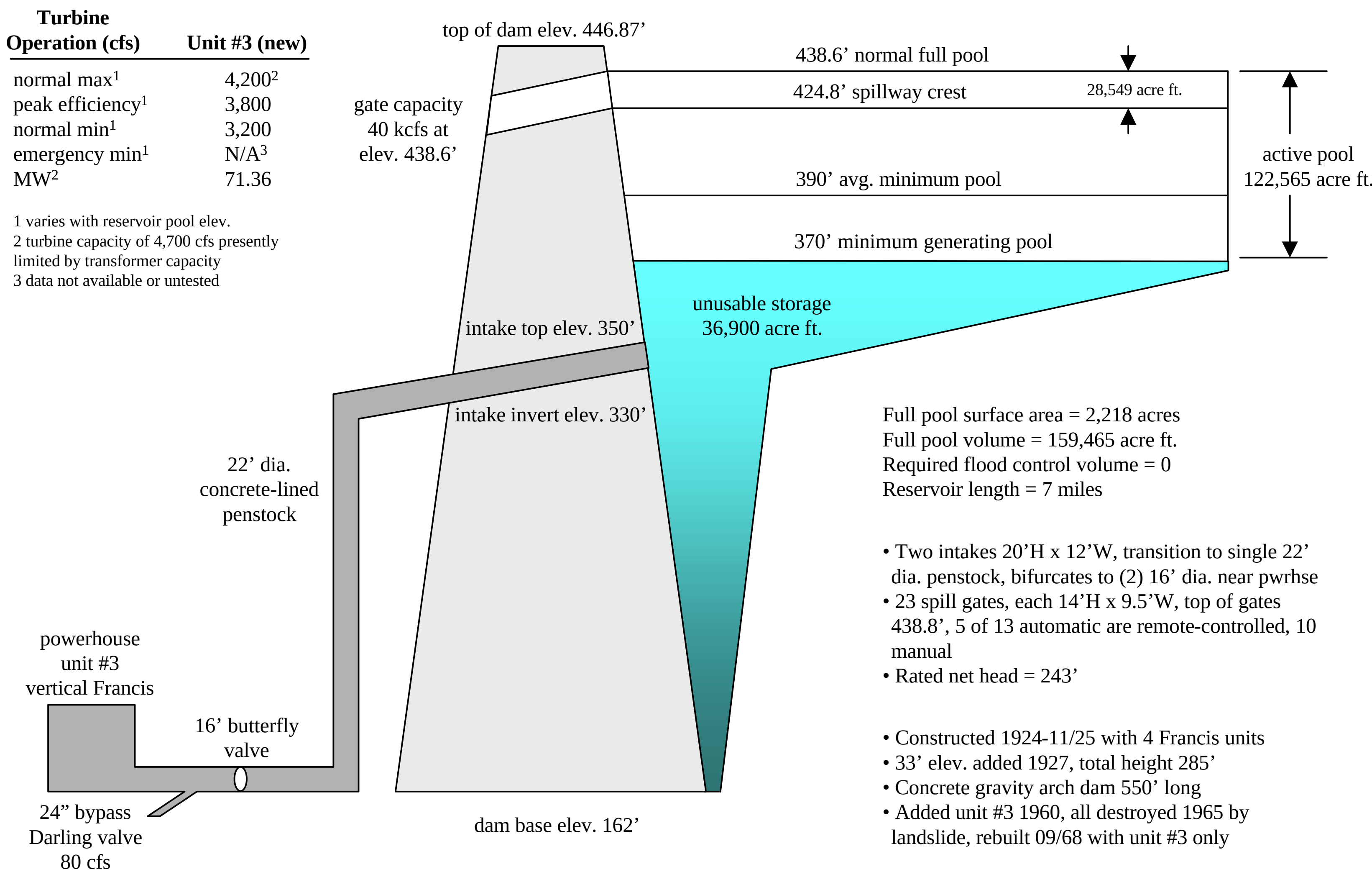


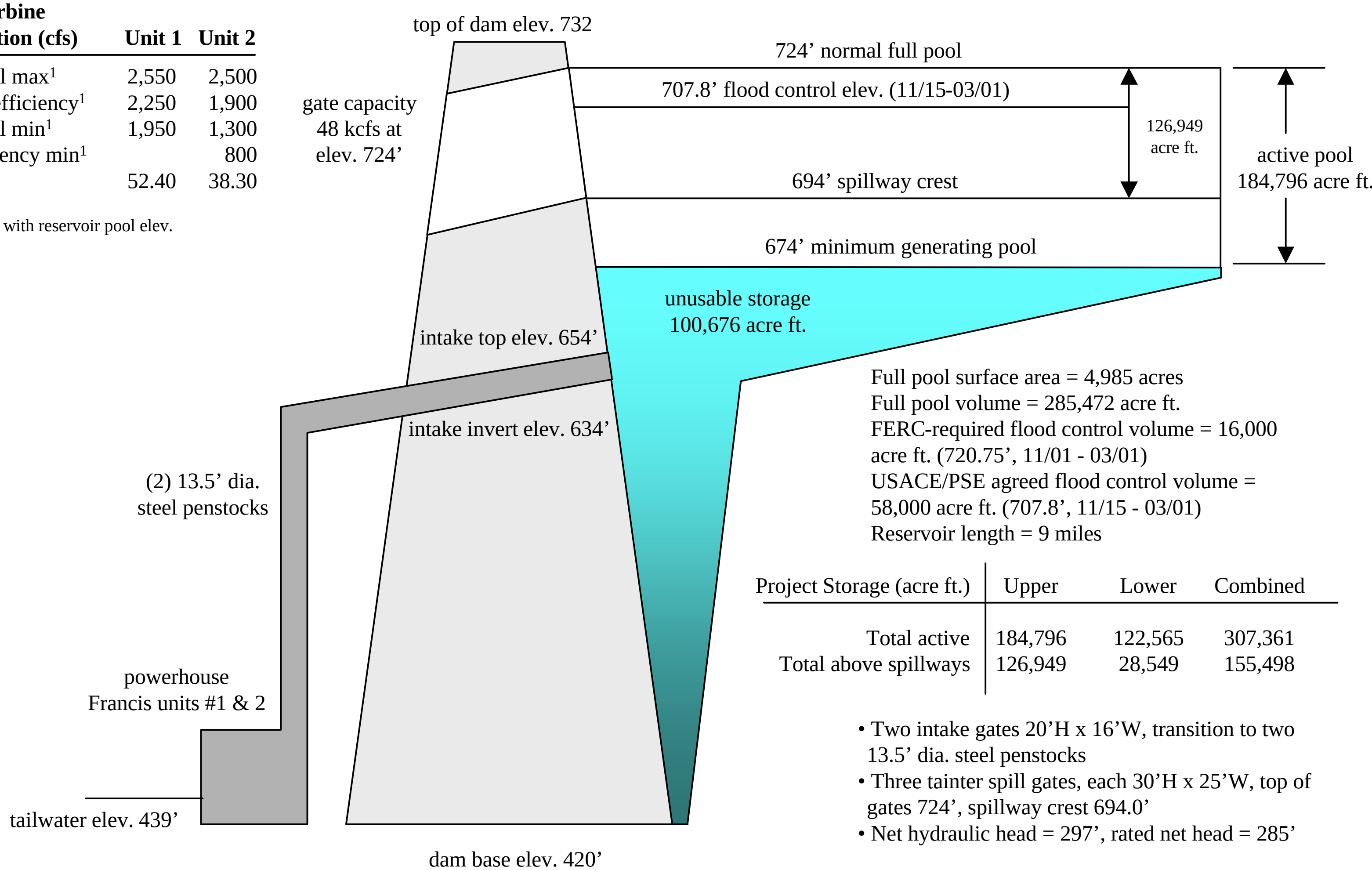
Figure 1-2. Schematic of Lower Baker Development

Upper Baker Dam

Section View - Not to Scale

Turbine Operation (cfs)	Unit 1	Unit 2
normal max[1]	2,550	2,500
peak efficiency[1]	2,250	1,900
normal min[1]	1,950	1,300
emergency min[1]		800
MW	52.40	38.30

1 varies with reservoir pool elev.



Full pool surface area = 4,985 acres
Full pool volume = 285,472 acre ft.
FERC-required flood control volume = 16,000 acre ft. (720.75', 11/01 - 03/01)
USACE/PSE agreed flood control volume = 58,000 acre ft. (707.8', 11/15 - 03/01)
Reservoir length = 9 miles

Project Storage (acre ft.)	Upper	Lower	Combined
Total active	184,796	122,565	307,361
Total above spillways	126,949	28,549	155,498

- Two intake gates 20'H x 16'W, transition to two 13.5' dia. steel penstocks
- Three tainter spill gates, each 30'H x 25'W, top of gates 724', spillway crest 694.0'
- Net hydraulic head = 297', rated net head = 285'

- Constructed 06/56 - 10/59 with 2 Francis units
- Concrete gravity dam 1200' long, 312' high
- 12' roadway at elev. 732'

Figure 1-3. Schematic of Upper Baker Development

1.3 STUDY APPROACH

The overall geomorphic evaluation includes three primary components: 1) an assessment of changes in the hydrologic regime of the Baker and Skagit rivers conducted using a modified version of the Indicators of Hydrologic Alteration (IHA) methodology developed by Richter et al. (1996); 2) development of reach-scale sediment budget (inputs/storage/output) and transport capacity of the Baker River under continued project operations and without the influence of the project; and 3) an evaluation of channel responsiveness and reach-scale changes in channel morphology in the Lower Baker and Skagit rivers downstream of the Project that would occur under ongoing project operations and without the influence of the Baker Project. This report describes Part 1 of Study A24: the hydrologic analysis.

The results of the hydrologic analysis conducted for Study A24 illustrate the effects of current Baker Project operations relative to the unregulated flow regime, and provide information that may be used to identify target flow values that could be used to maintain specific components of the flow regime within the natural range of variability. The results of this study can be integrated with an assessment of species distribution and habitat utilization to identify flow components of biological importance within the mainstem Skagit River. However, Study A24 is not predictive – it does not answer the question of what the flow regime would look like under different future flow management scenarios. Development of instream flow criteria will require coordination with other water users and regulatory agencies responsible for resource management throughout the Skagit River Watershed. Predictions of the flow regime under future operational scenarios will be conducted using the HYDROPS model under development by the Baker Relicensing Economics Working Group (Van Do and Howard, 1988) and are beyond the scope of this effort.

2. METHODS

Hydrologic analyses conducted for this study relied on historical measured flow data (regulated) and synthesized "unregulated" flow data for the same time period. Historical flow and stage data for the Baker River at Concrete and Skagit River near Concrete gages and other gages of interest was obtained from the U.S. Geological Survey (USGS). Data used for this analysis covered the period from water year (WY) 1960 through 1999 for the Baker River at Concrete gage and WY 1960 through 1996 for the Skagit River near Concrete gage. This period of record is shorter than the available period of record (approximately 1928 through present for both gages), but was selected because it reflects the presence and operation of both the Upper Baker and Lower Baker Developments. PSE and the USACE provided synthesized unregulated hydrologic data. Synthesized data for the Baker River at Concrete gage used for this analysis covered the period of record from WY 1960 through WY 1999 (40 year period of record). Synthesized unregulated data for the Skagit River near Concrete gage used for this analysis covered the period from 1960 through 1996; however, data from WY 1993 and 1994 were not available (i.e., 35 year period of record).

Variations in the hydrologic regime over space and time play an important role in determining habitat conditions and biodiversity (Poff and Ward, 1990; Poff et al., 1997). The natural flow regime of a river varies on time scales of years, seasons, days and hours. Interannual variations (droughts or floods) are responsible for maintaining riparian communities, and floodplain and channel features. Seasonal flow variations provide cues for initiating life stage transitions (e.g., spawning or juvenile outmigration). Daily or hourly flow changes may affect the amount or suitability of available habitats for some species.

The USACE and PSE had each previously developed a set of synthesized "unregulated" daily flows to facilitate a flood frequency analysis (USACE, 1998). The availability of both measured daily flow data and synthesized unregulated daily flow data for both the Baker and Skagit rivers presents a unique opportunity to evaluate changes in the flow regime resulting from operation of the Baker Project. The historical data are assumed to sufficiently represent conditions that are likely to occur under the future 40-year license term. Although operations at the Baker Project have changed over time in response to changes in energy demands, data from the period from WY 1960 to 1999 (with both Upper and Lower Baker Dams in place) are considered to be representative of ongoing operations for the purpose of this analysis. Synthesized unregulated flow data developed from the same data set are considered to be representative of the range of climatic conditions and flow events that are likely to occur under the future 40-year license period.

The hydrology of the Baker and Skagit rivers and the effects of the Baker Project on the flow regime are characterized using a modified version of the Indicators of Hydrologic Alteration (IHA) and Range of Natural Variability Approach (RVA) developed by the Nature Conservancy (Richter et al., 1996; and Richter et al., 1998). In this approach, the range of natural variation in a set of parameters that are assumed to be ecologically relevant (called indices of hydrologic alteration) is evaluated, with the overall goal of identifying values of some or all of those parameters that could be maintained or restored within a range that encompasses some or all of the natural variability (Richter et al., 1998).

Characteristic runoff patterns unique to the Baker and Skagit River systems were identified by reviewing a series of synthesized unregulated annual hydrographs from the Baker River at Concrete and Skagit River near Concrete USGS gage sites. Flow components (IHA parameters) relevant to the Baker and Skagit rivers were identified from this initial review and discussions between members of the Baker Relicensing Aquatic Resources Working Group (Table 2-1). Selected parameters describe variations in the magnitude, timing, frequency and duration of flow components that provide key habitat features and biological cues over annual, seasonal and daily/hourly time scales. Differences in the mean and range of each selected parameter were calculated under regulated as compared to unregulated conditions.

Table 2-1. IHA Parameters evaluated to assess potential ongoing effects of hydropower operations of the Baker Project on flows in the Baker and middle Skagit rivers, Washington.

Parameter	Time Scale	Ecological Issue
• Peak flows (annual 3-day maximum) • 5%, 10% and 25% annual exceedence	Interannual	• Floodplain and riparian maintenance and connectivity
• Annual 7-day low flow	Interannual	• Habitat availability • Water quality
• Mean monthly flow	Seasonal	• Habitat availability
• Daily exceedence flows by month	Seasonal	• Cues for aquatic biota life history (e.g., spawning; juvenile migration, seedling germination)
• Frequency of high flow pulses	Seasonal	• Habitat connectivity • Biological cues (e.g., upstream migration; juvenile outmigration)
• 2-day minimum flow by month	Seasonal	• Salmonid spawning and incubation
• Duration of low flow events	Seasonal	• Habitat connectivity • Habitat availability
• Daily flow range	Daily	• Habitat availability • Varial zone productivity
• Diurnal flow fluctuations	Hourly	• Varial zone productivity
• Mean rise and fall rate of pulse events	Hourly	• Stranding/trapping of juvenile fishes
• Number of rapid stage decreases by month	Hourly	• Stranding/trapping of juvenile fishes

Data analysis focused on four temporal scales: annual flow variations, seasonal flow variations, daily flow variations and hourly flow variations. Measured and synthesized daily flows from the Baker River at Concrete and Skagit River near Concrete gages were utilized to conduct the evaluation of differences in annual and seasonal flow components under regulated versus unregulated conditions. Unit value data on a time step of 15-minutes to 1-hour are required to effectively evaluate daily and hourly flow components. Unregulated flow data synthesized on a daily time-step do not reflect hourly changes, thus data from a gage site on the nearby unregulated Sauk River were used as an unregulated analog to the regulated Baker River at Concrete and Skagit River near Concrete gages. Because each of these data sets represent measured flow data from different locations, quantitative analyses of the differences between hourly flow components under regulated versus unregulated conditions is not possible. However, data from the three gage sites can be compared to assess differences in the magnitude, timing, frequency and duration of hourly flow components between managed and unmanaged basins.

An analysis of changes in flood frequency was not specifically included as part of this study because the USACE recently completed such a study for the gage sites of interest. However, the results of that study are summarized within the section describing the results of the analysis of annual flow components.

Incoming tributaries are currently unregulated, with the exception of the Rocky and Sulphur creeks which are affected by the Koma Kulshan Project. Small hydropower projects have been proposed on a number of other large tributaries (Noisy Creek, Swift Creek, Park Creek, Sandy Creek, Anderson Creek, Thunder Creek and Bear Creek). At present, the only active FERC license application is for Anderson Creek.

3. RESULTS

The hydrologic regime is one of the primary processes responsible for determining a river channel's morphologic characteristics. Changes in the hydrologic regime can dramatically alter a river's ability to shape and maintain its channel. Reduced peak flows may result in a gradual reduction in the channel width and complexity, as bars formed of sediment that was formerly frequently mobilized become less active, and vegetation encroaches on stable, exposed surfaces. Channel complexity may also be altered by changes in low flows, if sediment or debris is deposited in side channels or backwater habitats, separating them from the mainstem, or if the seasonal connectivity is reduced due to reduced flow volumes. However, flow regulation may also provide opportunities to benefit resources of concern, via low flow augmentation, for example.

Chapter 3 describes the effects of the Baker Project on the hydrologic regime of the Baker River and middle Skagit River. This evaluation was conducted using an analysis approach known as Indices of Hydrologic Alteration (IHA) and Range of Natural Variability (RVA) developed by the Nature Conservancy (Richter et al., 1996). Characteristic runoff patterns (flow components) unique to the Baker and Skagit River systems were identified by reviewing a series of annual hydrographs from the Baker River at Concrete and Skagit River near Concrete. The IHA analysis approach is used to describe annual, seasonal, daily and hourly flow components under regulated and unregulated conditions. Annual and seasonal flow components are described using statistical analysis of average daily flow data. Daily and hourly flow components are described using statistical analysis of 15-minute to 1-hour unit interval data. The results of the analyses are presented in the following sections, for the Baker River and middle Skagit River.

The primary gage sites used for this analysis include the Baker River at Concrete gage (USGS gage Station 12193500) located approximately 0.3 miles downstream of Lower Baker Dam at RM 0.7 on the Baker River and the Skagit River near Concrete gage USGS gage Station 12194000 located approximately 2.5 miles downstream of the confluence with the Baker River at RM 56.5 on the Skagit River. Data from the Skagit River at Newhalem, Skagit River at Marblemount and the Sauk River near Sauk gages were used to conduct supplementary analyses of daily and hourly flow components. The location of these gage sites is shown in Figure 3-1. Table 3-1 summarizes the watershed characteristics for each gage site.

Table 3-1. Skagit and Baker basin gage locations and drainage basin areas used for the hydrologic analysis of the Baker Project, Washington.

Gage	Location	Drainage Area (square miles)
Baker River at Concrete (12193500)	RM 0.7	297
Skagit River near Concrete (12194000)	RM 54.1	2,737
Skagit River at Newhalem (1217800)	RM 93.7	1,175
Skagit River at Marblemount (12181000)	RM 78.7	1,381
Sauk River near Sauk (12189500)	RM 5.4	714

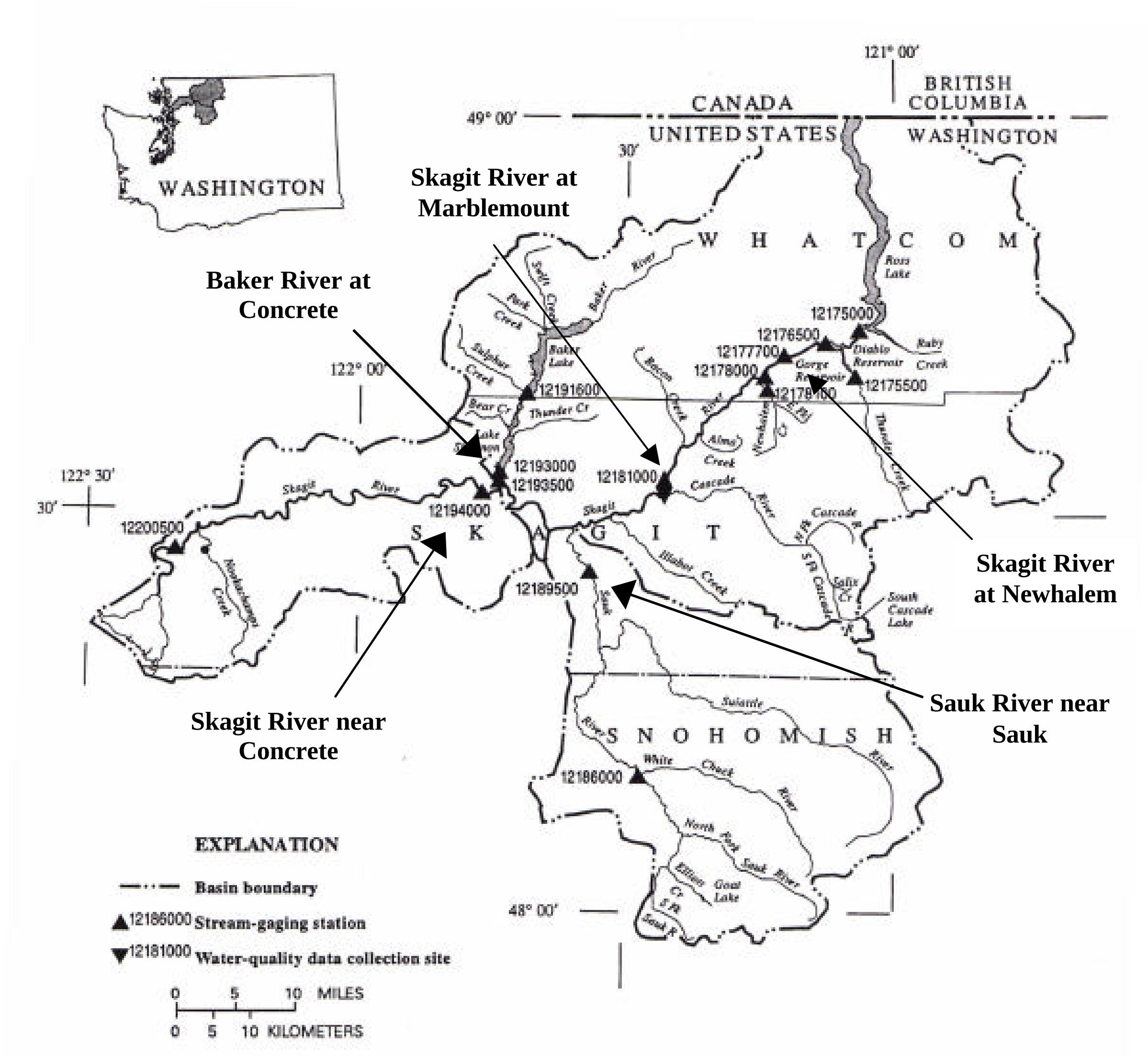


Figure 3-1. Map of Skagit River basin depicting the location of USGS gage sites utilized for the analysis of hydrology at the Baker River Project.

3.1 BAKER RIVER

The Baker River is the second largest tributary to the Skagit River system, contributing flows from a basin area of approximately 297 square miles (equivalent to about 18 percent of the Skagit River basin at the confluence of the two rivers). Streamflows in the Baker River are driven by runoff from fall rains, rain-on-snow events, spring snowmelt and, in the case of the larger tributaries in the northwestern portion of the Baker River basin, by glacial melt. The Baker River joins the Skagit River at RM 56.5.

The hydrologic regime of the Baker River may be described using a series of annual, seasonal, daily and hourly flow components. Annual and seasonal flow components are described using average daily flows. Specific flow components of interest include extreme high and low flows, and the overall duration of flows of various magnitudes throughout the year. Seasonal flow components include fall and winter flood events, spring snowmelt and summer baseflows. Daily and hourly flow components are described using a combination of average daily flow data and 15-minute to one-hour unit value data. Daily flow components include the frequency and duration of multi-day high or low flow events and the range of daily flows. Hourly flow components include diurnal fluctuations and the rise and fall rate of daily flow events. The following sections describe flow components of the Baker River under regulated and unregulated conditions.

3.1.1 Baker River Annual Flow Components

Flow characteristics generally used to characterize interannual variations in runoff patterns include the mean annual daily discharge, annual maximum daily flow, and the average seven-day low flow. Average daily flow data obtained from the USGS were used to represent regulated conditions. Unregulated flow conditions were represented by synthesized average daily flows provided by PSE (Baker River at Concrete gage) and the USACE (Skagit River near Concrete gage). In both cases, these data were generated using daily changes in reservoir pool elevations. Due to the way unregulated daily flow data were synthesized, the potential for error is high for any individual daily value, especially for low flows but is low when averaged over two or more days. For this reason the analysis was conducted using the 3-day annual maximum flow instead of the 1-day annual maximum flow.

Baker River Mean Annual Discharge

The mean annual daily flow generally reflects of the amount of precipitation delivered to a basin within a year. Comparing the mean annual discharge per unit area and variability in average daily flows for basins of interest provides a simple means of evaluating their overall similarity in terms of runoff processes, as these parameters integrate the effects of total precipitation as well as long-term storage, which is affected by factors such as soils, geology, or the presence or absence of glaciers or large lakes.

The mean annual daily discharge at the Baker River at Concrete gage under unregulated conditions is 2,664 cfs (Table 3-2). This is equivalent to 8.97 cfs/mi^2. For comparison purposes, average annual flow at the Sauk River near Sauk USGS gage, used later as an analog for the Baker River near Concrete gage, has an average annual daily flow of 4,375 cfs, equivalent to approximately 6.12 cfs/mi^2. The lower discharge per unit area for the Sauk River is due in part to the larger drainage area and in part to the proportionally smaller glaciated area in the Sauk River basin.

Table 3-2. Annual flow statistics for Baker River at Concrete under regulated and unregulated conditions (WY 1960 to 1999).

	Mean Annual Discharge (cfs)		Annual 3-day maximum (cfs)		Annual 7-day low flow (cfs)	
	Average	Standard Deviation [1]	Average	Standard Deviation	Average	Standard Deviation
Regulated	2,659	±424	9,517	±4,230	258	±245
Unregulated	2,664	±428	12,620	±4,938	739	±141

[1] Standard deviation of mean annual daily discharge between years

The mean annual daily discharge for the Baker River at Concrete gage under regulated conditions is 2,659 cfs, virtually the same as under unregulated conditions. The similarity between the two numbers results from the fact that the Baker Project re-regulates flow, but is not a consumptive water use. Thus, over long periods of time (such as a year) there is virtually no difference in the volume of water moving through the system. As subsequent sections will show, the primary effects of the Baker Project are changes in the pattern and timing of runoff.

Baker River Peak Flows

Flood control operations at the Baker Project alter annual peak flows. The range of the annual average 3-day maximum flow at the Baker River near Concrete gage has shifted down, although the annual variability has remained comparable (Table 3-2). The annual average 3-day maximum flow under regulated conditions is approximately 25 percent less than under regulated conditions.

Because of the lack of data on unregulated instantaneous peak flows, no flood frequency analysis has been conducted for the Baker River at Concrete gage. Limited measured data are available to characterize unregulated flows at the Baker Project. The highest instantaneous peak flow measured over the period from 1911 to 1914, under unregulated conditions, is 31,100 cfs. The highest instantaneous peak flow on record at the Baker River near Concrete gage is 36,600 cfs, which occurred in 1963 (Figure 3-2). This flow event occurred after completion of Upper Baker Dam but prior to implementation of the current flood control agreement with the USACE.

Baker River 7-Day Low Flow

The annual average 7-day low flow is frequently used to represent baseflow conditions. Under unregulated conditions, the annual seven-day low flow in the Baker River generally occurs in the late summer or early fall, but may also occur during the winter (Figure 3-3). This bimodal distribution of low flows is typical of glacial fed rivers in the Pacific Northwest, which have relatively high summer baseflows as compared to non-glacially fed rivers. Winter low flows occur during prolonged periods of cold, dry weather. Under regulated conditions, the annual 7-day low flow may occur during any month, but most frequently occurs during spring refill in April, May and June. The increased variability in timing is primarily related to the occurrence of maintenance outages during which outflows from the project may be reduced to the required minimum 80 cfs fish release flow for several consecutive days or weeks.

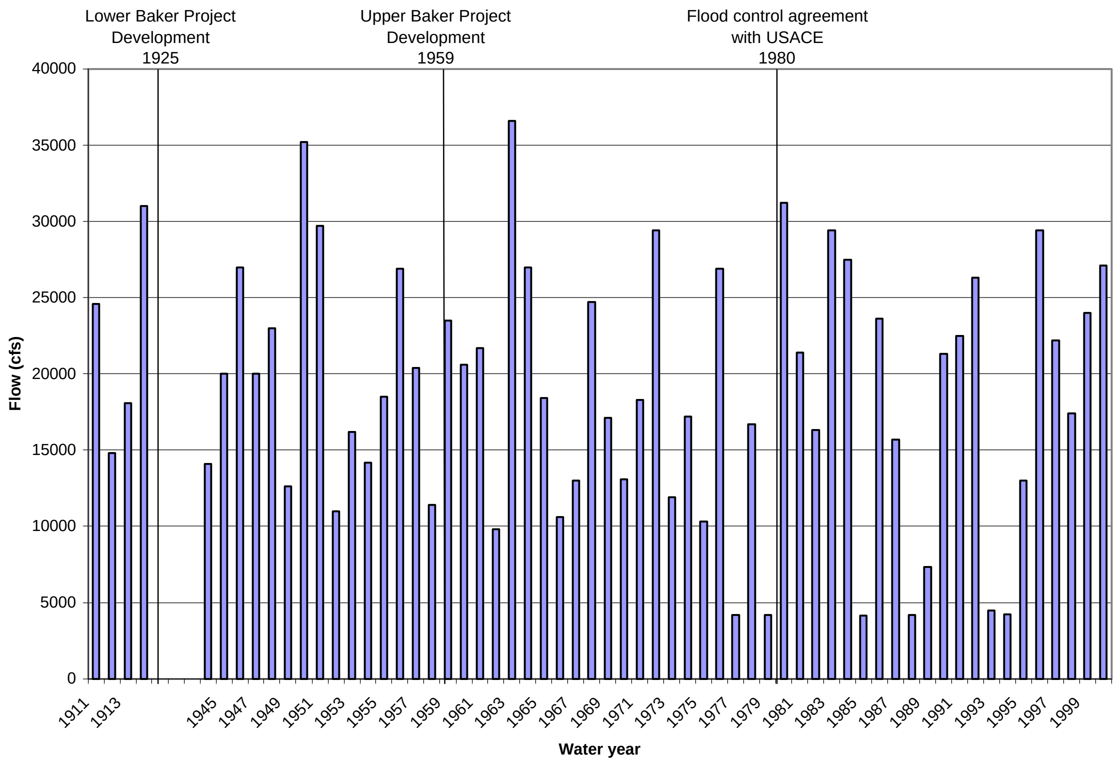


Figure 3-2. Instantaneous peak flows recorded at the Baker River at Concrete gage (USGS Station No. 12193500) from 1911 through 2000 (discontinuous record).

The magnitude of the seven-day low flow at the Baker River near Concrete gage under regulated conditions is substantially less than under unregulated conditions (Table 3-2). The overall range of variability is shifted downward as compared to unregulated conditions. However, interannual variations have increased, as evidenced by the greater standard deviation.

Baker River Flow Duration

The Baker Project has also altered the duration of daily flows of various magnitudes in the Baker River (Figure 3-4). The relatively flat portion of the regulated flow duration curve between 4,200 cfs and 3,200 cfs reflects the typical range of outflows during power generation from Lower Baker Dam. The Lower

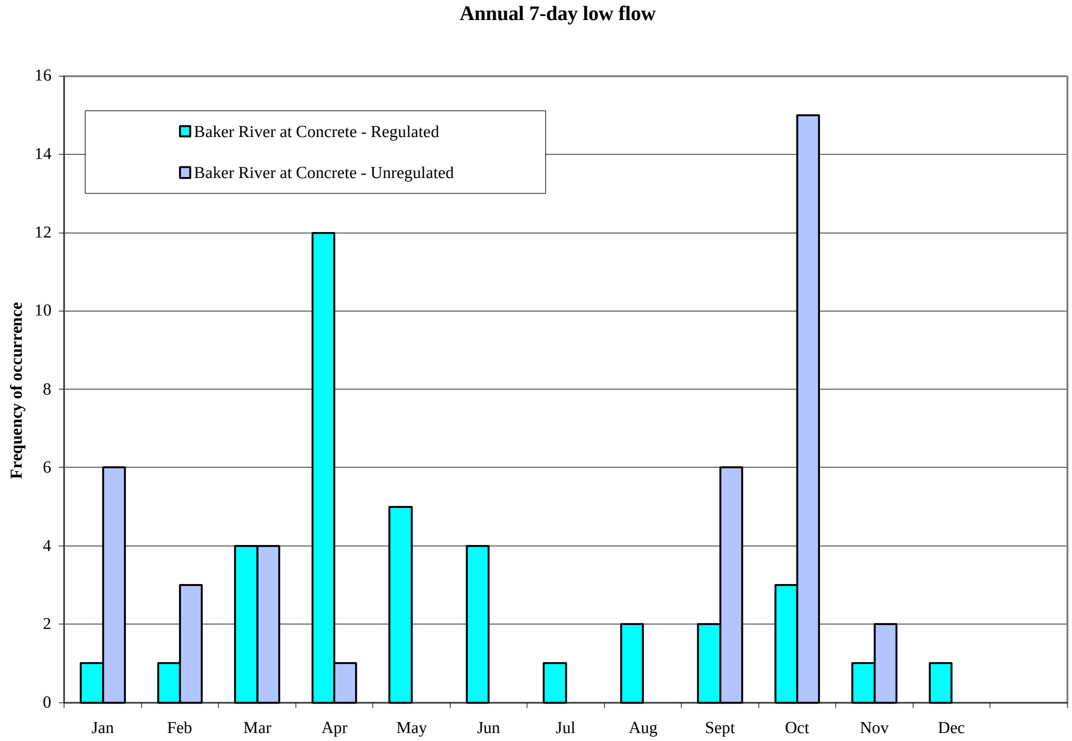


Figure 3-3. **Timing of annual 7-day low flows at the Baker River at Concrete under regulated and unregulated conditions (1959-1999).**

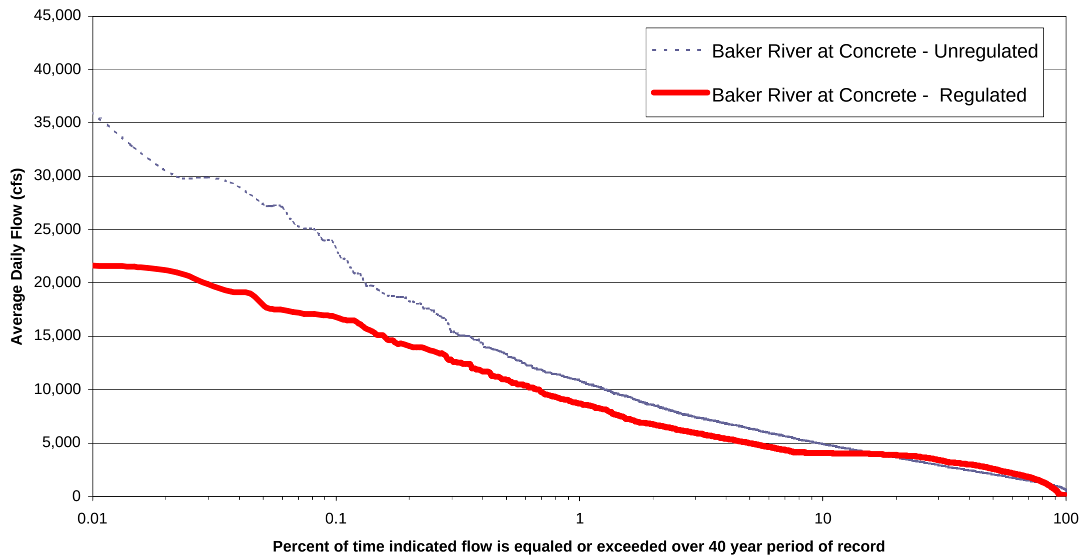


Figure 3-4. **Annual flow duration curves for the Baker River at Concrete gage (1959-1999)**

Baker Development is equipped with a single turbine generator that is currently limited to a maximum generating flow of 4,200 cfs. The single turbine has a capacity of 4,700 cfs, but generation is limited by the transformer capacity. Operation flow releases below about 2,800 cfs are restricted as cavitation becomes pronounced and can potentially damage the turbine. Discharge in the lower Baker River therefore typically fluctuates between 80 cfs and 4,200 cfs in any given day, resulting in a daily average flow that differs substantially from flows that are measured in the river on a 15-minute unit interval basis. The range of typical daily flow fluctuations is discussed further in Section 3.1.3. Although flow releases from Lower Baker dam of between 2,800 cfs and 130 rarely occur, the apparent duration of average daily flows between 1,200 to 2,800 cfs has increased. The duration of flows greater than approximately 3,900 cfs has decreased.

3.1.2 Baker River Seasonal Flow Components

Large rivers in the Skagit basin, such as the Baker River, exhibit annual hydrographs that consist of four primary seasonal flow components: 1) large, short duration fall and winter peaks driven by rain or rain-on-snow events; 2) low, late winter flows interrupted by occasional smaller peak flow events; 3) moderate, long duration spring snowmelt; and 4) summer baseflows. Annual unregulated hydrographs from 1995 provides a typical example of each of these seasonal flow components (Figure 3-5). The period of fall and winter high flows generally extends from November through January. Winter lowflows occur in February and March. Spring snowmelt begins in April and continues through June. Summer baseflows occur from July through October. Parameters used to describe seasonal flow components include: mean monthly flow, seasonal maximum and minimum flow, and the frequency and duration of multi-day flow pulses. Seasonal flow components are evaluated using measured and synthesized average daily flow data.

Baker River Mean Monthly Flows

Operation of the Baker River Developments alters seasonal runoff components, particularly in the fall, winter and spring. The reservoirs are evacuated in the early fall (starting in September) such that the flood control pool elevation of 708 feet MSL is achieved by November 15. The reservoirs have been maintained at or below this pool elevation from November 15 through March 1 (Figure 3-6). Spring refill typically began in March, with the reservoirs reaching full pool elevation around the end of May (Figure 3-6). The reservoirs have generally been held at full pool until September, then gradually drafted. The pattern of reservoir pool fluctuations exhibited during the period used to conduct this analysis (WY 1960 to 1996) may not be indicative of future operations. For instance, proposed interim operations include the fall drawdown of reservoir pool levels one or two months earlier than has generally been practiced under the current license.

The reservoir operational patterns described above alters seasonal flows in the Baker River, primarily during the fall, winter and spring (Figure 3-7). Evacuation of reservoir storage during September and October results in generally higher average daily flows at the Baker River at Concrete gage during those months compared to unregulated conditions (Table 3-3). Flood control operations result in the capture

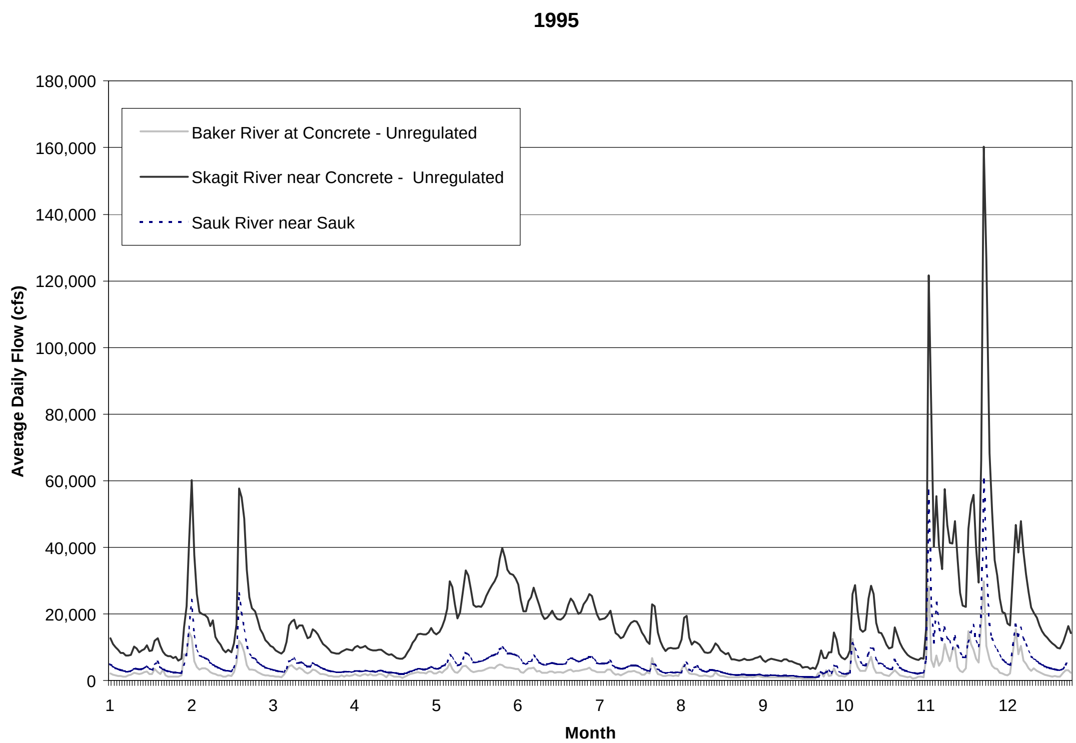
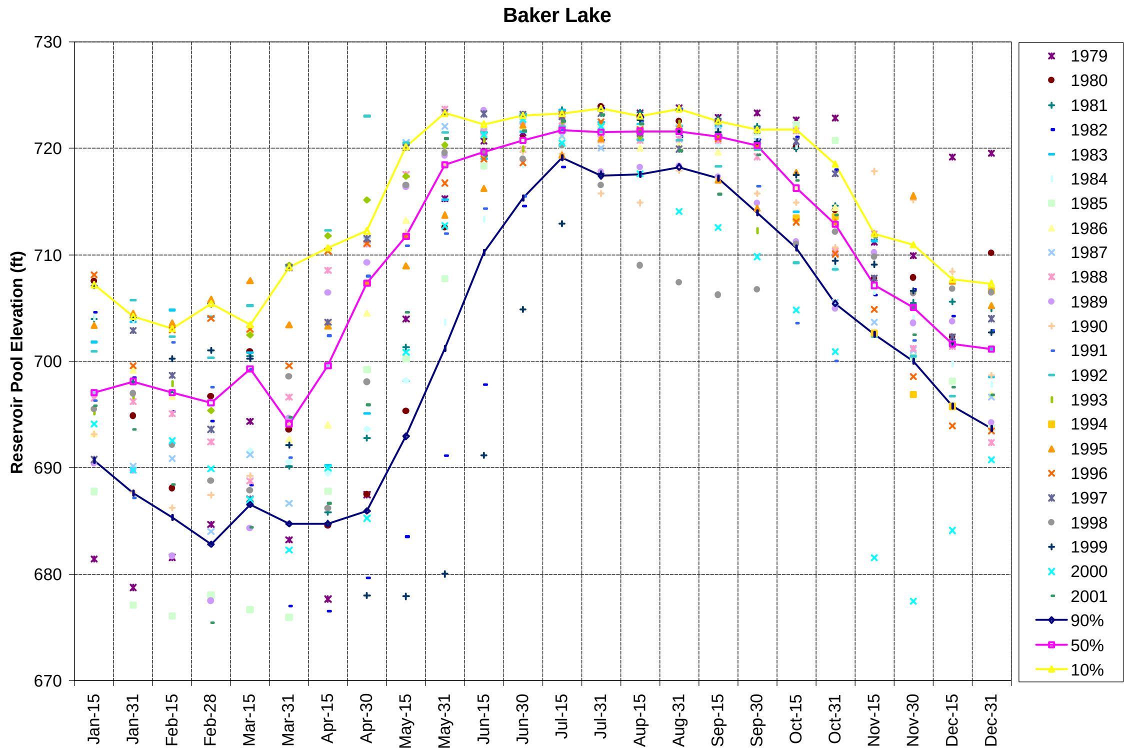


Figure 3-5. Typical unregulated annual hydrograph for the Skagit River and it's major tributaries, illustrating seasonal flow components (Data from USGS, PSE and USACE).

and gradual release of flood flows. For individual flood events, the magnitude of peak is truncated, but the duration of the event is increased, as water is stored within the reservoirs then released following passage of the flood peak (Figure 3-7). This results in higher average daily flows from December through March under regulated conditions (Table 3-3). Reservoir refill reduces flows at the Baker River at Concrete gage from April through June as compared to unregulated conditions. Once the reservoir reaches full pool in July outflows are generally similar to inflows. Small differences in the average daily flows in those months under regulated versus unregulated conditions are primarily the result of the current limited operational range of Lower Baker Dam.

Overall, although operation of the Baker Project alters seasonal runoff patterns, mean daily flows for each month remain within the unregulated range of variability (RVA) throughout most of the year (Figure 3-8). The exception occurs within May, when refill regularly reduces daily flows in the Baker River to the extent that the average daily flow is outside of (less than) the unregulated RVA. The range of flows under regulated conditions is shifted downward as compared to unregulated conditions throughout the spring and early summer. Day-to-day fluctuations are also somewhat greater, as evidenced by the wider range



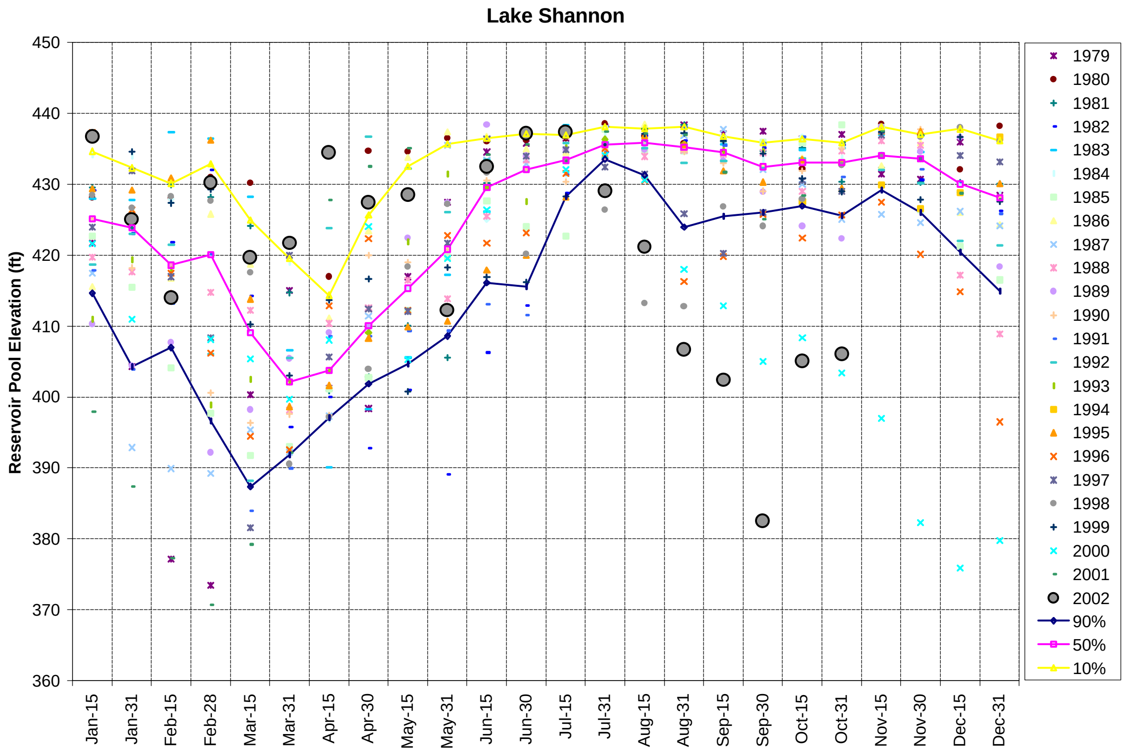


Figure 3-6. Half-monthly reservoir pool elevation and exceedence intervals for Baker Lake and Lake Shannon.

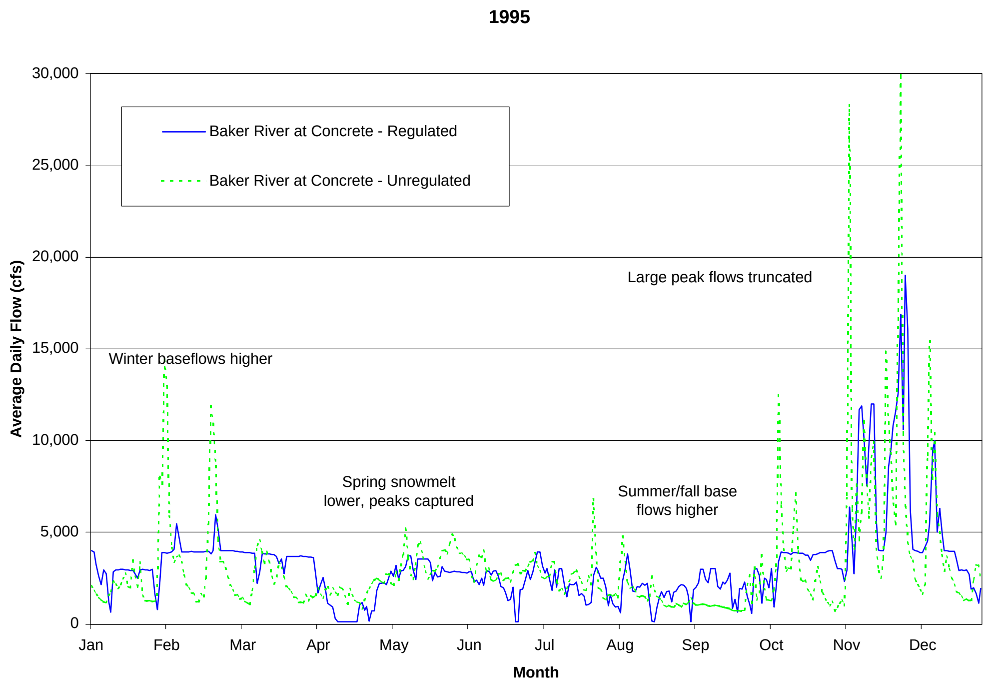


Figure 3-7. Typical annual hydrograph for the Baker River at Concrete gage under regulated and unregulated conditions, illustrating the effect of the Baker Project on seasonal flow components (Data from USGS and PSE).

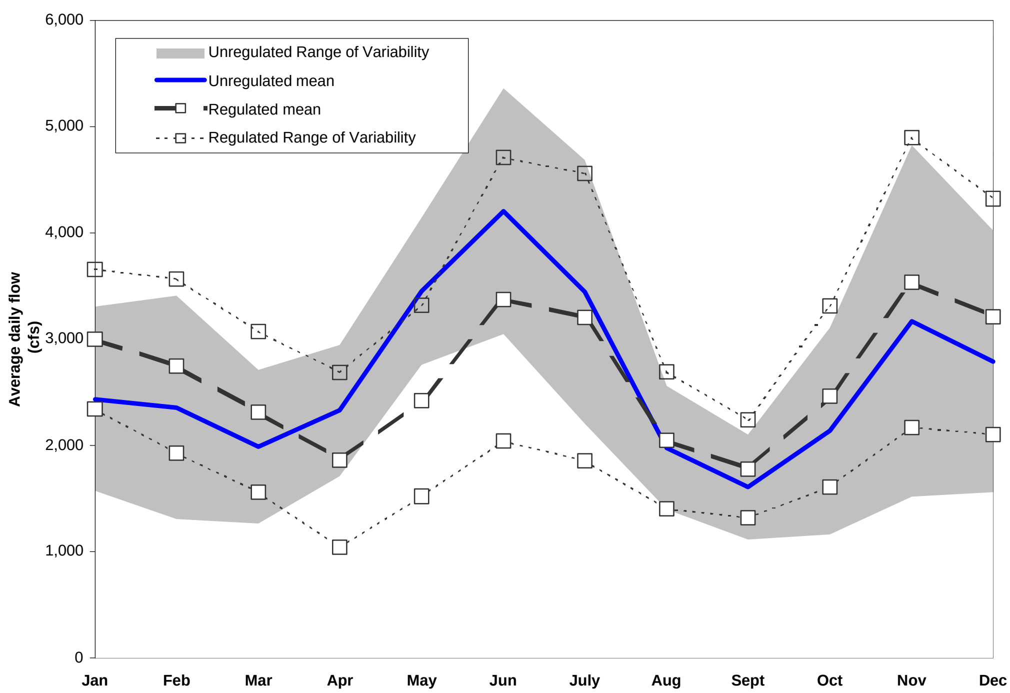


Figure 3-8. Range of variability and mean monthly flows at the Baker River at Concrete gage under regulated and unregulated conditions (1959 to 1999). For the purpose of this analysis, the range of variability (RVA) is defined as the range of flows that fall within one standard deviation of the mean.

(greater standard deviation). The increased flow variability in the spring and summer results from the fact that the limited operational range of Lower Baker Dam (flows between 2,800 to 4,200 cfs when generating and around 80 to 130 cfs when off line) is substantially greater than the unregulated flow variability in those months. The increased variation in average daily flows also reflects occasional one to two day periods when the Lower Baker Development is off-line.

In contrast, flows during the late summer, fall and winter are generally shifted upward and are somewhat less variable as compared to unregulated conditions. The reduced day-to-day variability in fall and winter results from truncation and extension of peak flows.

Table 3-3. Average daily flows by month at the Baker River at Concrete gage under regulated and unregulated conditions (WY 1960-1999) [1].

	Regulated	Unregulated
January	2,995	2,469
February	2,727	2,309
March	2,344	2,012
April	1,889	2,333
May	2,430	3,484
June	3,446	4,255
July	3,251	3,495
August	2,136	2,012
September	1,786	1,618
October	2,498	2,178
November	3,605	3,205
December	3,206	2,793

[1] Note that these values differ from values presented in the Initial Consultation Document (PSE, 2002) as a result of the different period of record used for this analysis.

Baker River Monthly Flow Exceedences

Differences in seasonal flow patterns under regulated and unregulated conditions are also illustrated by comparing exceedence flows on a monthly basis (Tables 3-4a and 3-4b). During the winter, average daily flows greater than 2,500 to 3,000 cfs are relatively rare under unregulated conditions (occur less than 20% percent of the time from January through March). In contrast average daily flows exceed 2,500 cfs from 50 to 70 percent of the time during the same period under regulated conditions. At the same time, average daily flows in the winter are lower than 1,400 cfs almost 30 percent of the time under unregulated

Table 3-4a. Monthly exceedence flows for the Baker River at Concrete gage under regulated conditions (WY 1960-1999).

	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%
Oct	4,229	3,665	3,268	2,932	2,718	2,491	2,252	1,950	1,568	1,151	885
Nov	6,355	5,284	4,388	3,965	3,676	3,343	3,070	2,806	2,488	2,078	1,818
Dec	5,588	4,767	3,870	3,506	3,227	3,034	2,907	2,654	2,287	1,881	1,456
Jan	4,168	3,992	3,694	3,483	3,328	3,064	2,861	2,632	2,328	1,826	1,458
Feb	3,748	3,638	3,412	3,250	3,086	2,848	2,575	2,299	2,029	1,684	1,399
Mar	3,605	3,446	3,194	2,830	2,648	2,448	2,186	1,894	1,516	1,105	917
Apr	3,606	3,228	2,793	2,472	2,085	1,734	1,448	1,187	994	663	508
May	3,849	3,700	3,443	3,038	2,680	2,414	2,170	1,918	1,640	1,104	806
June	4,977	4,686	4,346	4,096	3,751	3,491	3,169	2,894	2,553	2,099	1,749
Jul	5,408	4,730	4,126	3,853	3,573	3,239	2,827	2,498	2,184	1,783	1,422
Aug	3,362	3,092	2,779	2,582	2,348	2,091	1,898	1,725	1,492	1,168	866
Sep	3,321	2,960	2,438	2,166	1,938	1,749	1,541	1,286	962	577	409

Table 3-4b. Monthly exceedence flows for the Baker River at Concrete gage under unregulated conditions (WY 1960-1999).

	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%
Oct	5,229	3,967	2,867	2,204	1,844	1,618	1,425	1,241	1,081	962	857
Nov	7,933	6,104	4,200	3,335	2,764	2,404	2,096	1,832	1,581	1,370	1,238
Dec	6,577	5,117	3,745	2,930	2,398	2,084	1,770	1,554	1,376	1,207	1,116
Jan	6,032	4,364	3,104	2,492	2,083	1,824	1,623	1,405	1,252	1,123	1,043
Feb	5,077	3,894	2,919	2,426	2,135	1,908	1,683	1,456	1,320	1,176	1,108
Mar	4,133	3,176	2,493	2,146	1,867	1,685	1,511	1,383	1,267	1,135	1,072
Apr	4,180	3,576	2,933	2,528	2,272	2,047	1,859	1,723	1,589	1,450	1,352
May	5,864	5,225	4,549	3,952	3,471	3,165	2,880	2,606	2,351	2,076	1,925
June	6,514	5,851	5,153	4,721	4,335	4,040	3,775	3,491	3,211	2,856	2,679
Jul	5,495	4,791	4,178	3,768	3,501	3,287	3,074	2,861	2,620	2,397	2,244
Aug	3,008	2,719	2,361	2,195	2,048	1,910	1,770	1,659	1,550	1,424	1,350
Sep	3,121	2,541	1,937	1,618	1,447	1,337	1,250	1,165	1,076	981	923

conditions. Average daily flows exceed 1,400 cfs 95 percent of the time during January and February, and 80 percent of the time in March under regulated conditions.

In April and May, average daily flows exceed 1,400 cfs more than 90 to 95 percent of the time under unregulated conditions. Under regulated conditions, average daily flows of that magnitude occur only 60 to 80 percent of the time. During June, the 40 percent exceedence flow under both regulated and unregulated conditions remains around 4,000 cfs. However, average daily flows greater than 5,000 cfs more than occur 20 percent of the time under unregulated conditions, but less than 5 percent of the time under regulated conditions. During the late summer, the range of variability in average daily flows has increased under regulated conditions, illustrated by the fact that the 90 and 95 percent exceedence flows are higher, while the 5, 10 and 20 percent exceedence flows are lower. This results primarily from operational constraints on the amount of flow that can be released at the Lower Baker Development. During the fall, the 90 and 95 percent exceedence flows are higher under regulated conditions, but the 5 and 10 percent exceedence flows are substantially lower, reflecting an overall reduction in the variability in average daily flows resulting from flow regulation.

Baker River Frequency of Freshets

Abrupt, short duration increases in flow often provide important cues for movement of biological organisms. For example, results of outmigration studies in the Green River have shown that a sharp increase in flow can stimulate increased downstream movement of smolts (Dilley and Wunderlich, 1992, 1993). In the upper Snake River, Idaho, researchers found that a two-fold increase in flow increased the migration rate by eight to 12-fold for hatchery chinook, 3.5- to 4.6-fold for wild chinook salmon, 1.6- to 2.1-fold for hatchery steelhead trout, and 2.4-fold for wild steelhead (Buettner and Brimmer, 1996). Adult fish may delay upstream migration or spawning until flows begin to rise in the fall (Neave, 1943; Sumner, 1953). Flow fluctuations may also influence insect drift; Brusven (1978) studied drift rates and standing crop relationships above and below Dworshak Dam and observed that insect drift increases in response to daily flow fluctuations.

The timing and frequency of rapid, substantial flow increases (freshets) that extend over multi-day periods were assessed by month, using measured and synthesized average daily flow data[1]. Freshets are defined as average daily flow increases of more than 50 percent relative to the mean flow over the preceding three-day period. For the Baker River under regulated conditions, freshets were defined as periods of spill (i.e., flows in excess of the 4,200 cfs generating capacity). Regular daily flow fluctuations resulting from load following are not considered equivalent to irregular, multi-day freshets and are discussed further in Section 3.1.4.

[1] Hourly flow changes and the rise and fall rate of short duration events are considered hourly flow components, and are discussed further in Section 3.1.4.

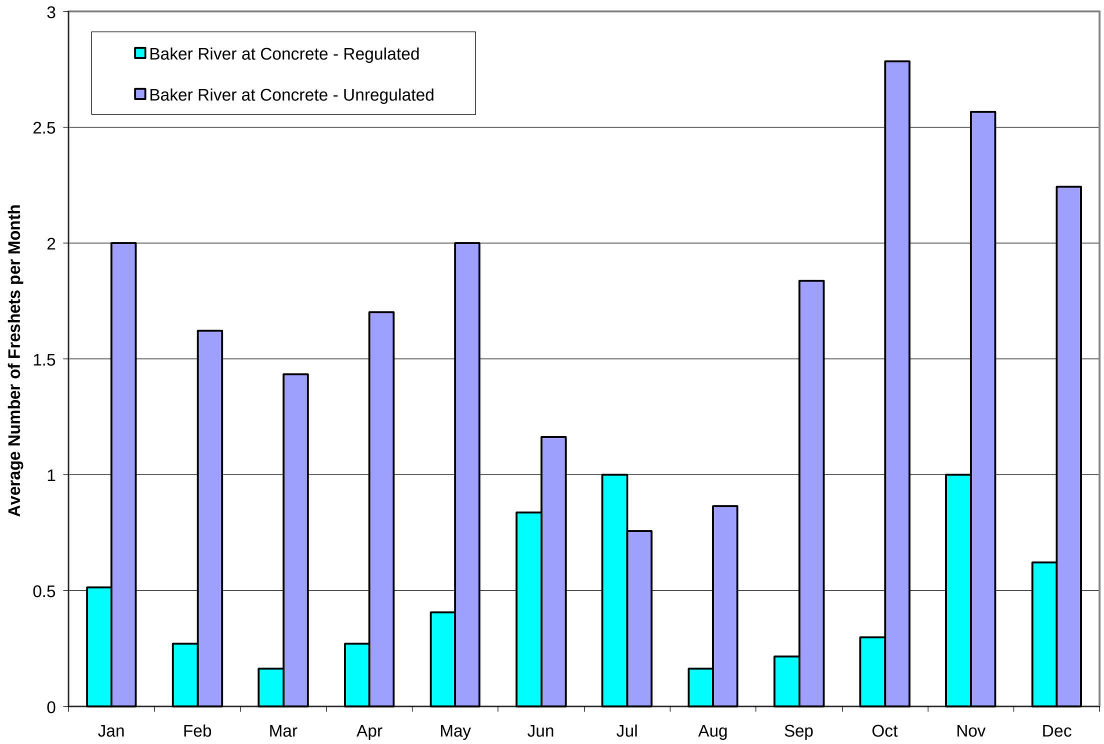


Figure 3-9. Monthly frequency of freshets at the Baker River at Concrete gage under regulated and unregulated flow conditions for the period from 1959 through 1999 (data from USGS and PSE).

The average number of freshets at the Baker River at Concrete gage under unregulated conditions ranges from 0.5 to 1 per month (Figure 3-9). Precipitation is markedly seasonal, with the heaviest precipitation occurring from November through May. The distribution of freshets under unregulated conditions reflects these climatic patterns. Freshets are most common in the spring and fall; at least one freshet occurred in each month over ninety percent of the time over the period from WY 1960 through 1999. In the fall, periodic intense rain events associated with frontal weather systems result in extreme, but often short duration flood events. Later in the winter, the majority of precipitation falling in the Baker basin is snow. Precipitation falling as snow is stored in a seasonal snowpack rather than immediately contributing to runoff, thus freshets are less common. In the spring, freshets may result from both rain events and snowmelt. Freshets are uncommon during June, July and August; no freshets occurred in approximately one-third of the years from WY 1960 through 1999.

Under regulated conditions, freshets caused by spill events are most common in the early summer and fall, and less common in the winter and spring (Figure 3-9). Spill events were most frequent in the period from 1960 through 1970. From 1960 to 1980, at least one spill event per month occurred in the fall (October through December) in seven out of ten years. Spill events were also common in May and June (at least one spill event per month in seven of the ten years). Spill events were less common in the early spring and late summer, but still occurred monthly in 3 out of ten years.

Since the flood control agreement with the USACE was signed in 1980, spill events have been less common. Spill events occurred only about every other year in November and December. During the rest of the year, at least one spill event per month occurred only 15 to 20 percent of the time.

Baker River 2-Day Low Flow

Low flow events may also influence aquatic organisms. Researchers have observed that incubating salmon eggs exposed to short-term dewatering (< 48-hour) may survive provided the egg pockets do not freeze, but salmon alevins (pre-emergent fry) in subsurface redd pockets suffer substantial mortality if dewatered for only minutes (Becker et al., 1983). The seasonal duration of very low flows is also an important factor in determining habitat availability.

The magnitude of the 2-day low flow for each month was estimated for regulated and unregulated conditions. Under unregulated conditions the monthly two-day low flow is highest in May, June and July and lowest in September and October (Figure 3-10). In the spring and summer, the median monthly two-day low flow is around 2,000 to 2,500 cfs. Monthly two-day low flows under unregulated conditions are relatively consistent from year to year; the 25th and 75th percentiles fall within 25 to 50 percent of the median.

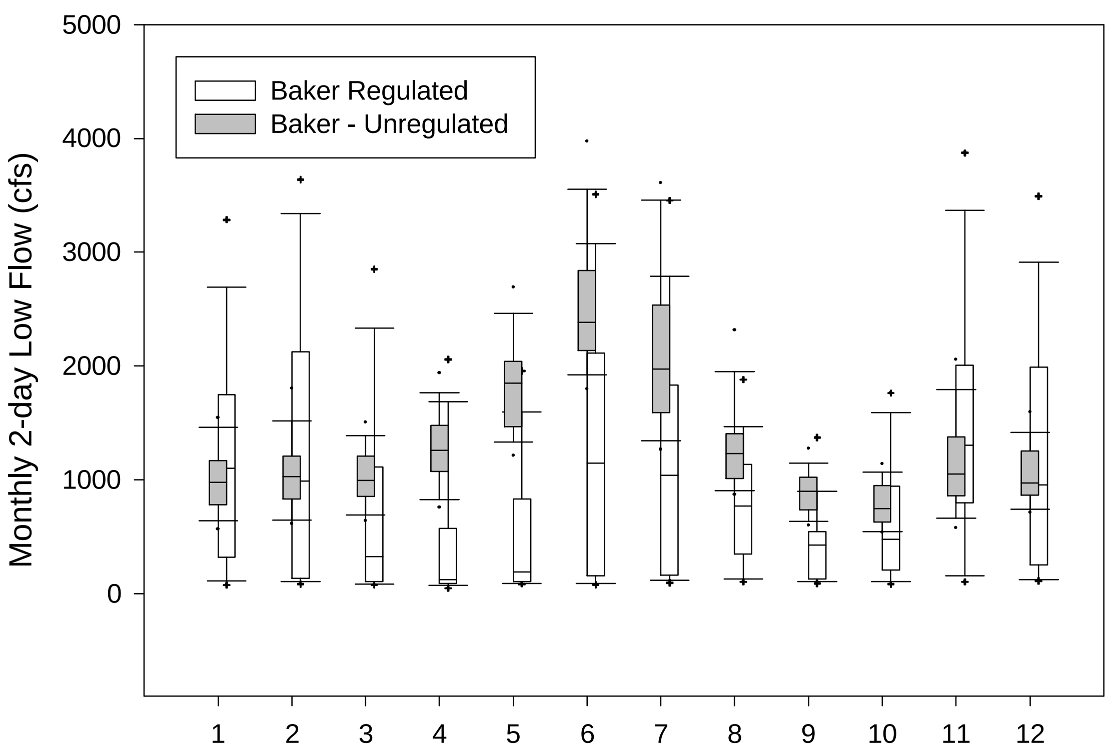


Figure 3-10. Monthly two-day low flow at the Baker River at Concrete gage for the period from 1959 to 1999. Boxes represent median and 25th to 75th percentile. Whiskers represent 10th and 90th percentiles. Points represent 5th and 95th percentiles.

Under regulated conditions, monthly two-day low flows are lowest in April and September, and are highest in the summer (June and July) and fall (November). The range of monthly two-day low flows from year to year is high; the 25th and 75th percentiles differ from the median by 100 to 400 percent (Figure 3-10). In all months, the lowest two-day low flow recorded is around 120 cfs, equivalent to the minimum flow release of 80 cfs plus leakage from the dam. The median monthly two-day low flow under regulated conditions ranges from 120 cfs in April to over 1,300 cfs in November.

Baker River Low Pulses

The duration of low flow events was examined by developing non-exceedence flow tables. Seasonal variability of low flows is described using monthly durations for average daily flows between 100 and 4,000 cfs for the Baker River. The greatest number of consecutive and total days per month that average daily flows were below given flow values for the period of WY 1960 through 1999 under regulated conditions are presented in the lower portion of Table 3-5. The monthly low-flow durations that occurred under normal conditions are represented by the median monthly non-exceedence durations as presented in the upper portion of Table 3-5.

Under regulated conditions, flows less than 250 cfs normally occur for periods of 1 to 2 days during the spring (March through May) and late summer (September). Flows less than 1,000 cfs typically occur in most months, but generally only for periods of 1 to 3 consecutive days. Extreme low flows of a duration longer than 1 to 2 days usually result from maintenance outages or reservoir refill during the spring. During such events flows are typically less than 100 cfs for 2 to 4 days, but may remain low for almost 2 weeks.

Under unregulated conditions, average daily flows are never less than 250 cfs even in the driest years (Table 3-6). Extended low flows may occur in winter or late summer, when flows are typically below 1,250 cfs for periods of five or more consecutive days. During the fall rainy period (November and December) flows are rarely below 500 cfs and then generally for only a single day. Typical low flows in November and December are greater than 1,000 cfs. Baseflows tend to be highest during snowmelt (May through July) when flows are never less than 750 cfs and typically do not fall below 1,500 cfs.

3.1.3 Baker River Daily Flow Components

As noted previously, annual and seasonal variations in flow were analyzed using measured and synthesized average daily flows from the period of WY 1960 through 1999. However, daily flow fluctuations also have important implications for the productivity and quality of aquatic habitats. Daily flow fluctuations were quantified using 15-minute or one-hour unit value data, depending on the minimum time-step available for each gage site of interest. Daily flow components analyzed for this study include the range of flows that occur on a daily basis throughout a typical flow year. The period of record used for this analysis includes the 1998 calendar year. Streamflows in 1998 were near or slightly lower than average overall; on a seasonal basis flows were normal through the winter months (January

Table 3-5. Total and consecutive number of days per month that flow was below given flow values in the Baker River at Concrete for the period from WY 1960 through 1999 under regulated conditions. Numbers in bold italics represent consecutive days.

Median number of days per month that flow was below given flow value

Flow(cfs)	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
100	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***
250	0	***0***	0	***0***	1	***1***	4	***2***	1	***1***	0	***0***	0	***0***	0	***0***	2	***1***	0	***0***	0	***0***	0	***0***
500	0	***0***	0	***0***	2	***1***	5	***2***	2	***2***	0	***0***	0	***0***	0	***0***	2	***1***	1	***1***	0	***0***	0	***0***
750	0	***0***	0	***0***	3	***2***	7	***3***	3	***2***	0	***0***	0	***0***	2	***1***	4	***2***	2	***2***	0	***0***	1	***1***
1,000	1	***1***	1	***1***	5	***3***	9	***5***	4	***2***	0	***0***	1	***1***	3	***1***	6	***3***	4	***2***	0	***0***	2	***1***
1,250	1	***1***	2	***2***	6	***3***	10	***6***	4	***4***	0	***0***	3	***1***	4	***2***	9	***4***	5	***3***	0	***0***	2	***1***
1,500	1	***1***	3	***2***	7	***4***	11	***7***	6	***4***	1	***1***	4	***2***	7	***3***	12	***5***	9	***4***	1	***1***	3	***2***
2,000	4	***3***	5	***3***	11	***6***	17	***12***	9	***5***	3	***2***	7	***3***	17	***10***	19	***9***	12	***6***	4	***2***	4	***3***
2,500	8	***4***	8	***5***	15	***9***	19	***15***	14	***8***	4	***4***	13	***6***	25	***14***	25	***17***	19	***10***	8	***4***	11	***5***
3,000	13	***8***	15	***11***	22	***14***	25	***18***	19	***11***	9	***6***	16	***9***	29	***21***	27	***20***	23	***12***	12	***6***	16	***7***
3,500	17	***12***	19	***13***	26	***22***	28	***26***	22	***16***	12	***7***	20	***13***	31	***31***	29	***28***	26	***22***	18	***11***	19	***11***
4,000	30	***25***	28	***28***	31	***31***	30	***30***	31	***31***	21	***14***	25	***17***	31	***31***	30	***30***	30	***29***	21	***14***	24	***18***

Maximum number of days per month that flow was below given flow value

Flow(cfs)	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
100	4	***3***	6	***6***	11	***9***	16	***13***	11	***11***	9	***6***	5	***4***	5	***2***	8	***4***	3	***2***	4	***2***	4	***2***
250	7	***5***	6	***6***	22	***22***	28	***28***	15	***13***	22	***14***	7	***7***	17	***14***	8	***5***	8	***5***	5	***2***	6	***5***
500	8	***5***	8	***6***	22	***22***	28	***28***	16	***13***	23	***14***	12	***9***	17	***14***	12	***6***	8	***5***	6	***2***	6	***5***
750	10	***5***	8	***8***	22	***22***	28	***28***	18	***13***	24	***24***	13	***9***	17	***14***	12	***7***	10	***5***	6	***5***	9	***6***
1,000	13	***7***	9	***9***	22	***22***	28	***28***	19	***13***	24	***24***	14	***9***	18	***14***	15	***7***	14	***7***	10	***7***	11	***8***
1,250	16	***10***	12	***9***	24	***22***	28	***28***	23	***16***	24	***24***	15	***12***	18	***14***	20	***11***	15	***9***	12	***11***	12	***8***
1,500	16	***10***	14	***11***	25	***23***	28	***28***	25	***16***	24	***24***	15	***12***	24	***15***	26	***17***	18	***9***	12	***11***	16	***11***
2,000	19	***15***	23	***21***	28	***23***	30	***30***	29	***27***	28	***25***	19	***18***	31	***31***	30	***30***	29	***19***	17	***16***	25	***13***
2,500	30	***26***	27	***24***	30	***27***	30	***30***	31	***31***	29	***25***	25	***22***	31	***31***	30	***30***	29	***27***	28	***18***	29	***21***
3,000	31	***31***	28	***28***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***	31	***31***	30	***30***	31	***31***	30	***30***	30	***29***
3,500	31	***31***	29	***29***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***
4,000	31	***31***	29	***29***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***

Table 3-6. Total and consecutive number of days per month that flow was below given flow values in the Baker River at Concrete for the period from WY 1960 through 1999 under unregulated conditions. Numbers in bold italics represent consecutive days.

Median number of days per month that flow was below given flow value

Flow(cfs)	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
100	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***
250	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***
500	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***
750	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	1	***1***	0	***0***	0	***0***
1,000	2	***1***	0	***0***	1	***1***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	3	***2***	6	***4***	1	***1***	1	***1***
1,250	7	***6***	6	***5***	7	***5***	1	***1***	0	***0***	0	***0***	0	***0***	2	***1***	11	***7***	11	***6***	3	***2***	5	***3***
1,500	12	***8***	10	***8***	14	***8***	6	***4***	0	***0***	0	***0***	0	***0***	8	***4***	19	***11***	15	***10***	6	***5***	10	***7***
2,000	19	***12***	16	***11***	21	***14***	15	***10***	3	***2***	0	***0***	2	***1***	21	***13***	25	***17***	20	***12***	12	***7***	15	***11***
2,500	23	***14***	22	***14***	25	***19***	20	***14***	8	***5***	2	***2***	8	***6***	28	***20***	27	***21***	24	***13***	16	***9***	20	***13***
3,000	25	***16***	24	***16***	28	***23***	24	***18***	14	***10***	6	***4***	15	***11***	29	***24***	28	***22***	27	***18***	20	***12***	23	***14***
3,500	27	***18***	26	***17***	30	***25***	25	***20***	19	***11***	11	***6***	23	***14***	31	***31***	29	***24***	27	***21***	23	***14***	24	***17***
4,000	28	***18***	26	***22***	30	***29***	27	***22***	22	***14***	17	***8***	26	***18***	31	***31***	29	***27***	28	***22***	25	***15***	26	***17***

Maximum number of days per month that flow was below given flow value

Flow(cfs)	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
100	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***
250	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***
500	6	***4***	4	***4***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	6	***3***	2	***1***	0	***0***
750	21	***8***	16	***12***	7	***4***	2	***2***	0	***0***	0	***0***	0	***0***	0	***0***	11	***8***	22	***22***	8	***8***	7	***7***
1,000	30	***19***	25	***16***	22	***18***	9	***8***	0	***0***	0	***0***	1	***1***	14	***14***	21	***20***	27	***27***	23	***14***	22	***15***
1,250	30	***19***	27	***17***	30	***30***	19	***10***	1	***1***	0	***0***	1	***1***	22	***17***	28	***23***	30	***30***	26	***26***	30	***25***
1,500	31	***31***	27	***23***	30	***30***	30	***30***	8	***8***	1	***1***	8	***8***	28	***23***	30	***30***	30	***30***	30	***30***	31	***31***
2,000	31	***31***	28	***28***	31	***31***	30	***30***	16	***12***	7	***3***	23	***20***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***
2,500	31	***31***	28	***28***	31	***31***	30	***30***	21	***19***	20	***13***	29	***25***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***
3,000	31	***31***	29	***29***	31	***31***	30	***30***	26	***22***	26	***22***	30	***26***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***
3,500	31	***31***	29	***29***	31	***31***	30	***30***	28	***27***	27	***23***	31	***31***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***
4,000	31	***31***	29	***29***	31	***31***	30	***30***	30	***27***	29	***28***	31	***31***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***

through March), slightly lower than normal in April and May, and normal from June through September (Wiggins et al., 1998). In the fall of 1998 flows were slightly higher than normal (Wiggins et al., 1999)

The Baker Project is operated on a load following basis. Demand varies from day to day as well as seasonally, thus operations are variable. As noted previously, the current maximum generating flow at Lower Baker Dam is 4,200 cfs and the minimum machine flow is 3,200 cfs. A flow of 80 cfs is continually released below Lower Baker Dam. Leakage through Lower Baker Dam may contribute an additional 50 to 60 cfs depending on the reservoir elevation.

Daily flow variations at the Baker River near Concrete gage in 1998 are depicted in Figure 3-11. Four distinct operational patterns can be observed in Figure 3-11: load following, continuous generation, outages and spill. During load following operations, flows may fluctuate on an hourly basis several times per day. As a result, flows at the Baker River at Concrete gage within any given day typically range from a maximum of 3,000 to 4,000 cfs to a minimum of 130 cfs. The average daily flow during load following operations typically falls between those extremes (Figure 3-11); thus, average daily flows are a poor representation of lower Baker River flows during periods of load-following operations.

During the winter and early summer following reservoir refill, continuous generation at the Lower Baker Development for several consecutive days is not uncommon. At such times flows are consistently about 4,000 cfs and the mean, minimum and maximum flows are virtually the same. A similar situation occurs when the Lower Baker Development is offline, except that the mean, minimum and maximum flows are all approximately 80 to 130 cfs.

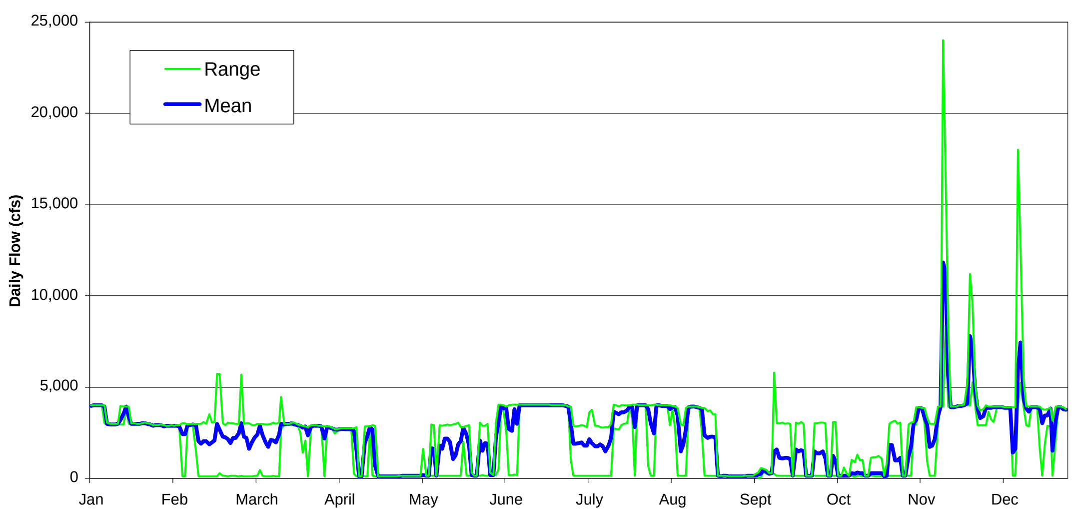


Figure 3-11. Daily mean flow and flow range under regulated conditions at the Baker River at Concrete gage in 1998.

When Lake Shannon is full and inflows to the reservoir exceed the maximum machine flow at the Lower Baker powerhouse, water may be spilled over Lower Baker Dam. Such situations are most common in the fall and winter, as depicted in Figure 3-11; however, spill events may also occur as a result of summer rainstorms that occur when the reservoirs are maintained at or near full-pool to promote recreation. Flow levels during spill events may vary widely over a period of hours, and thus daily average flows may differ substantially from the daily maximum and minimum flow (Figure 3-11). The average daily variation when flows are not held constant by the Lower Baker Development is ±75 percent of the average daily flow.

Flow variations in large unregulated rivers in the northern Cascades exhibit a relatively consistent pattern of daily flow variation (Figure 3-12). As noted previously, unregulated unit-value flow data for the Baker River are not available, thus unregulated flow variations observed at the Sauk River near Sauk gage are used as an analog. The average daily flow range of the Sauk River at the Sauk River near Sauk gage in 1998 was about ± 10 percent of the average daily flow. The largest daily flow fluctuations observed at the Sauk River near Sauk gage occur during floods, when daily flow fluctuations as high as ± 90 percent of the average daily flow were recorded. The Sauk River is likely somewhat "flashier" (i.e., flows change more rapidly in response to rain events) than the Baker River because the drainage basin does not contain a large lake and floodplains are generally narrow. However, the area draining to the Sauk River near Sauk gage is larger than the Baker drainage basin (715 square miles compared to 297 square miles), which would tend to moderate the "flashiness" of the Sauk River relative to the Baker River.

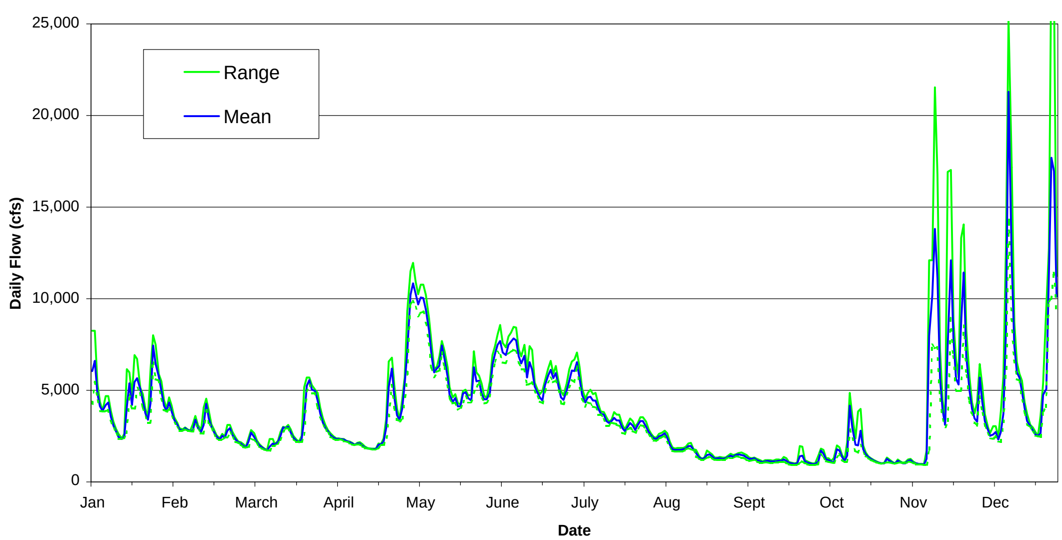


Figure 3-12. Daily mean flow and flow range in the unregulated Sauk River at the Sauk River near Sauk gage in 1998.

3.1.4. Baker River Hourly Flow Components

Hourly flow components analyzed for this study include the magnitude, timing, and frequency of hourly changes in flow. Hourly flow components were quantified using 15-minute or one-hour unit value data, depending on the time step available for each gage site of interest. Unregulated flow data synthesized on a daily time-step (such as those generated for the Baker river at Concrete gage), cannot be used to assess hourly flow changes, thus data from a gage site on the nearby Sauk River were used as an unregulated analog to the regulated Baker River at Concrete and Skagit River at Concrete gages.

Hourly flows at the Baker River at Concrete gage are almost entirely governed by flow regulation, except during periods of spill. Under regulated conditions, hourly fluctuations in flow occur primarily as a result of load following operations. Demand for power generally peaks during the morning and early evening and is lowest during the night (Figure 3-13). The Baker Project typically ramps up between 6:00 AM. and 8:00 PM. Downramping occurs between 8:00 PM and 10:00 PM. The Baker Project typically operates once or twice a day, usually during mornings (i.e., 6:00 AM to 10:00 AM) and evenings (i.e., 5:00 PM to 8:00 PM). These periods of operation vary daily, weekly and seasonally in response to power demands and power value.

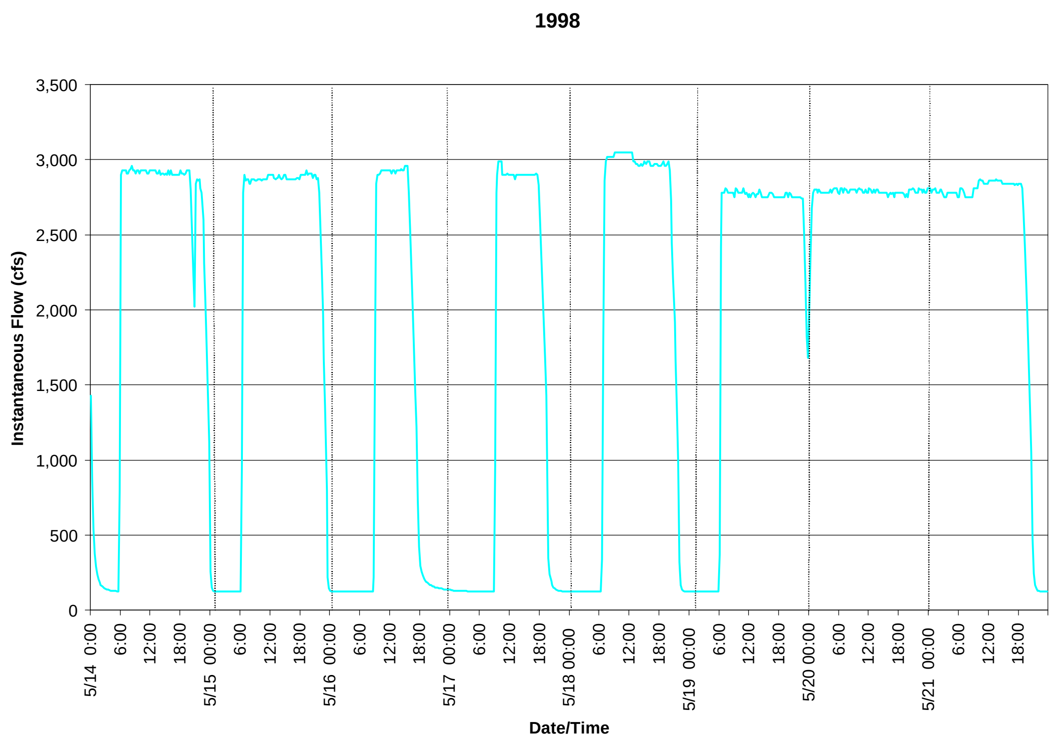


Figure 3-13. Example of the effect of daily load following operations at the Lower Baker Development on flow at the Baker River at Concrete gage.

An analysis of the frequency of downramping events that occurred over the period from 1996 through 1999 reveals that the average number of ramping events that occurred at the Baker River at Concrete gage as a result of Lower Baker Development operations ranged from 6 to 17 per month (Figure 3-14). Ramping events were most common in September and October and least common in June. The average annual frequency of ramping events was relatively consistent between months; however, the number of ramping events per month in each year varied widely.

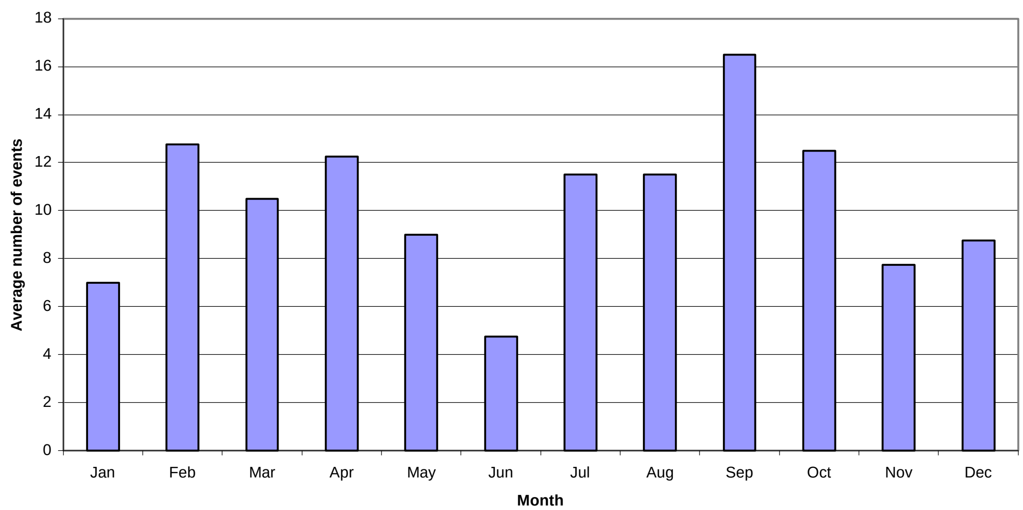


Figure 3-14. Average number of ramping events per month at the Baker River at Concrete gage in 1998.

As noted previously, power generation from Lower Baker Dam typically results in the release of flows between 2,800 to 4,100 cfs. The stage change associated with a downramp event from 4,100 cfs to 130 cfs at the Baker River at Concrete gage is approximately 3.3 feet (Figure 3-15). The average duration of fifteen typical downramp events in 1998 was 3.5 hours, with an average ramp rate of 10.8 inches/hour at the Baker River at Concrete gage. The maximum stage change observed over any 15-minute interval was 12 inches.

Regular and pronounced diurnal fluctuations in flow also occur in unregulated rivers. Diurnal flow fluctuations in unregulated river systems occur primarily as a result of snowmelt in the late spring and early summer. Diurnal flow fluctuations at the Sauk River near Sauk gage are generally first observed in April, and continue through September (Figure 3-16). Regular, pronounced daily flow fluctuations were not observed at the Sauk River near Sauk gage throughout the remainder of the year (Figure 3-16). Hourly flows were observed to change rapidly during freshet events, but these events do not occur at regular intervals and typically extend for more than 24 hours.

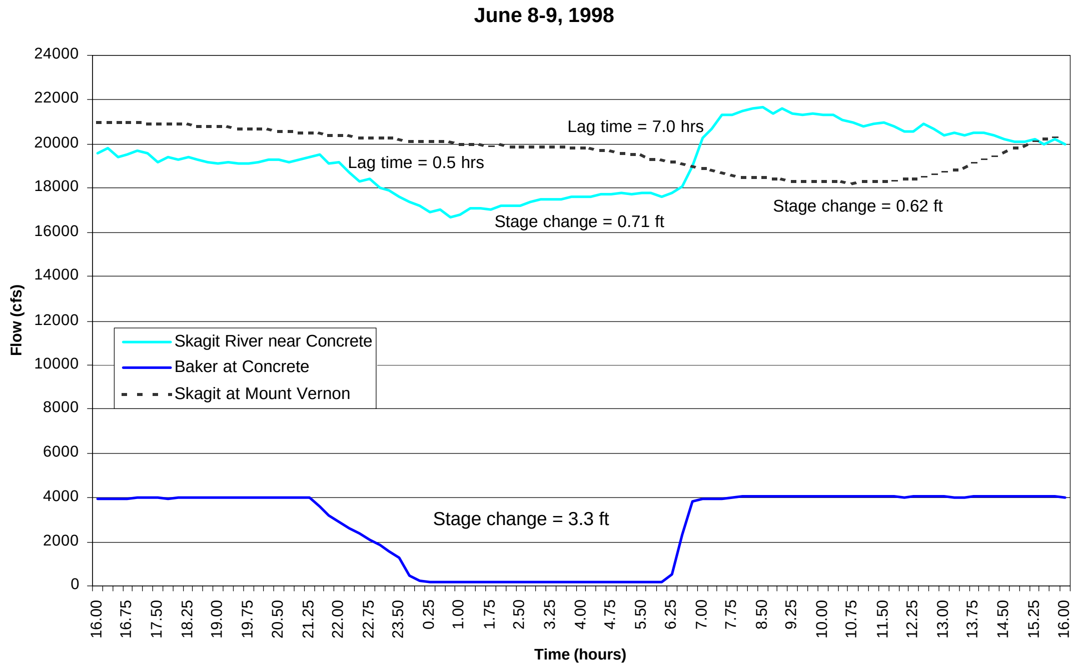


Figure 3-15. Example of attenuation and lag time to the Skagit River near Concrete gage and Skagit River near Mount Vernon gage associated with a typical load following event at the Lower Baker Development on June 9 1998

Diurnal flow fluctuations produced by snowmelt can result in flow changes of more than 2,000 cfs in the Sauk, which correspond to a stage change of about 6 to 8 inches at the Sauk River near Sauk gage, depending on the flow level (Table 3-7). Average diurnal flow fluctuations are equivalent to approximately 5 to 15 percent of the background flow rate. Diurnal fluctuations caused by snowmelt occur over a cycle of approximately 12-hours, thus the maximum rate of change is generally less than one inch per hour. On a daily basis, flows at the Sauk River near Sauk gage peak in the early morning and reach their lowest level at around 6:00 PM.

Table 3-7. Characteristics of daily snowmelt fluctuations at the Sauk River near Sauk gage from May through August (1994-2000).

	Average Daily Change in Q (cfs)	Average Daily Change in Stage (in)	Maximum Daily Change in Q (cfs)	Maximum Daily Change in Stage (in)	Maximum Hourly Stage Change (in/hr)	Start Time PDT (mode)
May	1,085	3.4	2,047	6.4	0.5	7:00 AM
June	1,028	3.7	2,873	8.5	0.7	6:00 AM
July	762	3.0	2,253	6.2	0.6	6:00 AM
August	488	2.3	1,820	5.6	0.3	7:00 AM

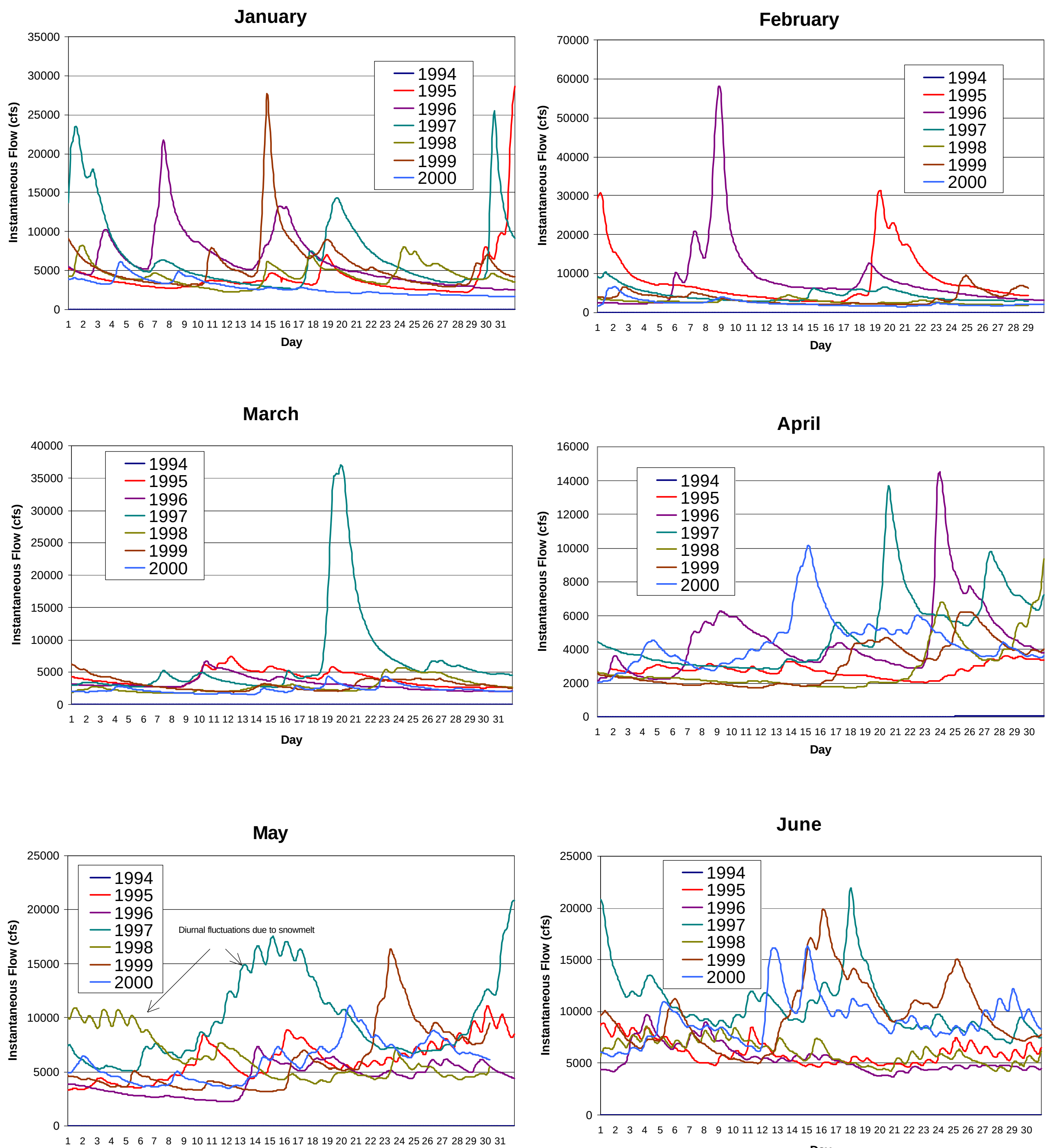


Figure 3-16. Daily flow fluctuations by month at the Sauk River near Sauk gage for the period from 1995 through 2000.

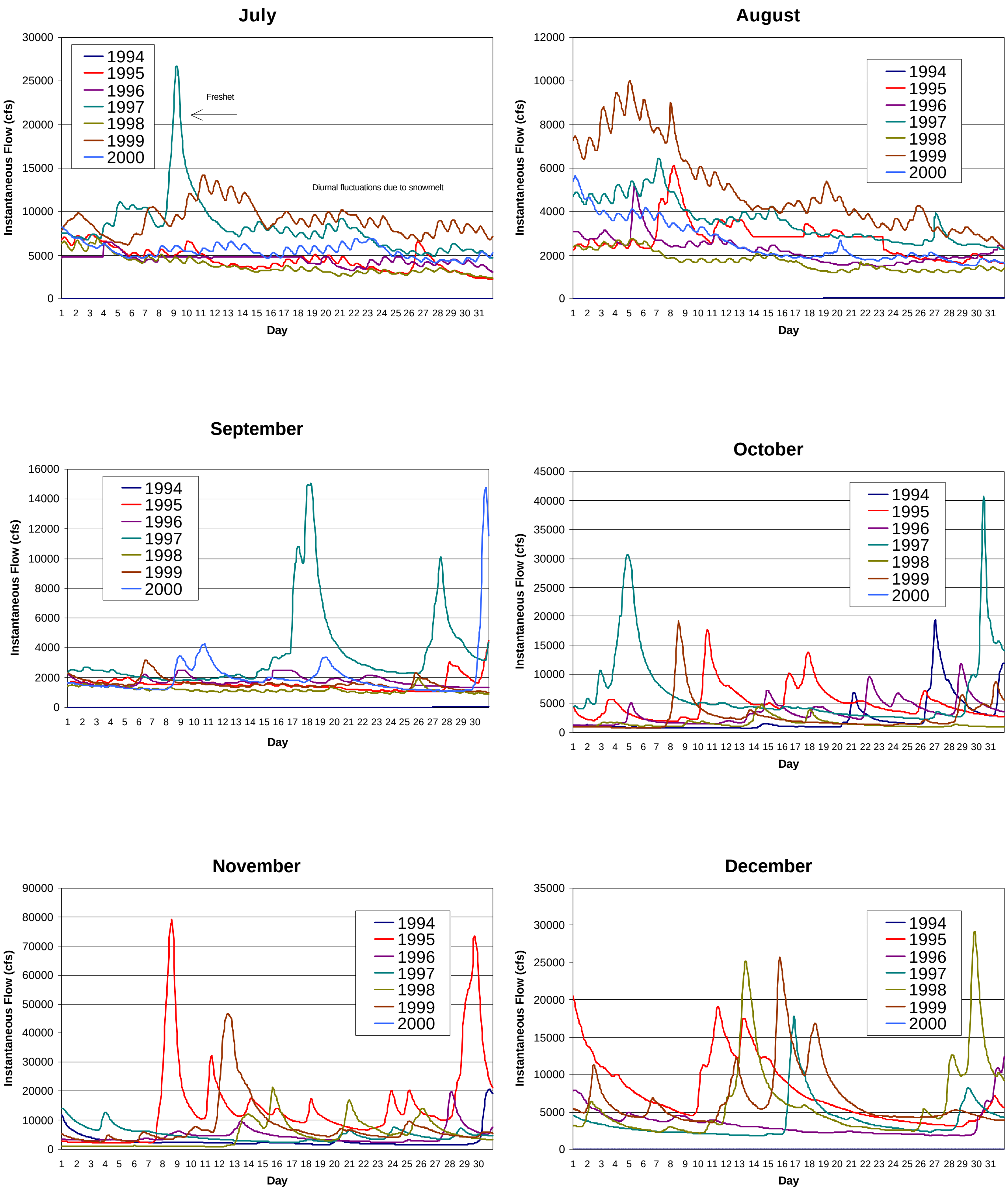


Figure 3-16. (continued) Daily flow fluctuations by month at the Sauk River near Sauk gage for the period from 1995 through 2000

Multi-day freshets also result in rapid increases and decreases in flows throughout the year. The rate of stage decline associated with freshet events is generally larger than that observed during spring snowmelt. The maximum hourly rate of change observed at the Sauk River near Sauk gage over the period of 1995 to 2000 was greater than 10 inches per hour. However, stage declines in excess of 6 inches per hour were observed only five times over the six years examined, and stage declines greater than 4 inches per hour occur only once or twice a year. Rapid stage declines of greater than 4 inches per hour occur exclusively during fall and winter floods in the unregulated Sauk River.

3.2 SKAGIT RIVER

The Skagit River originates in Canada, and flows south and west for over 100 miles before emptying into Puget Sound. The basin area contributing flows to the Skagit River near Concrete gage covers 2,737 square miles, consisting primarily of steep mountainous terrain of the North Cascades. Similar to the Baker River, streamflows in the Skagit River are driven by runoff from fall rain events, spring snowmelt and glacial melt. There are two major hydropower projects in the Skagit River basin – the Baker Project and Seattle City Light’s Skagit River Project (FERC No. 593) located on the upper mainstem Skagit River. The Skagit Project consists of three dams located between RM 96.6 and 105.2. The combined total reservoir capacity of Ross Reservoir, Diablo Reservoir, Gorge Reservoir and Gorge Reservoir is over 1.5 million acre-feet.

The following sections describe flow components of the Skagit River under the current regulated condition and a synthesized completely unregulated condition (i.e., without the influence of the Baker Project or Skagit Project). The relative effects of the Baker Project operations are evaluated using a third scenario under which the Baker River is unregulated, but the Skagit Project continues to operate. This scenario was synthesized by subtracting daily flows measured at the Baker River at Concrete gage from daily flows measured at the Skagit River near Concrete gage, then adding the synthesized “unregulated” flows for the Baker River at Concrete gage.

3.2.1 Skagit River Annual Flow Components

<u>Skagit River Mean Annual Discharge</u>

Similar to the Baker River, flow regulation does not affect the average daily flows of the Skagit River when calculated on an annual basis (Table 3-8). The Skagit Project is also operated primarily for hydropower production and short-term flood control and is not a consumptive use of water. Small differences in the mean annual daily flows at the Skagit River near Concrete gage site are primarily a function of the process used to synthesize the unregulated daily flow record. The average annual mean daily flow at the Skagit River near Concrete gage under unregulated conditions is 15,414 cfs, equivalent to 5.6 cfs per square mile of drainage area.

Table 3-8. Annual flow statistics for Skagit River near Concrete under regulated and unregulated conditions (WY 1960 to 1996).

	Mean Annual Discharge (cfs)		Annual 3-day maximum (cfs)		Annual 7-day low flow (cfs)	
	Average	Standard Deviation [1]	Average	Standard Deviation	Average	Standard Deviation
Regulated (Baker and Skagit Projects in operation)	15,475	±2,814	52,748	±21,287	5,658	±973
Skagit regulated, Baker unregulated	15,438	±2,771	54,873	±18,473	5,475	±963
Unregulated	15,414	±2,840	64,542	±24,396	4,204	±1076

[1] Standard deviation of mean annual daily discharge between years

Skagit River Peak Flows

The annual 3-day maximum average daily flow at the Skagit River near Concrete gage under regulated conditions is approximately 18 percent less than under regulated conditions, and the range has shifted downward, although the interannual variability remains similar (Table 3-6). Without the influence of the Baker Project, but with continued operation of the Skagit Project the annual 3-day maximum flow would be 15 percent less than the unregulated condition, indicating that most of the reduction in peak flows results from flood control operations at the Skagit Project. Ross Reservoir is required to provide 120,000 are-feet of flood storage, compared to the current flood storage requirement of 74,000 acre-feet in Upper Baker Reservoir (USACE, 1998).

Flood flows at the Skagit River near Concrete gage have been affected by regulation since completion of Lower Gorge dam in 1923. Six major historical flood events have been documented for the Skagit River (USGS). A flood of about 500,000 cfs occurred in 1815 and a flood of about 350,000 cfs occurred 1856. The magnitude of these discharges was estimated based on old high water marks and historical literature and may be subject to large errors. Research by Kunzler (1991) cited in the recent USFS Baker River Watershed Analysis (USFS, 2002) indicates that these two early floods were likely caused by geologic events - mudslides that blocked parts of the Sauk or Baker rivers and subsequently failed, or melting of ice and snow on volcanically active peaks in the basin. Other high flows that occurred in 1897, 1909, 1917 and 1921 are better documented by early photographs and news articles. Since regulation began in 1924, the largest flow measured at the Skagit River near Concrete gage was 154,000 cfs in 1953 (Figure 3-17).

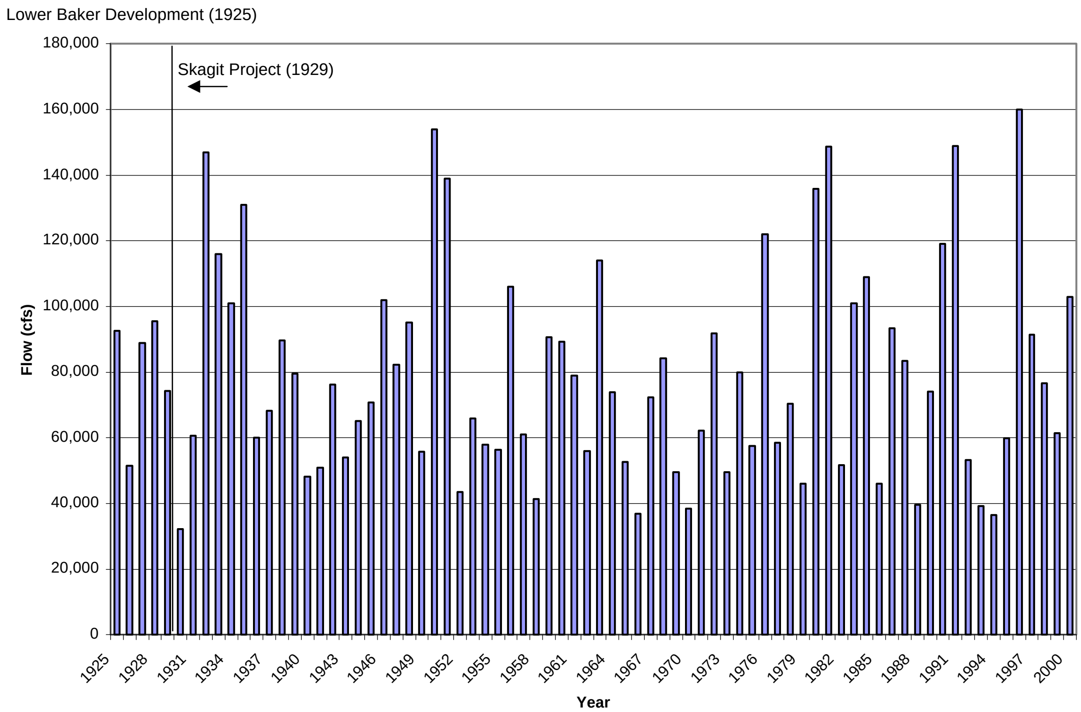


Figure 3-17. Instantaneous peak flows recorded at the Skagit River near Concrete gage from 1925 through 2000.

Flood frequency analyses conducted by the USACE indicate that flow regulation by the Baker and Skagit Projects combined have a moderate effect on peak flow magnitudes in the Skagit River basin. The estimated 100-year unregulated peak flow at the Skagit River near Concrete gage is 293,000 cfs, compared to a 100-year peak flow under current flood storage regulations of 222,000 cfs; the largest possible reduction in the 100-year peak flow (assuming no reservoir discharge) is 88,000 cfs (Figure 3-18). Flows greater than approximately 160,000 cfs (equivalent to a 10-year return interval under unregulated conditions) still occur, but have an estimated return interval of 40-years under the existing flood regulation requirements. These very large flow events may cause extensive property damage, but in natural river systems large floods are important for maintaining the dynamic channel morphology typical of anastomosing alluvial rivers such as the middle Skagit.

Skagit River 7-Day Low Flow

Under unregulated conditions, the annual seven-day low flow in the Skagit River near Concrete is most likely to occur in September, October or early November (Figure 3-19). Like the Baker River however, there are years when the annual 7-day low flow occurs during the winter months, even under unregulated conditions (Figure 3-19). Under regulated conditions the annual 7-day low flow in the Skagit River near

Concrete is still most likely to occur during the fall; however, it tends to occur earlier than under unregulated conditions. As a result of regulation, the annual 7-day low flow is less likely to occur during cold spells in the winter, as the projects continue to operate, maintaining relatively high outflows as compared to unregulated conditions. The difference in the influence of hydropower operations on annual low flow timing between the Skagit and Baker rivers is due primarily to the high degree of influence of unregulated tributaries such as the Sauk River on flows in the lower Skagit River. Snowmelt in the Sauk River and other tributaries tends to moderate the influence of flow reductions from the Baker and Skagit Projects during spring refill.

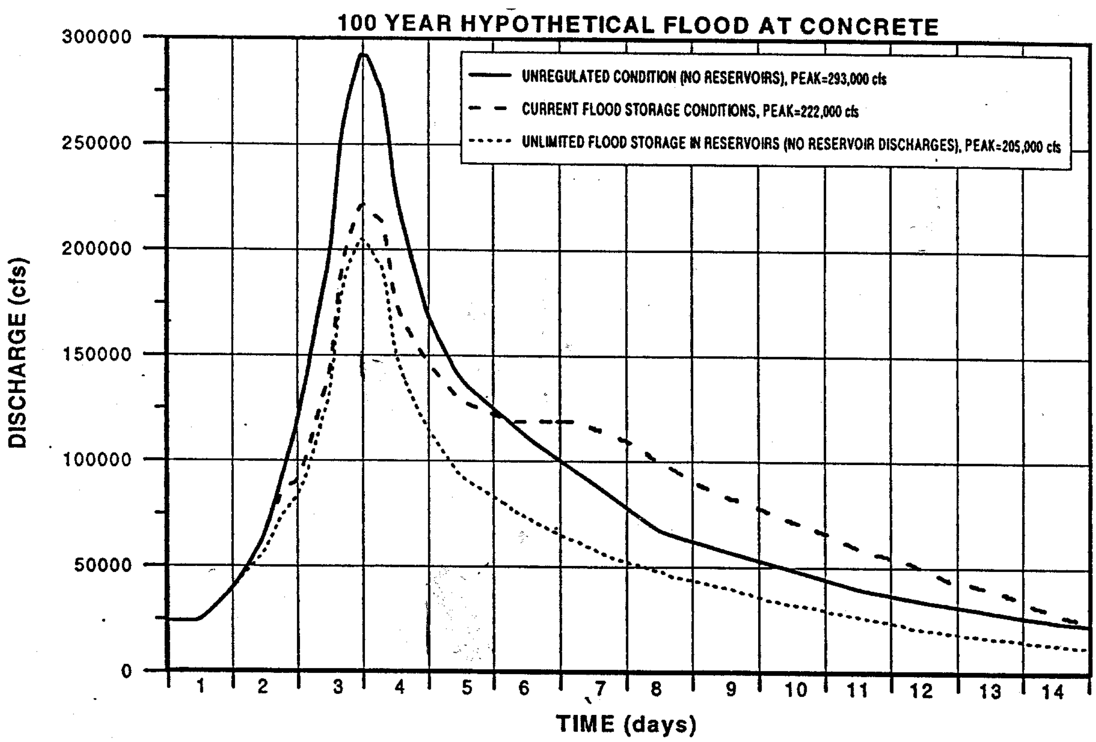


Figure 3-18. Effect of existing and future potential flood control at the Skagit and Baker Projects on the magnitude of the 100-year flood event at the Skagit River near Concrete gage (from USACE, 1998).

The seven-day low flow at the Skagit River near Concrete gage under regulated conditions is higher than under unregulated conditions, and the overall range of variability has shifted upward slightly but become less variable (Table 3-8). This is primarily because outflows from both the Baker Project and Skagit River when they are operating tend to be higher than unregulated annual low flows. The annual 7-day low flow with the Skagit Project in place, but without the influence of the Baker Project, is similar to fully regulated conditions. The Skagit Project appears to have been responsible for most of the low flow augmentation during the WY 1960 to 1996 period.

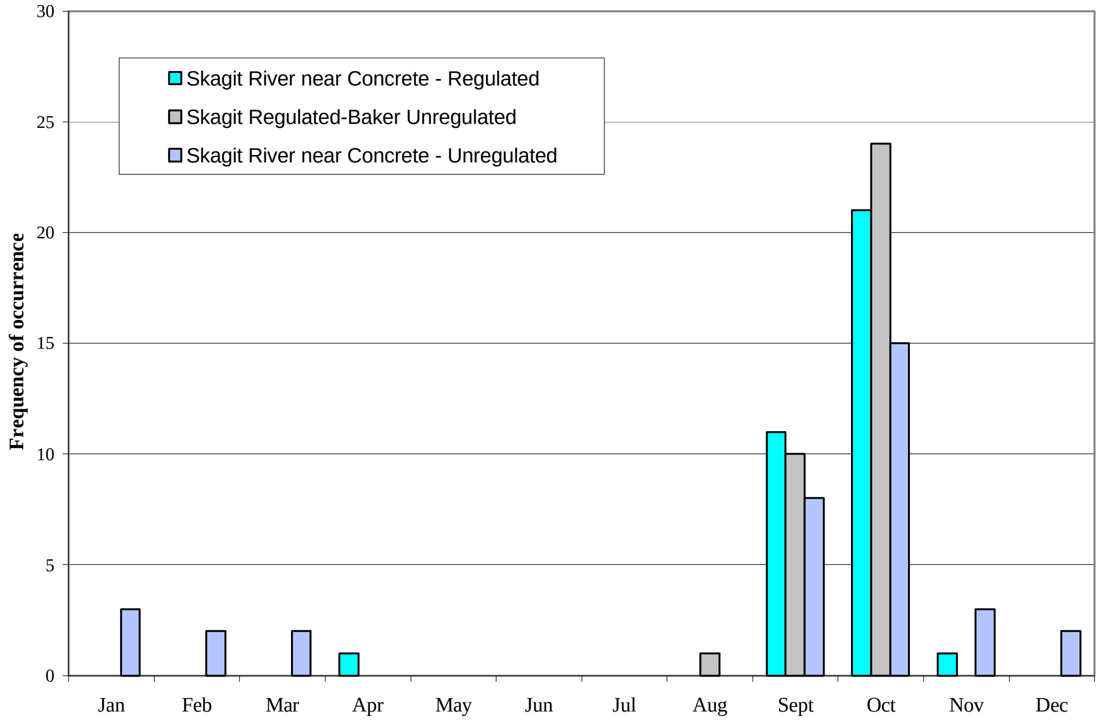


Figure 3-19. Timing of annual 7-day low flows at the Skagit River near Concrete gage under regulated, flow conditions, without the influence of the Baker Project but with the Skagit Projects and under unregulated conditions based on data from the period from 1959-1999 (Data from USGS, and USACE).

Skagit River Flow Duration

Hydropower operations also affect the duration of flows of various magnitudes in the Skagit River (Figure 3-20). The existing regulated flow duration curve for the Skagit River near Concrete reflects the influence of both the Baker Project and Skagit Project. The goal of flood control agreements at both dams is to limit flows greater than 90,000 cfs (USACE, 1998). To accomplish this, outflows at both projects are reduced to minimum flows when the discharge at the Skagit River near Concrete gage reaches about 65,000 cfs (USACE, 1998). The flow duration curve for the Baker River unregulated/Skagit River regulated scenario illustrates the greater flood control capacity of the Skagit Project, particularly for extremely high flows. The flow duration curves for the Skagit River near Concrete gage also illustrate that hydropower operations augment low flows (Figure 3-20).

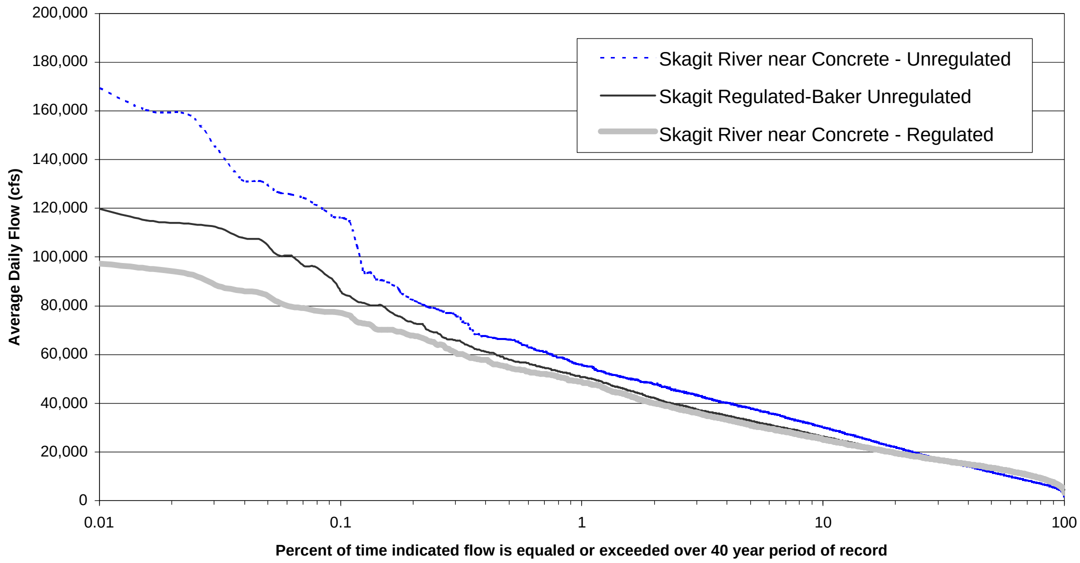


Figure 3-20. Annual flow duration curves for the Skagit River near Concrete gage under regulated conditions (both Baker River Project and Skagit Project operating), without the influence of the Baker Project (Skagit River Project operating) and under unregulated conditions (1959-1996).

3.2.2 Skagit River Seasonal Flow Components

Skagit River Mean Monthly Flows

Seasonal operational patterns at both the Baker Project and Skagit Project, as well as inflows from unregulated tributaries all influence seasonal flow fluctuations at the Skagit River near Concrete gage. Differences in regulated and unregulated seasonal flow patterns in the Skagit River are generally less pronounced than in the Baker River because of the large (approximately 46%) unregulated contributing area (Figure 3-21). The seasonal effects of flow regulation at the Skagit River near Concrete gage are dominated by the Skagit Project because of its greater storage and generating capacity. The Skagit Project Reservoirs have a combined active storage capacity of over one million acre-feet versus approximately 307,000 acre-feet for the Baker Project. The Skagit Project is required to provide 120,000 acre-feet of flood control storage, compared to the 74,000 acre-feet provided by the Baker Project.

Seasonal operations at the Skagit Project are generally similar to those at the Baker Project: reservoirs are drawn down in the fall for flood control; held at low pool through the winter, filled in the spring, and held at high pool during the summer. A detailed description of Skagit River operations is beyond the scope of this analysis; however, the 1996 license contains a description of current Skagit Project operations (SCL).

Evacuation of reservoir storage at both projects in the fall generally results in higher average daily flows at the Skagit River near Concrete gage during August, September and October (Table 3-9; Figure 3-21). A comparison of current regulated conditions with an estimate of the flows with the Skagit Project operating but without the Baker Project operating indicates that Baker Project operations account for 25 to 40 percent of the additional flow during the fall (Table 3-9).

Flood control operations at both reservoirs result in the capture and gradual release of flood flows from November through March. As a result, average daily flows for the months of December through March under regulated conditions are higher than under unregulated conditions (Table 3-9). Comparison of current regulated conditions with the Skagit Project operating but without the Baker Project operating scenario indicates that Baker Project operations consistently account for about 15 percent of the difference between regulated and unregulated flows.

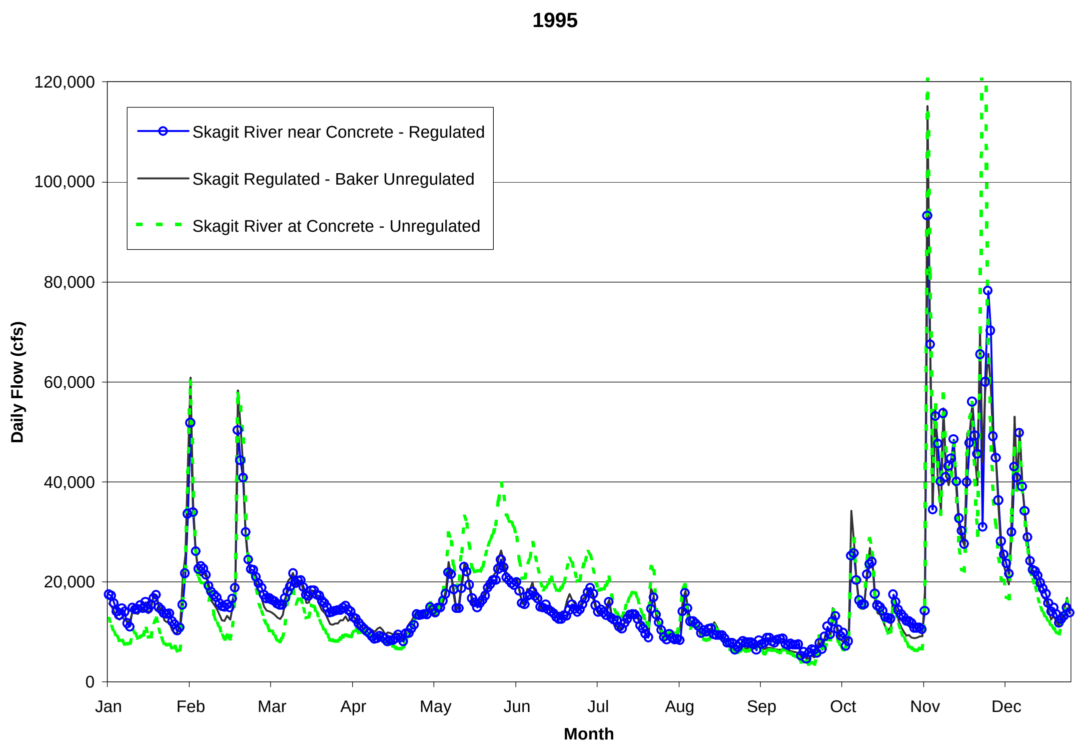


Figure 3-21. Typical annual hydrograph for the Skagit River near Concrete gage under regulated conditions, with the Baker River unregulated but Skagit River regulated, and under unregulated conditions (Data from USGS, PSE and USACE).

Table 3-9. Average daily flows (cfs) by month at the Skagit River near Concrete gage under regulated conditions (both Skagit Project and Baker Project in operation), without the influence of the Baker Project (only Skagit Project in operation) and under unregulated conditions (WY 1960-1996).

	Regulated (cfs)	Without Baker Influence (cfs)	Unregulated (cfs)
January	16,606	16,097	13,054
February	15,871	15,419	12,804
March	13,435	13,040	10,734
April	13,196	13,610	13,309
May	17,511	18,613	23,346
June	23,357	24,209	29,902
July	19,765	19,975	21,469
August	11,450	11,372	11,767
September	8,763	8,598	8,186
October	10,873	10,624	9,900
November	17,324	16,592	15,389
December	17,622	17,161	15,053

Even with the reduced contributions from the Baker River, the average daily flow at the Skagit River near Concrete gage in April is similar to what it would be under unregulated conditions (Figure 3-22). Reservoir refill at both Projects reduces flows at the Skagit River near Concrete gage in May and June as compared to unregulated conditions; Baker Project operations are responsible for 15 to 20 percent of the change. Once the reservoirs reach full pool in July outflows are generally similar to inflows, and differences in the mean daily flows for July and August under regulated versus unregulated conditions are small (Figure 3-22).

Overall, although operation of the both the Baker Project and Skagit Projects has altered the magnitude of seasonal runoff in the Skagit, mean monthly flows generally remain within the unregulated range of variability (Figure 3-22).

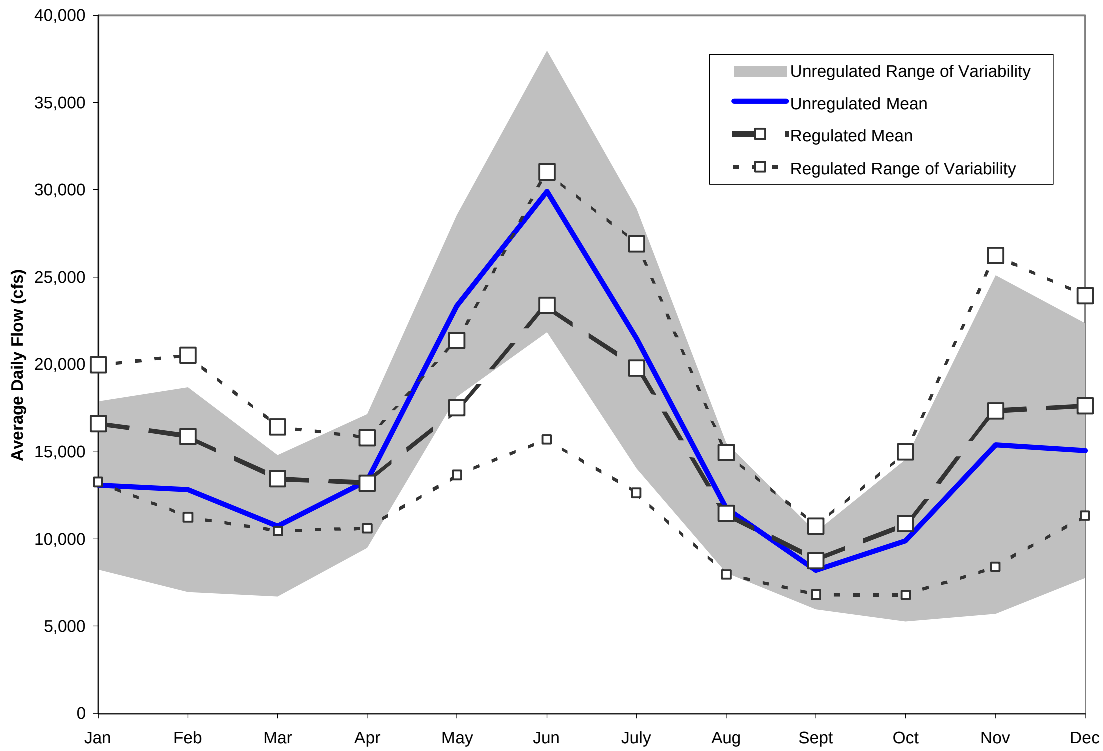


Figure 3-22. **Range of variability and average daily flows by month at the Skagit River near Concrete gage under regulated conditions (both Baker River and Skagit Projects operating) and under unregulated conditions, based on the period of record from 1959 to 1996 (Data from USGS and USACE).**

Skagit River Monthly Flow Exceedence

At the Skagit River near Concrete gage, differences in the monthly exceedence flows under regulated and unregulated conditions exhibit a similar pattern to those described for the Baker River at Concrete gage (Tables 3-10a, b and c). The major differences in the effects of hydropower operations at the Baker River at Concrete gage compared to the Skagit River near Concrete gage are the magnitude of the differences and the summer flow variability. The reduction in the magnitude of infrequent high flows (90 to 95 percent exceedence flow) in the fall and spring as a result of hydropower operations is greater at the Skagit River near Concrete gage than at the Baker River due to the combined influence of the Baker and Skagit Projects. In the summer, the range of variability in flows at the Skagit River near Concrete gage is similar under regulated versus unregulated conditions. The lack of a pronounced signature from the Baker Project on average daily flows for the summer months at the Skagit River near Concrete gage in the summer is due to the fact that the operational range of the Lower Baker Development is small relative to contributions from unregulated tributaries in the larger Skagit basin. However, as will be shown in Section 3.2.3, Baker Project operations have a pronounced effect on the daily and hourly flow variability at the Skagit River near Concrete gage during the same period.

Table3-10a. Monthly exceedence flows for the Skagit River near Concrete gage under regulated conditions (WY 1960-1996[1]).

	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%
Jan	28,117	23,046	19,411	17,450	15,844	14,860	13,943	13,162	12,337	11,492	10,831
Feb	24,402	21,513	18,301	16,814	15,768	14,854	13,988	13,218	12,560	11,718	10,972
Mar	18,703	17,097	15,483	14,351	13,657	13,049	12,459	11,867	11,144	10,196	9,588
Apr	18,628	17,205	15,444	14,236	13,434	12,653	11,897	11,303	10,747	9,927	9,477
May	26,264	24,220	21,486	19,260	17,714	16,634	15,450	14,388	13,359	12,210	11,394
June	32,341	30,227	27,715	25,891	24,265	22,699	21,309	19,952	18,952	17,303	16,406
Jul	27,987	26,409	23,549	21,646	20,243	19,032	17,721	16,840	15,851	14,691	13,644
Aug	15,833	14,932	13,599	12,679	11,709	11,015	10,351	9,765	9,226	8,498	8,006
Sep	13,787	12,029	10,261	9,344	8,652	8,085	7,643	7,187	6,751	6,252	5,862
Oct	18,859	16,156	13,472	11,852	10,729	9,947	8,970	8,141	7,464	6,459	5,993
Nov	31,992	26,161	21,462	18,730	16,876	15,183	14,048	12,840	11,179	10,218	9,701
Dec	32,320	26,404	22,086	18,563	16,444	15,101	14,238	13,167	12,189	11,276	10,467

[1]No data from WY 1992 and WY 1993

Table 3-10b. Monthly exceedence flows for the Skagit River near Concrete gage with Baker River unregulated and Skagit River regulated (WY 1960-1996[1]).

	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%
Jan	30,486	23,951	19,071	16,521	14,813	13,806	12,564	11,806	11,166	10,514	9,983
Feb	26,102	21,767	17,889	16,152	14,933	13,839	13,077	12,152	11,649	10,871	10,349
Mar	19,826	17,335	15,052	13,928	13,036	12,147	11,559	10,981	10,394	9,701	9,259
Apr	19,830	18,063	15,921	14,675	13,548	12,763	12,067	11,476	10,955	10,271	9,917
May	28,883	26,219	22,924	20,762	18,786	17,454	16,134	14,987	13,812	12,695	12,055
June	33,924	31,848	28,781	26,740	25,088	23,461	22,082	20,561	19,295	17,607	16,735
Jul	28,259	26,405	23,668	21,758	20,293	19,065	17,903	17,058	16,075	15,020	14,179
Aug	15,527	14,520	13,339	12,486	11,646	11,016	10,332	9,762	9,253	8,584	8,099
Sep	13,645	11,587	9,950	9,090	8,392	7,814	7,415	7,055	6,688	6,274	5,954
Oct	19,664	16,284	13,200	11,408	10,213	9,174	8,326	7,494	6,952	6,281	5,948
Nov	31,673	26,015	20,980	17,868	16,006	14,119	12,957	11,748	10,285	9,471	8,976
Dec	33,460	26,279	21,972	18,278	15,747	14,096	12,958	12,004	11,147	10,364	9,871

[1]Missing+A48 data from WY 1992 and WY 1993

Table 3-10c. Monthly exceedence flows for the Skagit River near Concrete gage under unregulated conditions (WY 1960-1996[1]).

	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%
Jan	29,276	21,774	16,258	13,631	11,599	10,492	9,076	8,142	7,463	6,760	6,448
Feb	25,067	20,605	15,782	13,642	12,171	11,048	10,084	9,025	8,168	7,353	6,987
Mar	18,555	15,819	13,089	11,552	10,368	9,662	8,950	8,299	7,733	7,071	6,788
Apr	21,352	19,202	16,547	14,704	13,287	12,182	11,200	10,439	9,840	8,939	8,495
May	39,303	35,404	30,644	27,035	24,065	21,516	19,303	17,484	15,497	13,769	12,886
June	43,492	40,407	36,529	33,450	30,920	28,500	26,843	24,821	23,041	20,908	19,744
Jul	30,932	28,546	25,541	23,466	21,720	20,733	19,121	18,111	17,020	15,925	14,937
Aug	16,474	15,338	14,037	12,993	12,136	11,341	10,531	9,895	9,292	8,654	8,222
Sep	13,798	11,781	9,589	8,612	7,905	7,329	6,838	6,438	6,073	5,610	5,337
Oct	20,717	16,549	12,850	10,658	9,274	7,934	7,124	6,320	5,752	5,136	4,795
Nov	34,495	27,285	20,428	16,674	13,955	12,222	10,845	9,416	8,231	7,238	6,802
Dec	34,112	25,627	20,072	16,361	13,760	11,815	10,354	9,123	8,188	7,277	6,797

[1]Missing data from WY 1992 and WY 1993

Skagit River Frequency of Freshets

The timing and frequency of rapid, substantial flow increases (freshets) that extend over multi-day periods were assessed by month, using measured and synthesized average daily flow data[2]. Freshets are defined as average daily flow increases of more than 50 percent relative to the mean flow over the preceding three-day period.

The average number of freshets at the Skagit River near Concrete gage under unregulated conditions ranges from 0.25 to 2 per month (Figure 3-23). Precipitation is markedly seasonal, with the heaviest precipitation occurring from November through May. The distribution of freshets under unregulated conditions reflects these climatic patterns. Freshets are most in the fall and winter; with a secondary peak occurring in the spring. Periodic intense rain events associated with frontal weather systems result in extreme, but often short duration, flood events. Such events produce at least one freshet per month from September through May, but are less common in the summer.

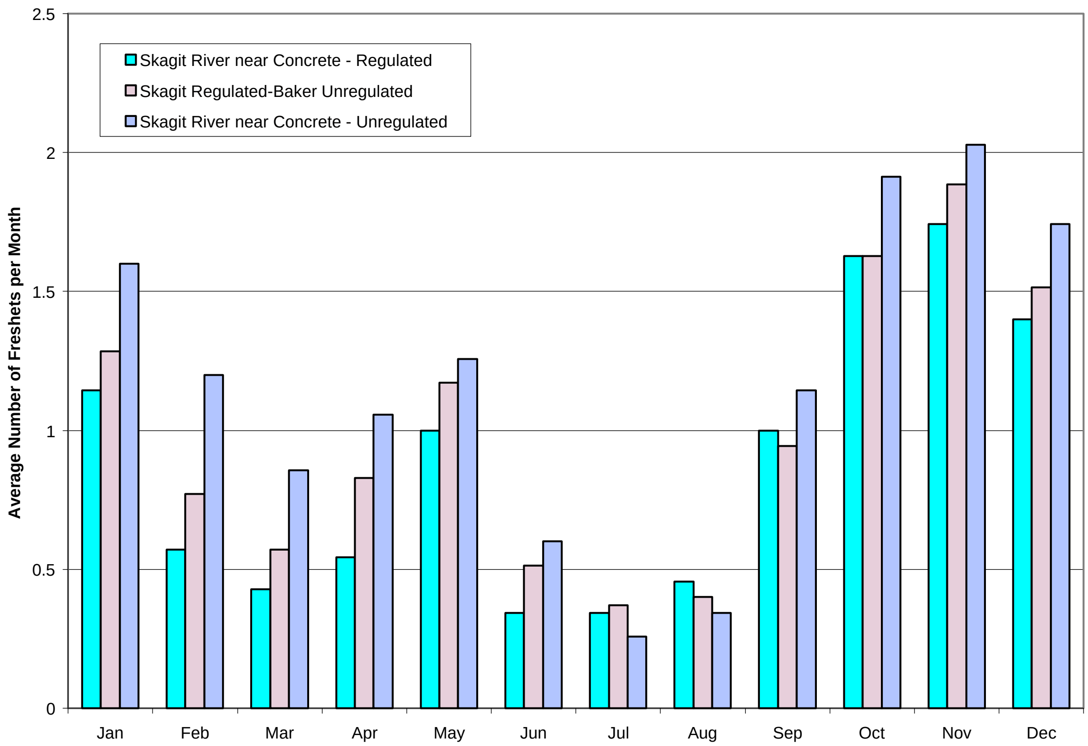


Figure 3-23. Monthly frequency of freshets at the Skagit River near Concrete gage under regulated conditions (both Baker River and Skagit Projects operating), without the influence of the Baker Project (with the Skagit Project operating) and under unregulated conditions, for the period of record from 1959 to 1996.

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[2] Hourly flow changes and the rise and fall rate of short duration events are considered hourly flow components, and are discussed further in Section 3.3.

Freshets typically begin to occur with increased frequency in September. At least one freshet occurred in September more than 90 percent of the time. The number of monthly freshets from September through January under unregulated conditions ranges from zero to five. The frequency of freshets decreases slightly during February and March, when the majority of precipitation in the mountainous drainage basin falls as snow.

During February, March and April, the typical number of freshets ranges from zero to three per month under unregulated conditions. In no case were there zero freshets over the three-month period, and a single freshet over the three-month period occurred less than 15 percent of the time. The greatest total number of freshets over the three-month period from February through April was six.

Under regulated conditions, the temporal distribution of freshets events is the same as under regulated conditions (Figure 3-23). Freshets are most common in the fall in winter, generally beginning in September. At least one freshet occurred in September over 60 percent of the time. The number of freshets per month in the fall and winter ranges from zero to five. At least one freshet per month occurs from September through January over 80 percent of the time.

Freshets are uncommon in the late winter and spring, the period when the Baker Project and Seattle City Light Reservoirs are being refilled. On average, less than one freshet per month occurs during the period from February though April under regulated conditions. Almost 50 percent of the time only a single freshet occurs over the three-month period, and in four of the 35 years analyzed no freshets were recorded between February 1 and April 30.

Without the influence of the Baker Project, but with the Skagit Project operating freshets are most common in the fall in winter, and least common in the summer (Figure 3-23). The number of freshets generally increases in September, and the average number of freshets per month exceeds 1 from October through January. The total number of freshets per month during this period ranges from zero to five.

Freshets are uncommon in the late winter and early spring. On average, less than one freshet per month occurs during the period from February though April under regulated conditions. Only a single freshet occurs over the three-month period over 30 percent of the time, and in four of the 35 years analyzed no freshets were recorded between February 1 and April 30.

Skagit River 2-Day Low Flows

The magnitude of the 2-day low flow for each month was estimated for regulated conditions, unregulated conditions and with the Baker River unregulated but Skagit River regulated. Under unregulated conditions the monthly two-day low flow is highest in June and July and lowest in September and October (Figure 3-24). In the spring and summer, the median monthly two-day low flow ranges from around 7,000 to 14,000 cfs. Monthly two-day low flows under unregulated conditions are relatively consistent from year to year; the 25th and 75th percentiles fall within 28 to 49 percent of the median.

Under regulated conditions, monthly two-day low flows are lowest in September and October, but remain low (i.e., less than 8,000 cfs) throughout the winter and early spring. The two-day low flows are highest in the early summer (June and July). Two-day low flows are generally consistent from year to year; the 25th and 75th percentiles differ from the median by 30 to 50 percent (Figure 3-24). In extremely dry years, the two-day lows flows are less than 4,000 cfs.

Without the influence of the Baker Project but with flow regulation by the Skagit Project monthly two-day low flows are lowest in September and October, and exceed 8000 cfs throughout the remainder of the year. The two-day low flows are highest in the early summer (June and July). Two-day low flows are generally consistent from year to year; the 25th and 75th percentiles differ from the median by 30 to 50 percent (Figure 3-24).

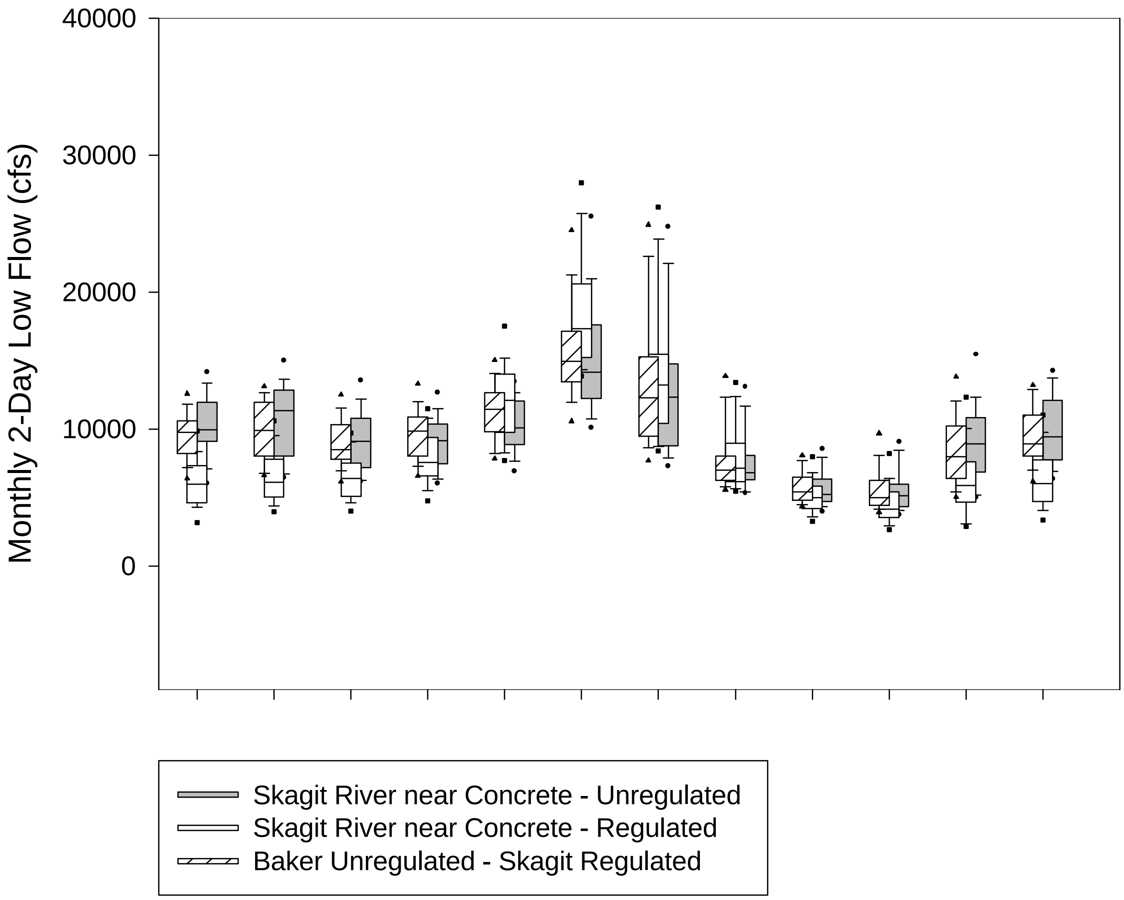

Figure 3-24. Monthly two-day low flow at the Skagit River at Concrete gage for the period from 1960 to 1996. Boxes represent median and 25th to 75th percentile. Whiskers represent 10th and 90th percentiles. Points represent 5th and 95th percentiles. (Regulated flow data from USGS; synthesized regulated flow data from USACE and PSE)

Skagit River Low Pulses

The duration of low flow events was examined by developing non-exceedence flow tables. Seasonal variability of low flows is described using monthly durations for average daily flows between 4,000 and 30,000 cfs for the Skagit River near Concrete gage. The greatest number of consecutive and total days per month that average daily flows were below given flow values for the period of WY 1960 through 1999 under regulated conditions are presented in Tables 3-11, 3-12 and 3-13. The upper part of the table lists monthly low-flow durations that occurred under normal conditions as represented by the median monthly non-exceedence durations. The lower part of each table represents monthly low-flow durations that occur under extremely dry conditions.

Under unregulated conditions, flows less than 5,000 cfs normally occur for periods of 1 to 4 days during the late summer and early fall (September and October). Flows less than 4,000 cfs typically do not occur, but in extremely dry years flows may be less than 4,000 cfs for extended periods (approximately 1 to 3 weeks) during the fall and winter months (Table 3-11). Baseflows are typically highest during snowmelt (May, June and July), when flows typically do not fall below 10,000 cfs. Even in extremely dry years, baseflows during May, June and July do not fall below 10,000 cfs for periods of more than a week, and were rarely less than 8,000 cfs.

Under regulated conditions, average daily flows are rarely less than 4,000 cfs even in the driest years, and if they do occur, persist for less than two consecutive days (Table 3-12). Baseflows of 7,000 to 8,000 cfs are more typical during the late summer and fall period, and may last for as much as a week or more (Table 3-12). Baseflows are typically highest during the winter, when flood flows are captured and gradually released by the Baker and Skagit Projects and in early summer following reservoir refill (Table 3-12). In the winter under regulated conditions, flows normally do not fall below 10,000 cfs for longer than 1-day. However, during extremely dry periods flows may be less than 8,000 cfs for periods of a week or more in December and January.

In May, June and July, flows do not fall below 10,000 cfs in most years. In extremely dry years, baseflows during May, June and July may be less than 10,000 cfs for periods of more 2 days to a week or more, but are rarely less than 8,000 cfs.

The monthly non-exceedence durations for the scenario in which the Baker River is unregulated, but Skagit River is regulated are presented in Table 3-13. Without the influence of the Baker Project, average daily flows are rarely less than 5,000 cfs in most years, but may be less than 5,000 cfs for periods of approximately one to three weeks in extremely dry years (Table 3-13). In the winter flows normally do not fall below 10,000 cfs for longer than 1-day. However, during extremely dry periods flows may be less than 7,000 cfs for periods of 5 to 10 days in December and January.

Baseflows are typically highest from May through July following reservoir refill (Table 3-13). During the late spring and early summer flows do not fall below 10,000 cfs in most years. In extremely dry years, baseflows during May, June and July may fall below 8,000 cfs for periods of 2 to 5 days.

Table 3-11. Total and consecutive number of days per month that flow was below given flow values in the Skagit River near Concrete for the period from WY 1960 through 1996 under unregulated conditions. Numbers in bold italics represent consecutive days.

Median number of days per month that flow was below given flow value																								
Flow(cfs)	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
4,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	6	4	0	0	0	0
6,000	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	4	11	8	1	1	1	1
7,000	3	3	5	5	5	3	0	0	0	0	0	0	0	0	1	1	14	8	15	11	5	4	3	3
8,000	10	8	8	6	11	7	2	2	0	0	0	0	0	0	4	3	20	13	17	12	7	5	7	6
9,000	15	10	10	8	17	12	5	4	0	0	0	0	0	0	8	6	23	17	19	12	11	6	11	9
10,000	17	12	14	10	20	14	9	6	0	0	0	0	0	0	14	10	26	19	22	13	12	9	13	10
15,000	23	17	25	16	28	26	22	19	6	5	0	0	4	3	29	23	29	28	28	22	22	14	23	16
20,000	27	19	28	25	31	31	28	22	15	11	4	3	19	12	31	31	30	30	30	28	25	21	27	20
25,000	29	22	28	28	31	31	30	30	22	16	11	7	27	21	31	31	30	30	30	30	28	23	28	22
30,000	30	25	28	28	31	31	30	30	24	18	18	12	31	31	31	31	30	30	31	31	29	27	30	23

Maximum number of days per month that flow was below given flow value																								
Flow(cfs)	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
4,000	25	13	6	6	4	1	0	0	0	0	0	0	0	0	0	0	8	6	26	26	21	12	7	7
5,000	30	20	19	7	18	15	7	6	0	0	0	0	0	0	1	1	15	11	30	28	26	26	10	10
6,000	31	31	25	23	28	22	11	11	0	0	0	0	0	0	11	11	27	27	31	31	28	27	26	23
7,000	31	31	28	28	29	24	15	14	1	1	0	0	0	0	15	15	30	30	31	31	30	30	30	25
8,000	31	31	28	28	31	31	25	19	2	2	0	0	1	1	23	17	30	30	31	31	30	30	31	31
9,000	31	31	28	28	31	31	30	30	4	4	0	0	3	3	30	26	30	30	31	31	30	30	31	31
10,000	31	31	28	28	31	31	30	30	6	6	0	0	11	7	31	31	30	30	31	31	30	30	31	31
11,000	31	31	28	28	31	31	30	30	8	8	0	0	17	8	31	31	30	30	31	31	30	30	31	31
12,000	31	31	29	29	31	31	30	30	13	9	0	0	21	16	31	31	30	30	31	31	30	30	31	31
13,000	31	31	29	29	31	31	30	30	16	16	1	1	26	17	31	31	30	30	31	31	30	30	31	31
14,000	31	31	29	29	31	31	30	30	19	17	5	3	28	24	31	31	30	30	31	31	30	30	31	31
15,000	31	31	29	29	31	31	30	30	21	19	7	4	30	25	31	31	30	30	31	31	30	30	31	31
16,000	31	31	29	29	31	31	30	30	24	22	10	8	31	31	31	31	30	30	31	31	30	30	31	31
17,000	31	31	29	29	31	31	30	30	27	27	20	10	31	31	31	31	30	30	31	31	30	30	31	31
18,000	31	31	29	29	31	31	30	30	27	27	24	10	31	31	31	31	30	30	31	31	30	30	31	31
19,000	31	31	29	29	31	31	30	30	27	27	26	12	31	31	31	31	30	30	31	31	30	30	31	31
20,000	31	31	29	29	31	31	30	30	27	27	27	12	31	31	31	31	30	30	31	31	30	30	31	31
25,000	31	31	29	29	31	31	30	30	31	31	30	30	31	31	31	31	30	30	31	31	30	30	31	31
30,000	31	31	29	29	31	31	30	30	31	31	30	30	31	31	31	31	30	30	31	31	30	30	31	31

Table 3-12. Total and consecutive number of days per month that flow was below given flow values in the Skagit River near Concrete for the period from WY 1960 through 1996 under regulated conditions. Numbers in bold italics represent consecutive days.

Median number of days per month that flow was below given flow value

Flow(cfs)	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
4,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***
5,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	1	***1***	1	***1***	0	***0***	0	***0***
6,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	4	***2***	4	***2***	0	***0***	0	***0***
7,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	1	***1***	10	***5***	9	***5***	0	***0***	0	***0***
8,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	4	***3***	16	***9***	11	***7***	0	***0***	0	***0***
9,000	0	***0***	0	***0***	2	***1***	1	***1***	0	***0***	0	***0***	0	***0***	10	***5***	21	***13***	15	***10***	1	***1***	0	***0***
10,000	1	***1***	0	***0***	4	***3***	3	***2***	1	***1***	0	***0***	0	***0***	15	***9***	24	***17***	18	***12***	4	***2***	2	***1***
15,000	15	***10***	13	***11***	25	***15***	22	***18***	13	***8***	2	***2***	7	***4***	30	***27***	29	***29***	28	***24***	19	***12***	17	***13***
20,000	26	***17***	26	***24***	31	***31***	30	***30***	23	***16***	14	***7***	22	***15***	31	***31***	30	***30***	30	***29***	26	***19***	26	***19***
25,000	29	***22***	28	***28***	31	***31***	30	***30***	28	***21***	24	***14***	30	***23***	31	***31***	30	***30***	31	***31***	28	***23***	29	***21***
30,000	30	***28***	28	***28***	31	***31***	30	***30***	31	***31***	29	***28***	31	***31***	31	***31***	30	***30***	31	***31***	29	***29***	30	***27***

Maximum number of days per month that flow was below given flow value

Flow(cfs)	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
4,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	2	***2***	5	***2***	1	***1***	0	***0***
5,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	2	***2***	7	***5***	9	***5***	5	***2***	0	***0***
6,000	3	***2***	1	***1***	2	***2***	7	***4***	0	***0***	0	***0***	0	***0***	9	***7***	21	***10***	21	***21***	10	***7***	3	***3***
7,000	6	***3***	3	***2***	7	***5***	15	***6***	3	***3***	0	***0***	2	***2***	15	***14***	26	***13***	27	***24***	11	***11***	6	***4***
8,000	10	***6***	7	***3***	13	***7***	18	***14***	4	***3***	0	***0***	10	***6***	22	***19***	29	***28***	31	***31***	16	***11***	16	***10***
9,000	14	***9***	12	***11***	17	***14***	23	***15***	9	***7***	0	***0***	20	***8***	31	***31***	30	***30***	31	***31***	22	***17***	23	***15***
10,000	23	***14***	20	***12***	23	***17***	26	***16***	14	***11***	2	***2***	24	***15***	31	***31***	30	***30***	31	***31***	28	***27***	30	***22***
15,000	31	***31***	29	***29***	31	***31***	30	***30***	28	***26***	25	***21***	31	***31***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***
20,000	31	***31***	29	***29***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***
25,000	31	***31***	29	***29***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***
30,000	31	***31***	29	***29***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***

Table 3-13. Total and consecutive number of days per month that flow was below given flow values in the Skagit River near Concrete for the period from WY 1960 through 1996 with the Baker River unregulated and Skagit River regulated. Numbers in bold italics represent consecutive days.

Median number of days per month that flow was below given flow value

Flow(cfs)	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
4,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	**0**	0	***0***
5,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	1	***1***	0	**0**	0	***0***
6,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	3	***3***	4	***3***	0	**0**	0	***0***
7,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	1	***1***	12	***6***	10	***7***	0	**0**	0	***0***
8,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	4	***3***	18	***12***	12	***10***	1	**1**	0	***0***
9,000	0	***0***	0	***0***	2	***2***	0	***0***	0	***0***	0	***0***	0	***0***	10	***6***	22	***15***	17	***12***	3	**3**	1	***1***
10,000	2	***1***	1	***1***	6	***4***	2	***1***	0	***0***	0	***0***	0	***0***	14	***10***	24	***17***	19	***13***	6	**4**	4	***3***
15,000	20	***11***	18	***12***	26	***21***	24	***15***	11	***7***	2	***1***	6	***4***	30	***28***	29	***29***	27	***22***	20	**12**	20	***12***
20,000	26	18	26	***23***	29	***29***	29	***24***	21	***15***	13	***7***	21	***15***	31	***31***	30	***30***	30	***28***	25	**19**	27	***19***
25,000	28	20	28	***28***	31	***31***	30	***30***	27	***19***	22	***13***	30	***23***	31	***31***	30	***30***	31	***31***	28	**23**	28	***21***
30,000	29	23	28	***28***	31	***31***	30	***30***	30	***24***	27	***24***	31	***31***	31	***31***	30	***30***	31	***31***	29	**26**	30	***23***

Maximum number of days per month that flow was below given flow value

Flow(cfs)	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
4,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	7	***7***	1	**1**	0	***0***
5,000	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	0	***0***	1	***1***	10	***6***	24	***21***	3	**2**	0	***0***
6,000	7	***4***	1	***1***	1	***1***	0	***0***	0	***0***	0	***0***	0	***0***	3	***3***	23	***13***	30	***30***	11	**8**	1	***1***
7,000	10	***5***	3	***3***	8	***5***	7	***4***	1	***1***	0	***0***	0	***0***	11	***8***	26	***22***	31	***31***	17	**16**	13	***10***
8,000	13	***7***	12	***8***	13	***10***	15	***7***	4	***2***	0	***0***	6	***5***	23	***20***	30	***30***	31	***31***	21	**21**	21	***16***
9,000	20	***13***	21	***11***	19	***12***	24	***15***	8	***5***	0	***0***	21	***8***	31	***31***	30	***30***	31	***31***	25	**23**	30	***30***
10,000	26	***21***	27	***25***	28	***28***	27	***16***	9	***6***	1	***1***	26	***15***	31	***31***	30	***30***	31	***31***	30	**30**	31	***31***
15,000	31	***31***	29	***29***	31	***31***	30	***30***	27	***27***	21	***12***	31	***31***	31	***31***	30	***30***	31	***31***	30	**30**	31	***31***
20,000	31	31	29	***29***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***	31	***31***	30	***30***	31	***31***	30	**30**	31	***31***
25,000	31	31	29	***29***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***	31	***31***	30	***30***	31	***31***	30	**30**	31	***31***
30,000	31	31	29	***29***	31	***31***	30	***30***	31	***31***	30	***30***	31	***31***	31	***31***	30	***30***	31	***31***	30	**30**	31	***31***

3.2.3 Skagit River Daily Flow Components

Flows at the Skagit River near Concrete gage integrate the influence of both daily flow fluctuations resulting from both hydropower operations and natural flow fluctuations. Both the Baker and Skagit Projects are operated on a load following basis, as described in Section 3.1.3 As noted previously, the current maximum generating flow at Lower Baker Dam is 4,200 cfs and the minimum machine flow is 3,200 cfs. The minimum flow required under the exisiting license is 80 cfs; flow releases of 80 cfs are supplemented by leakage through Lower Baker Dam which contributes an additional 50 to 60 cfs depending on the reservoir elevation. The operating range of the Skagit River Project is greater. Minimum and maximum flows releases for the Skagit Project vary seasonally (FERC, 1991). Gorge Powerhouse is capable of passing a maximum of 7,200 cfs; typical generation releases range from 1,300 cfs to 6,000 cfs (RW Beck and Associates, 1989). The Skagit Project operations have been subject to limits governing ramping rates, minimized and maximum instream flows since signing of a Settlement Agreement in April 1991 (FERC, 1991).

Daily flow variations at the Skagit River near Concrete gage in 1998 are depicted in Figure 3-25. The channel configuration and attenuation of flow fluctuations as they move downstream tend to reduce the magnitude of stage changes and prolong the duration of abrupt flow changes originating at the Baker and Skagit River Projects. However, flow variations remain more pronounced than the typical daily flow range observed in unregulated rivers (See Figure 3-10b), represented by the Sauk River near Sauk age as described in Section 3.1.3.

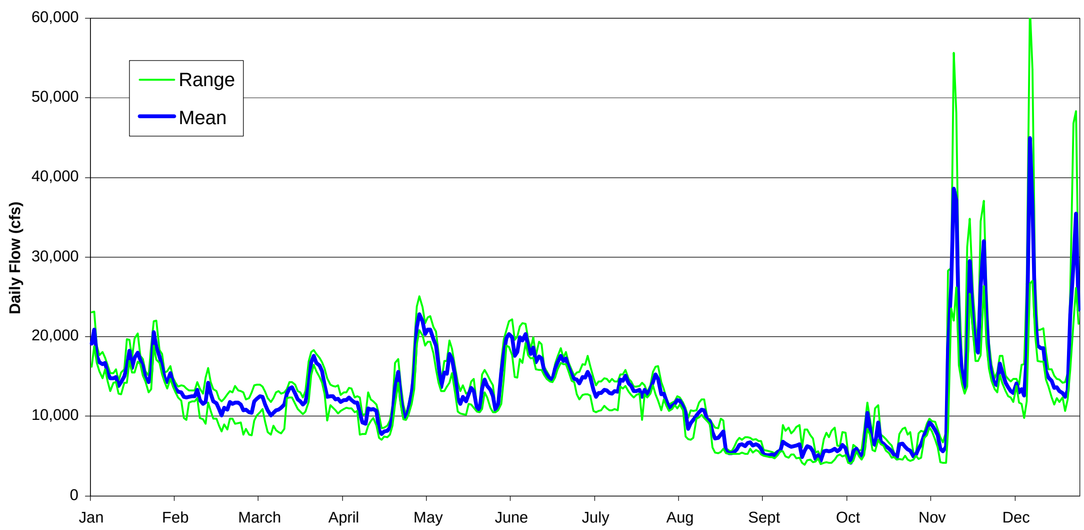

Figure 3-25. Daily mean flow and flow range at the Skagit River near Concrete gage in 1998.

The average daily flow range of the Skagit River near Concrete gage in 1998 was about ±13 percent of the average daily flow. The largest daily flow fluctuations observed at the Skagit River near Concrete gage occur during large floods, when daily flow fluctuations as high as ± 50 to 75 percent of the average daily flow were recorded. Daily flow fluctuations during low flow periods when freshets did not occur (e.g., mid-February to mid-March or late September to early October) varied by around 15 to 25 percent of the mean daily flow.

3.2.4 Skagit River Hourly Flow Components

Daily and hourly flows at the Skagit River near Concrete gage reflect a mixture of flow regulation effects and natural variation (Figure 3-26). Although the Skagit Project released relatively constant flows during May 1998, regular and pronounced diurnal fluctuations like those resulting from Baker Project operations are also observed as a result of Skagit Project operations (R2, 2000).

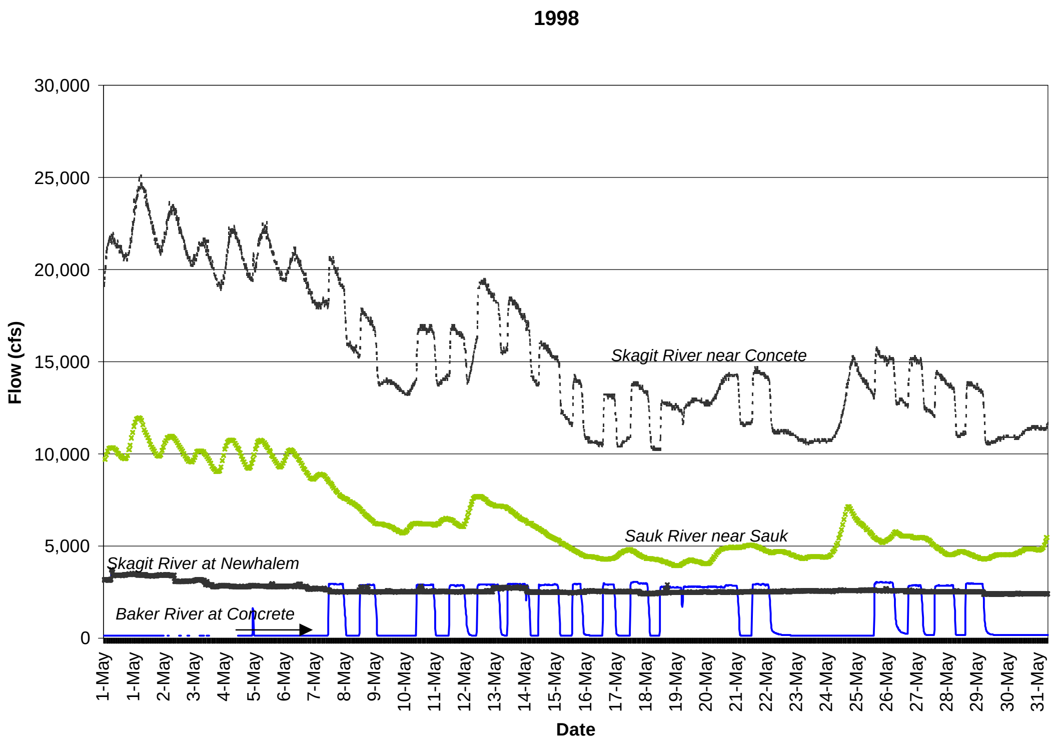

Figure 3-26. Example of the effect of hydropower operations and natural diurnal fluctuations on flow at the Skagit River near Concrete gage. Note that the Skagit Project is not load following during this period. Flow fluctuations in early May result from diurnal snowmelt cycles in unregulated tributaries such as the Sauk River. After May 7, diurnal flow fluctuations at the Skagit River near Concrete gage result from load following operations at the Lower Baker Development.

Daily flow variations resulting from load following operations at the Baker Project and Skagit Project occur throughout the year. As noted in Section 3.1.4, load following operations at the Baker Project resulted in an average of 6 to 17 ramping events per month over the period from 1996 to 1999. Daily load following at the Skagit River Project also influences hourly flows at the Skagit River near Concrete gage. Over the same four year period, load following at the Skagit River Project resulted in an average of 1 to 27 ramping events per month (Figure 3-27).

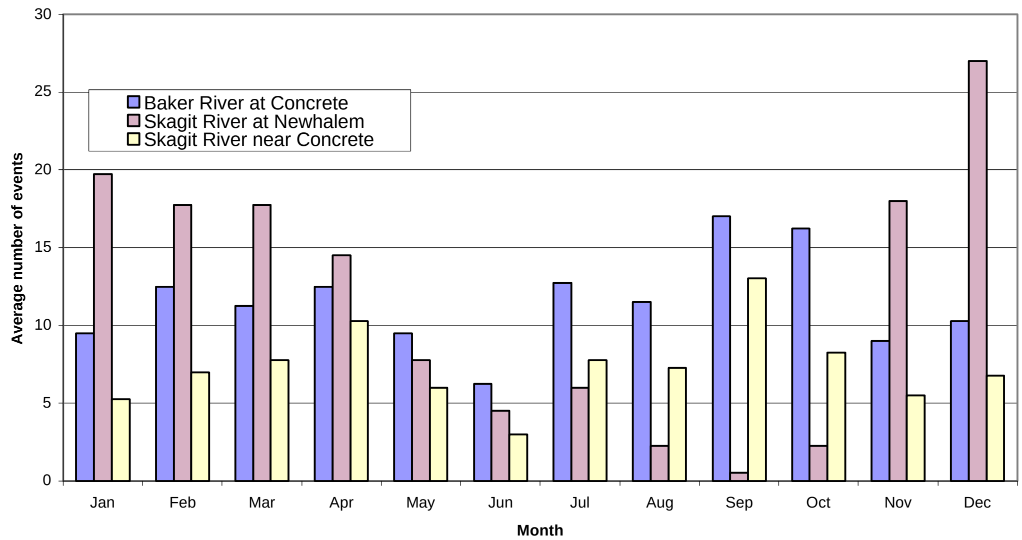

Figure 3-27. Average frequency of downramping events with a rate of more than 6 inches per hour for the period from 1996 through 1998.

The stage change at the Skagit River near Concrete gage associated with a downramp event from 4,100 cfs to 130 cfs at the Baker Project varies depending on the flow stage in the Skagit River. For a set of 15 typical downramp events in 1998, stage changes of 2.9 to 3.5 feet at the Baker River at Concrete gage corresponded to stage changes of 0.65 to 1.5 feet at the Skagit River near Concrete gage. Flows in the Skagit River during those events ranged from 8,300 to 19,500 cfs.

The Skagit River near Concrete gage is located 2.4 miles downstream of the Baker River confluence. Downramp events at the Baker Project reach the Skagit River near Concrete gage within about an hour, and little attenuation occurs over that distance (the duration of downramp events originating from the Baker Project is approximately 4 hours at the Skagit River near Concrete gage, as compared to about 3.5 hours at the Baker River at Concrete gage). This indicates that the difference in stage is influenced primarily by the large size of the Skagit River channel. The average ramp rate at the Skagit River near Concrete gage for the 15 events analyzed was 1.5 to 4.6 inches per hour, and the maximum stage change that occurred over any 15-minute interval was 2.2 inches.

Ramping events at the Skagit River Project also influence hourly flows at the Skagit River near Concrete gage. The magnitude of downramping events at the Skagit Project tends to be more variable than that which typically occurs at the Baker Project. The magnitude of a set of ramping events originating from the Skagit Project in 1998 ranged from 1,260 to 3,120 cfs. The stage change at the Skagit River at Newhalem gage associated with those events ranged from 0.75 to 1.7 feet. The stage change associated with the same ramping events at the Skagit River near Concrete gage ranged from 0.4 to 1.0 feet. An example of the lag time and attenuation of a typical Skagit Project downramp is illustrated in Figure 3-28.

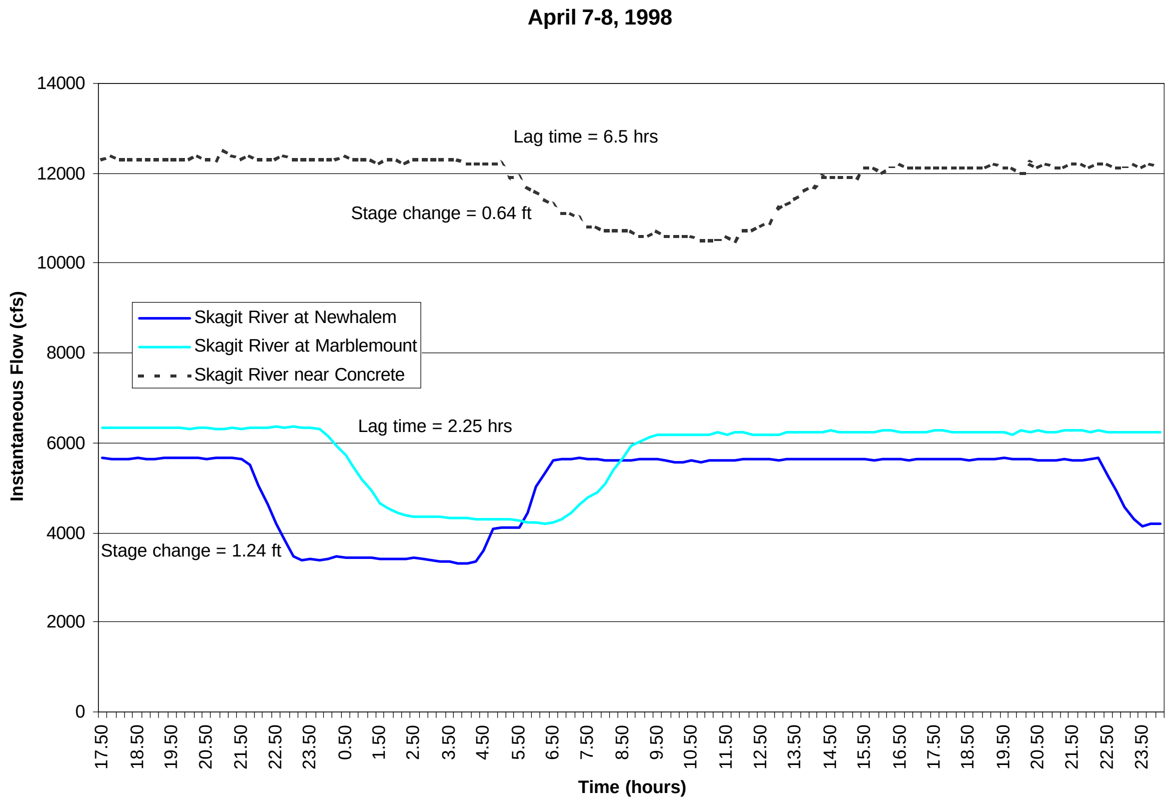

Figure 3-28. Example of attenuation and lag time to the Skagit River near Concrete gage associated with a typical load following event at Seattle City Light's Skagit Project on April 7 and 8 1998.

The Skagit River near Concrete gage is located 39.6 miles downstream of the Skagit River at Newhalem gage. Downramp events at the Skagit Project take about 8 hours to reach the Skagit River near Concrete gage, and substantial attenuation occurs over that distance. The average ramp rate at the Skagit River near Concrete gage resulting from load following operations at the Skagit Project was 1-inch per hour.

Diurnal flow fluctuations driven by snowmelt also occur at the Skagit River near Concrete gage. The cumulative effect of diurnal flow fluctuations produced by snowmelt in the unregulated portions of the Skagit River basin can result in flow changes that are comparable in magnitude to those resulting from Baker Project operations (Figure 3-26). As described in Section 3.1.4, diurnal fluctuations caused by snowmelt occur over a cycle of approximately 12-hours. The average rate of change at the Skagit River near Concrete gage resulting from diurnal flow fluctuations resulting from snowmelt is about one inch per hour; the maximum rate of change observed over any 15-minute interval was about 1.5 inches. Diurnal flow fluctuations peak at the Skagit River near Concrete gage at around 5:00 AM and reach their lowest level at around 4:30 PM.

The magnitude and frequency of diurnal snowmelt events at the Skagit River near Concrete gage is similar to the frequency of ramping events during the late spring and early summer (April through August). However, the rate of change differs substantially as diurnal flow fluctuations resulting from snowmelt rarely result in stage changes of more than 2 inches per hour, while ramping associated with load following operations often results in stage changes of more than 6 inches per hour. In addition, diurnal stage changes associated with snowmelt occur only during the spring and summer, while load following operations occur throughout the year.

4. CONCLUSIONS

The primary influences of Baker Project operations on flows in the Baker and Skagit rivers have been to reduce flood peaks, alter seasonal runoff patterns and increase the frequency and hourly rate of change for daily flow fluctuations. Effects are more pronounced in the lower Baker River than in the Skagit River. The following sections summarize the major findings of Chapter 3 for the Baker River at Concrete gage and the Skagit River near Concrete gage.

4.1 BAKER RIVER

Flow regulation by the Baker Project has not altered annual runoff volume, but does affect short duration annual flow components, seasonal flow patterns and daily and hourly flow fluctuations. The magnitude of annual peak flows is reduced, but the duration of high flow events increases as floodwaters are captured in the reservoirs then slowly released. Annual low flows in the Baker River are exacerbated, because even when supplemented by leakage through the dam, existing minimum flows (80 cfs) are substantially lower than unregulated annual low flows.

The primary effect of Baker Project operations on seasonal flow components occur during the spring as a result of reservoir refill and in the fall and winter as a result of flood control operations. Average daily flows in May and June are 20 to 30 percent lower under regulated conditions as early snowmelt runoff is captured when the reservoirs are refilled. Once the reservoirs fill, average daily flows differ by less than 10 percent under regulated versus unregulated conditions. However, daily load following commonly produces flow pulses lasting less than one day in the late summer, whereas summer low flows under unregulated conditions exhibit less frequent and longer duration flow pulses resulting from rain storms. During the fall and winter, average daily flows are 15 to 20 percent higher under regulated conditions. This results primarily from the increased duration of flood flows. In addition, periods of very low flow lasting days or weeks occur during winter cold spells under unregulated conditions. In contrast, flows resulting from hydropower operations are consistently higher during winter cold spells in response to power generation.

Daily and hourly flows in the lower Baker River are almost entirely governed by hydropower operations, except during periods of spill. The maximum stage change and rate of change that occur in the lower Baker River are substantially higher than those associated with natural daily flow fluctuations observed in nearby unregulated rivers.

4.2 SKAGIT RIVER

The effect of Baker Project operations on the flow regime of the Skagit River are less pronounced than in the Baker River, although some important differences are observed. Annual and seasonal flow components are less affected by Baker Project operations than for the Baker River because of differences in channel configuration and inputs from other large, unregulated tributaries. However, Baker Project operations in conjunction with hydropower operations at the Seattle City Light Skagit Project can result in additive effects. As for the Baker River, annual runoff volumes and the mean annual discharge are similar under regulated and unregulated conditions. Peak flows are reduced, although Baker Project operations are responsible for only about 15 percent of the total reduction. Overall, existing levels of flood control at both the Baker Project and Skagit Projects reduce the magnitude of a 100-year return interval flow event from 293,000 cfs to about 220,000 cfs (USACE, 1998). Flows greater than 160,000 cfs (equivalent to a 10-year return interval event) still occur, but have a return interval of 40 years under regulated conditions. Low flows are less likely to occur during the winter, and are higher than for unregulated conditions.

The seasonal effects of flow regulation on the Skagit River are similar to those observed for the Baker River. Average daily flows are generally similar to unregulated conditions in the late summer, but the frequency of freshets is higher. Average daily flows are higher in the late fall and winter. Baker Project operations account for about almost 40 percent of the increase in November when the reservoirs are being drawn down for flood control, and for about 15 percent of the increase in December through March. During the spring flows in the Skagit River are currently lower than for unregulated conditions. Baker Project operations account for the majority of the difference in April, and from 20 to 25 percent of the difference in May and June. Hydropower operations capture freshets in the spring, reducing frequency of such events. Overall, monthly flows in the Skagit River under regulated conditions remain within the range of variability exhibited by unregulated flows.

The most notable change in the flow regime in the Skagit River resulting from Baker Project operations is in the timing, frequency and rate of change of daily flow fluctuations. Daily and hourly flow fluctuations in the Skagit River reflect a mixture of flow regulation effects and natural variability. The rate of change for hourly flow fluctuations is substantially greater than for unregulated conditions, frequently exceeding 6 inches per hour. Both the Baker Project and Skagit Project generate daily flow fluctuations. The rate of change associated with events originating at the Skagit Project attenuates by the time those flows reach the Skagit River near Concrete gage. Daily stage changes resulting from Baker Project operations attenuate somewhat as a result of the much larger size of the Skagit River channel as compared to the Baker River channel. However, stage changes resulting from Baker Project operations have a greater rate of change than those originating at the Skagit Project. The rate of change resulting from natural freshets in the fall and winter may approach the rate of change resulting from Baker Project operations, but is generally lower. Operations at the Baker Project flow changes resulting from operations at the Skagit Project, and natural flow fluctuations may result in additive or compensatory effects depending on the timing, magnitude and duration of flow changes.

In the spring, unregulated rivers in the Skagit basin experience regular daily flow fluctuations as a result of spring snowmelt. Diurnal fluctuations at the Skagit River near Concrete gage may have a magnitude similar to stage changes resulting from Baker Project operations (i.e., 2,800 to 4,000 cfs). However, diurnal flow fluctuations resulting from snowmelt generally occur over a 12-hour period as compared to an approximately 4-hour period for flow fluctuations resulting from Baker Project operations. As a result, the rate of change resulting from Baker Project operations is substantially greater that for unregulated diurnal flow fluctuations.

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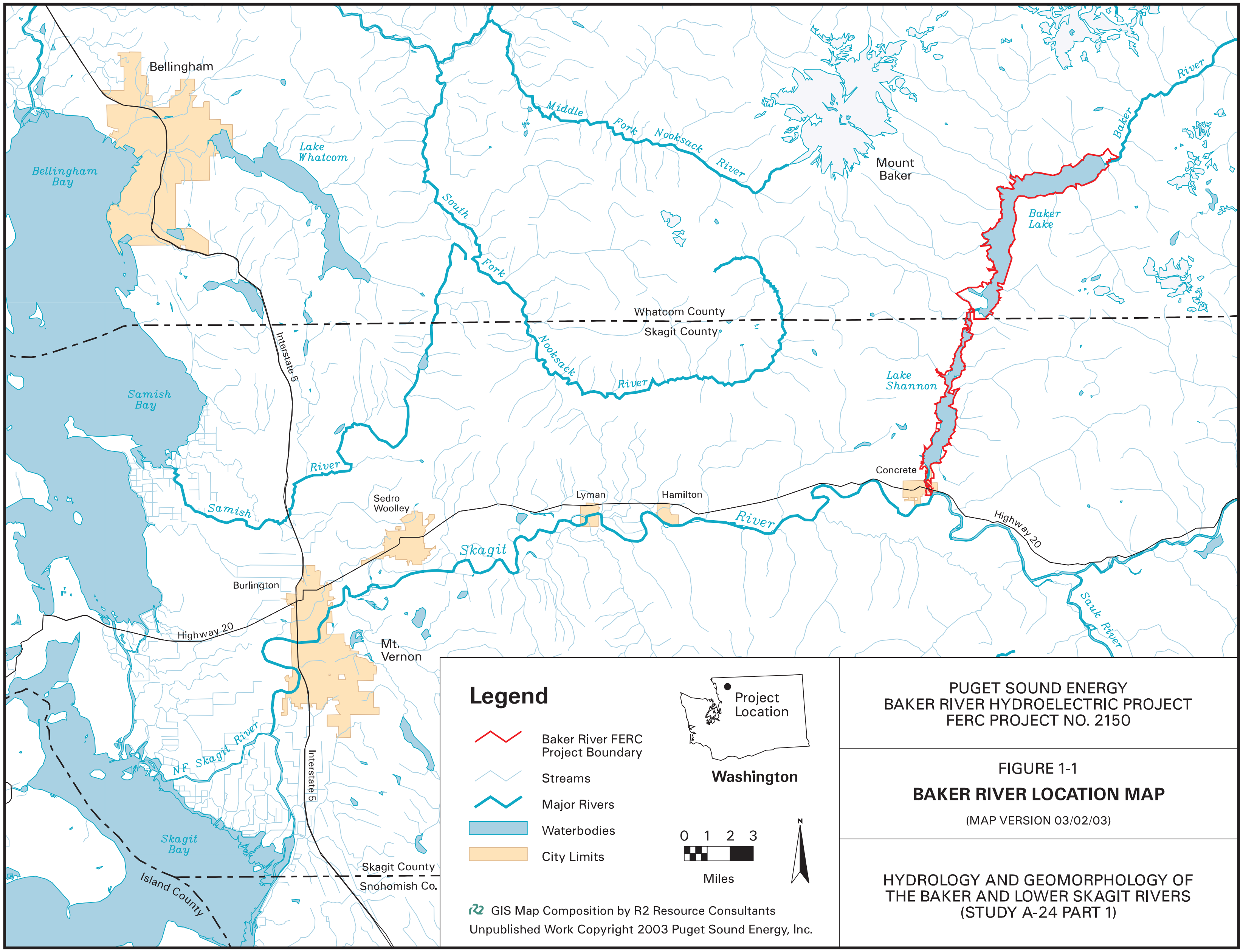

PUGET SOUND ENERGY
BAKER RIVER HYDROELECTRIC PROJECT
FERC PROJECT NO. 2150

FIGURE 1-1

BAKER RIVER LOCATION MAP

(MAP VERSION 03/02/03)

HYDROLOGY AND GEOMORPHOLOGY OF THE BAKER AND LOWER SKAGIT RIVERS (STUDY A-24 PART 1)