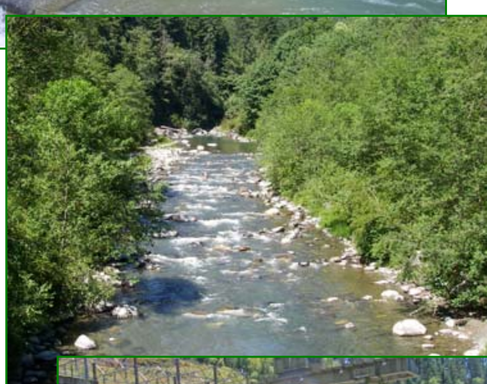
FINAL REPORT

HENRY M. JACKSON HYDROELECTRIC PROJECT

FERC No. 2157

Study Plan 23

Indicators of Hydrologic Alteration/Range of Variability Analysis (IHA/RVA) in the Sultan River Downstream of Culmback Dam



Prepared for:

Public Utility District No. 1
of Snohomish County
City of Everett

Prepared by:

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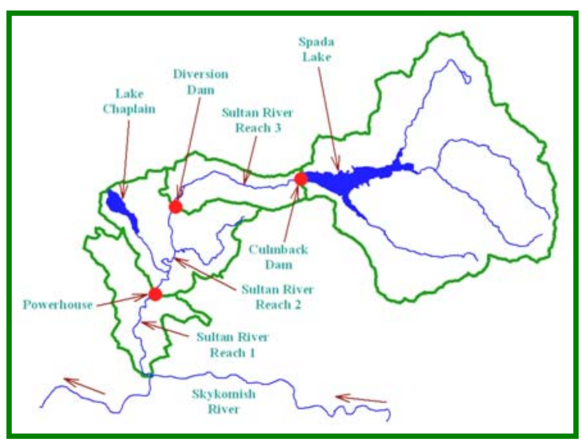

January 2008

Contents

Figures

Tables

EXECUTIVE SUMMARY

As part of relicensing activities for the Henry M. Jackson Hydroelectric Project (FERC No. 2157) (Project) an Indicators of Hydrologic Alteration/Range of Variability (IHA/RVA) study was requested by the Tulalip Tribes to quantify flow differences between pre-Project and post-Project conditions. Of particular interest are changes in the frequency and duration of intermediate-level flows that provide connectivity between main channel and lateral habitat areas, as well as the frequency and duration of higher flows that help maintain habitat diversity and natural levels of disturbance in the channel/riparian interface. The study was supported by other stakeholders including the U.S. Forest Service (USFS), Washington Department of Fish and Wildlife (WDFW), Washington Department of Ecology (Ecology), American Whitewater (AW), and Trout Unlimited (TU).

Indicators of Hydrologic Alteration/Range of Variability are components of an analytical software package typically used to characterize and compare complex river reach or river basin-scale hydrologic regimes from two or more periods of time, such as pre-dam and post-dam (The Nature Conservancy 2005). The program assesses and presents a summary of 67 hydrology statistics derived from daily hydrologic data (e.g., magnitude of monthly flows, timing of annual extreme water conditions, frequency and duration of high and low pulses, etc.). The results of an IHA/RVA analysis can then be used to illustrate the effects of Project operations on the unregulated (natural) flow regime.

In this study, the impact of Project operations was not assessed with respect to natural flows, but rather with respect to the flow regime associated with municipal water withdrawals. Three study reaches of the Sultan River downstream from Culmback Dam were presented as: from the Powerhouse to the confluence with the Skykomish River (Reach 1), from the Diversion Dam to the Powerhouse (Reach 2), and from Culmback Dam to the Diversion Dam (Reach 3). The IHA/RVA assessments were performed at the upstream and downstream ends of each of the three study reaches.

A common period was selected to perform this study, from July 1 1984 to June 30 2004. This 20-year period is representative of current Project operations. Pre-Project hydrology was synthesized using hydrologic records obtained from the US Geological Survey (USGS), the District, and the City. The selection of a common study period for comparing pre- and post-Project conditions enabled a direct assessment of Project-related effects without the confounding factors that would be associated with different study periods with differing hydrology.

Results of the analyses reported herein can be summarized on a reach by reach basis with respect to the five IHA parameter groups (magnitude of monthly water conditions, magnitude and duration of annual extreme water conditions, timing of annual extreme water conditions, frequency and duration of high and low pulses, rate and frequency of water condition changes), and with respect to the five Environmental Flow Component (EFC) parameter groups (monthly low flows, extreme low flows, high flow pulses, small floods, and large floods).

Summary results from the three study reaches of the Sultan River downstream from Culmback Dam are as follows:

1. ***Magnitude of monthly water conditions.*** Average monthly flows were increased in Reach 1 by the Project in July, August, September, December, and February, and were decreased in Reach 1 by the Project in October, November, January, March, April, May, and June. Average monthly flows were increased in Reach 2 by the Project in August and September, and were decreased in Reach 2 by the Project from October through July. Average monthly flows were decreased in Reach 3 by the Project for all 12 months of the year.

2. ***Magnitude and duration of annual extreme water conditions.*** The magnitudes of annual minimum flows were increased in Reaches 1 and 2 by the Project for all durations ranging from 1 to 90 days. The magnitudes of annual minimum flows were reduced in Reach 3 by the Project for all durations ranging from 1 to 90 days. The magnitudes of annual maximum flows were reduced in Reaches 1, 2, and 3 by the Project for all durations ranging from 1 to 90 days. There were no zero flow days in Reaches 1, 2, and 3 under pre-and post-Project conditions. The base flow index, defined as the ratio of the annual 7-day minimum flow divided by the annual mean flow, was increased in Reaches 1, 2, and 3 by the Project.

3. ***Timing of annual extreme water conditions.*** The annual 1-day minimum flow was shifted in Reach 1 by the Project earlier in the Water Year from September to August. The annual 1-day minimum flow at the upstream end of Reach 2 typically occurred in July under both pre-and post-Project conditions. The annual 1-day minimum flow was shifted at the downstream end of Reach 2 by the Project earlier in the Water Year from September to August. The annual 1-day minimum flow was shifted at the upstream end of Reach 3 by the Project earlier in the Water Year from September to July. The annual 1-day minimum flow at the downstream end of Reach 3 typically occurred in September under both pre-and post-Project conditions. The annual 1-day maximum flow was shifted in Reach 1 by the Project earlier in the Water Year from December to November. The annual 1-day maximum flow was shifted at the upstream end of Reach 2 by the Project earlier in the Water Year from December to November. The annual 1-day maximum flow at the downstream end of Reach 2 typically occurred in December under both pre-and post-Project conditions. The annual 1-day maximum flow was shifted at the upstream end of Reach 3 by the Project earlier in the Water Year from December to November. The annual 1-day maximum flow at the downstream end of Reach 3 typically occurred in December under both pre-and post-Project conditions.

4. ***Frequency and duration of high and low pulses.*** The occurrence of low flow pulses has been eliminated in Reaches 1 and 2 by the Project. The frequency of low flow pulses has been reduced and the duration has been increased in Reach 3 by the Project. The frequency of high flow pulses has decreased in Reach 1, and

the duration of high flow pulses has increased in Reach 1, as a result of Project operations. The frequency and duration of high flow pulses have both been decreased in Reaches 2 and 3, as a result of Project operations.

5. ***Rate and frequency of water condition changes.*** The rates of change of rising and falling flows have both been reduced in Reaches 1, 2, and 3 by the Project. The number of flow reversals in Reaches 1 and 2 have both been increased by the Project. The number of flow reversals has been reduced at the upstream end of Reach 3 and increased at the downstream end of Reach 3 by the Project.

6. ***Monthly low flows.*** The monthly low flows were increased in Reach 1 by the Project from July through March, and were decreased in Reach 1 by the Project from April through June. The monthly low flows were increased in Reach 2 by the Project from August through October, and were decreased in Reach 2 by the Project from November through July. The monthly low flows were decreased in Reach 3 by the Project for all 12 months of the year.

7. ***Extreme low flows.*** The occurrence of extreme low flows has been eliminated in Reaches 1 and 2 by the Project. The magnitude of extreme low flows has been reduced in Reach 3 by the Project. The duration of extreme low flows has been increased at the upstream end of Reach 3 and reduced at the downstream end of Reach 3 by the Project. Extreme low flows have been shifted at the upstream end of Reach 3 by the Project later in the Water Year from September to December. Extreme low flows have been shifted at the downstream end of Reach 3 by the Project later in the Water Year from September to January. The frequency of extreme low flows has been reduced at the upstream end of Reach 3 and increased at the downstream end of Reach 3 by the Project.

8. ***High flow pulses.*** The magnitude of high flow pulses was reduced, and the duration of high flow pulses was increased in Reach 1 by the Project. The magnitude and duration of high flow pulses have both been reduced in Reach 2 by the Project. The magnitude of high flow pulses has been increased at the upstream end of Reach 3 and reduced at the downstream end of Reach 3 by the Project. The duration of high flow pulses has been reduced in Reach 3 by the Project. High flow pulses typically occurred in February in Reach 1 under both pre- and post-Project conditions. High flow pulses were shifted at the upstream end of Reach 2 by the Project earlier in the Water Year from February to December. High flow pulses were shifted at the downstream end of Reach 2 by the Project earlier in the Water Year from February to January. High flow pulses were shifted at the upstream end of Reach 3 by the Project earlier in the Water Year from February to November. High flow pulses were shifted at the downstream end of Reach 3 by the Project earlier in the Water Year from February to December. The frequency of high flow pulses has been reduced in Reaches 1, 2, and 3 by the Project. The rates of change of rising and falling flows during high flow pulses have both been reduced in Reach 1 by the Project. The rate of change of rising flows during high flow pulses has been reduced in Reach 2 by the Project. The rate of change of falling flows has been increased at the

upstream end of Reach 2 and reduced at the downstream end of Reach 2 by the Project. The rates of change of rising and falling flows during high flow pulses have both been increased in Reach 3 by the Project.

9. ***Small floods.***

Based on Pre-Project conditions, small floods were defined to peak within the following ranges of flows:

- **Reach 1, Upstream End –** 10,300 to 16,600 cfs
- **Reach 1, Downstream End –** 11,200 to 17,700 cfs
- **Reach 2, Upstream End –** 9,000 to 15,300 cfs
- **Reach 2, Downstream End –** 10,300 to 16,600 cfs
- **Reach 3, Upstream End –** 8,500 to 14,700 cfs
- **Reach 3, Downstream End –** 9,100 to 15,500 cfs

The recurrence interval of small magnitude flows has been increased from 2 years to about 20 years in Reaches 1, 2, and 3 by the Project. The peak magnitude of small magnitude floods has been reduced and the duration of small magnitude floods has been increased in Reach 1 by the Project. The peak magnitude of small magnitude floods has been increased at the upstream end of Reach 2 and decreased at the downstream end of Reach 2 by the Project. The duration of small magnitude floods has been reduced in Reach 2 by the Project. The peak magnitude of small magnitude floods has been increased Reach 3 by the Project. The duration of small magnitude floods has been reduced in Reach 3 by the Project. The rates of change of rising and falling flows during small magnitude floods have both been reduced in Reach 1 by the Project. The rate of change of rising flows during small magnitude flows was increased and the upstream end of Reach 2 and reduced at the downstream end of Reach 2 by the Project. The rate of change of falling flows during small magnitude floods has been increased in Reach 2 by the Project. The rates of change of rising and falling flows during small magnitude floods have both been increased in Reach 3 by the Project.

10. ***Large floods.***

Based on Pre-Project conditions, large floods were defined to have peaks with the following magnitudes:

- **Reach 1, Upstream End –** greater than 16,600 cfs
- **Reach 1, Downstream End –** greater than 17,700 cfs
- **Reach 2, Upstream End –** greater than 15,300 cfs

- **Reach 2, Downstream End –** greater than 16,600 cfs
- **Reach 3, Upstream End –** greater than 14,700 cfs
- **Reach 3, Downstream End –** greater than 15,500 cfs

The recurrence interval of large magnitude flows has been increased from 10 years to about 20 years in Reaches 1, 2, and 3 by the Project. The peak magnitude of large magnitude floods and the duration of large magnitude floods have both been increased in Reach 1 by the Project. The peak magnitude of large magnitude floods has been increased in Reach 2 by the Project. The duration of large magnitude floods has been reduced in Reach 2 by the Project. The peak magnitude of large magnitude floods has been increased in Reach 3 by the Project. The duration of large magnitude floods has been reduced in Reach 3 by the Project. The rates of change of rising and falling flows during large magnitude floods have both been reduced in Reach 1 by the Project. The rates of change of rising and falling flows during large magnitude floods have both been increased in Reaches 2 and 3 by the Project.

1.0 STUDY OBJECTIVES AND DESCRIPTION

Indicators of Hydrologic Alteration/Range of Variability (IHA/RVA) are components of an analytical software package typically used to characterize and compare complex river reach or river basin-scale hydrologic regimes from two or more periods of time, such as pre-dam and post-dam (The Nature Conservancy 2005). The program assesses and presents a summary of 67 hydrology statistics derived from daily hydrologic data (e.g., magnitude of monthly flows, timing of annual extreme water conditions, frequency and duration of high and low pulses, etc.). The results of an IHA/RVA analysis can then be used to illustrate the effects of project operations on the unregulated (natural) flow regime.

As part of relicensing activities for the Henry M. Jackson Hydroelectric Project (FERC No. 2157) (Project) an Indicators of Hydrologic Alteration/Range of Variability (IHA/RVA) study was requested by the Tulalip Tribes to quantify flow differences between pre-Project and post-Project conditions. Of particular interest are changes in the frequency and duration of intermediate-level flows that provide connectivity between main channel and lateral habitat areas, as well as the frequency and duration of higher flows that help maintain habitat diversity and natural levels of disturbance in the channel/riparian interface. The study was supported by other stakeholders including the U.S. Forest Service (USFS), Washington Department of Fish and Wildlife (WDFW), Washington Department of Ecology (Ecology), American Whitewater (AW), and Trout Unlimited (TU).

The overall objective of the IHA/RVA study is to quantify flow differences between pre-Project and post-Project conditions. Project operations affect the flow in the Sultan River in three Project-affected reaches; between the Powerhouse and the confluence with the Skykomish River (Reach 1), between the Diversion Dam and the Powerhouse (Reach 2), and between Culmback Dam and the Diversion Dam (Reach 3), as shown in Figure 1-1. These changes affect the quantity and quality of habitat available for both the aquatic and riparian communities. Flow differences between pre-Project and post-Project conditions will be made at the upstream and downstream ends of each of these three reaches.

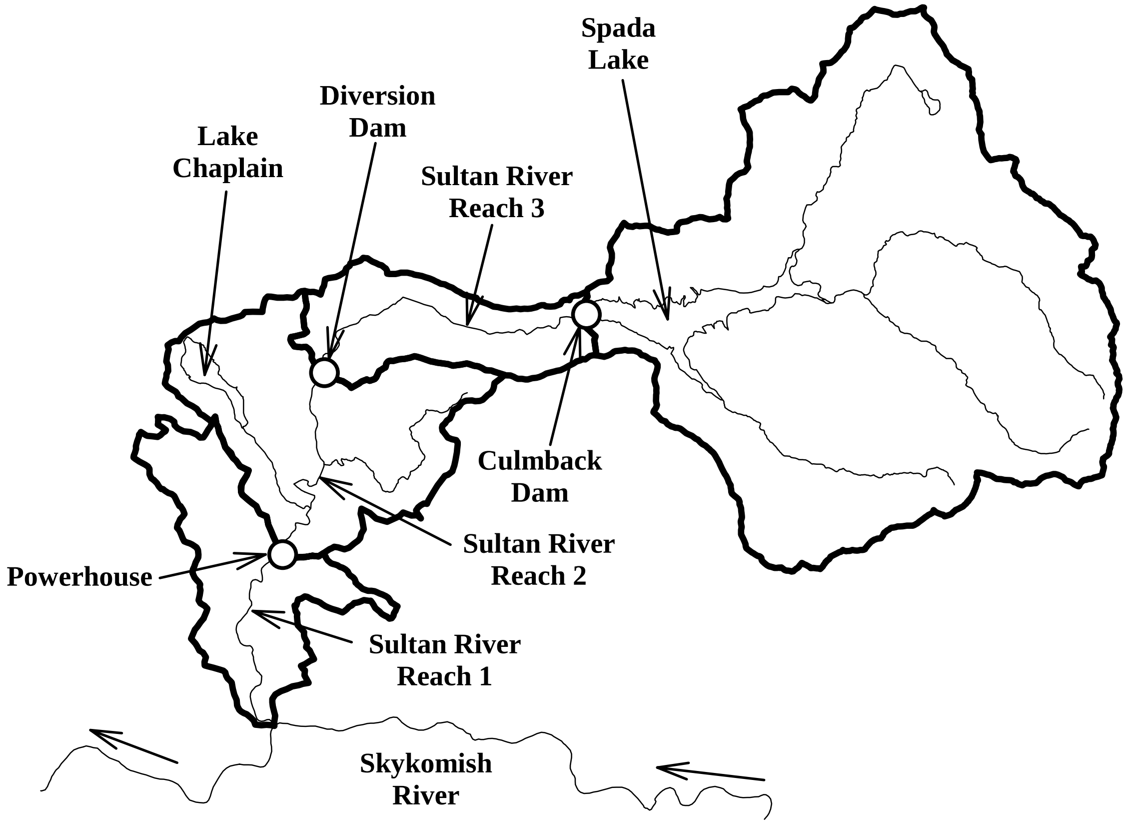

Figure 1-1 Study reaches 1, 2, and 3 on the Sultan River, Washington below Culmback Dam.

2.0 BACKGROUND INFORMATION

The Public Utility District No. 1 of Snohomish County (District) and the City of Everett (City) filed a joint application with the Federal Power Commission (now known as the Federal Energy Regulatory Commission or FERC) in 1960 to develop what was then known as the Sultan River Project (Public Utility District No. 1 of Snohomish County and City of Everett 2005 – much of the information presented in this report was obtained from this reference, unless otherwise cited). From the beginning, the Project was seen as serving two purposes; generating power for the District from the waters of the Sultan River and increasing the City's water supply system to meet growing demands. A license authorizing construction of the Project in two phases was issued on June 6, 1961.

The Stage I development was completed in 1965 and involved the construction of Culmback Dam and the creation of a reservoir known as Spada Lake, which greatly increased the City's water supply available from the Sultan River Basin. Originally, Stage II, the addition of the hydropower generation facilities, was to commence in 1967. Economic studies undertaken at that time indicated the cost of power from the Bonneville Power Administration (BPA) was still low enough to call into question the financial feasibility of moving ahead with Stage II. FERC granted a series of time extensions so the District and the City could investigate alternative plans.

In 1976, BPA, the source of almost all of the District's power at that time, announced it would not be able to meet the District's power needs after mid-1983. BPA offered to purchase the early years of power from new non-thermal resources, which motivated the District to develop the generating potential of the Sultan River.

On July 6, 1979, the District and the City filed an application with FERC to amend the original license with a revised hydroelectric scenario better suited to the regional economic and load demand projections, and to reduce the environmental impacts of the original design. FERC granted this amendment on October 16, 1981, and construction of generating facilities and raising of Culmback Dam commenced in 1982. One of the earliest Settlement Agreements with several state and federal agencies and the Tulalip Tribes (the Joint Agencies) was filed with the FERC and accepted in 1982. The Project was renamed after the late Senator Henry M. Jackson in 1984 when operation began. Several license-required plans were developed in consultation with the Joint Agencies and subsequently adopted by the FERC. These were the Wildlife Habitat Management Plan (1988), the Project Recreation Plan (1992), and the Project Operating Plan (1996). The current operating license for the Project will expire on May 31, 2011.

2.1 Sultan River Basin Description

The Jackson Project (Project) is located on the Sultan River, approximately 24 miles east of Everett, Washington, in south central Snohomish County. From its headwaters near Vesper Peak on the western slope of the Cascade Mountains, the Sultan River flows west for approximately 19 miles, then south-southwest for 11 miles to its confluence with the Skykomish River at the City of Sultan (river mile [RM] 34.4). The Skykomish River drains the northern 835 square miles of the Snohomish River Basin, the second largest river basin draining into Puget Sound (Haring 2002).

The Sultan River has a watershed area of approximately 105 square miles, as shown in Figure 2-1. The Sultan River watershed can be divided into four sub-basins: upstream from Culmback Dam (68.3 square miles): between Culmback Dam and the Diversion Dam (8.8 square miles); between the Diversion Dam and the Powerhouse (17.1 square miles); and between the Powerhouse and the confluence with the Skykomish River (10.7 square miles).

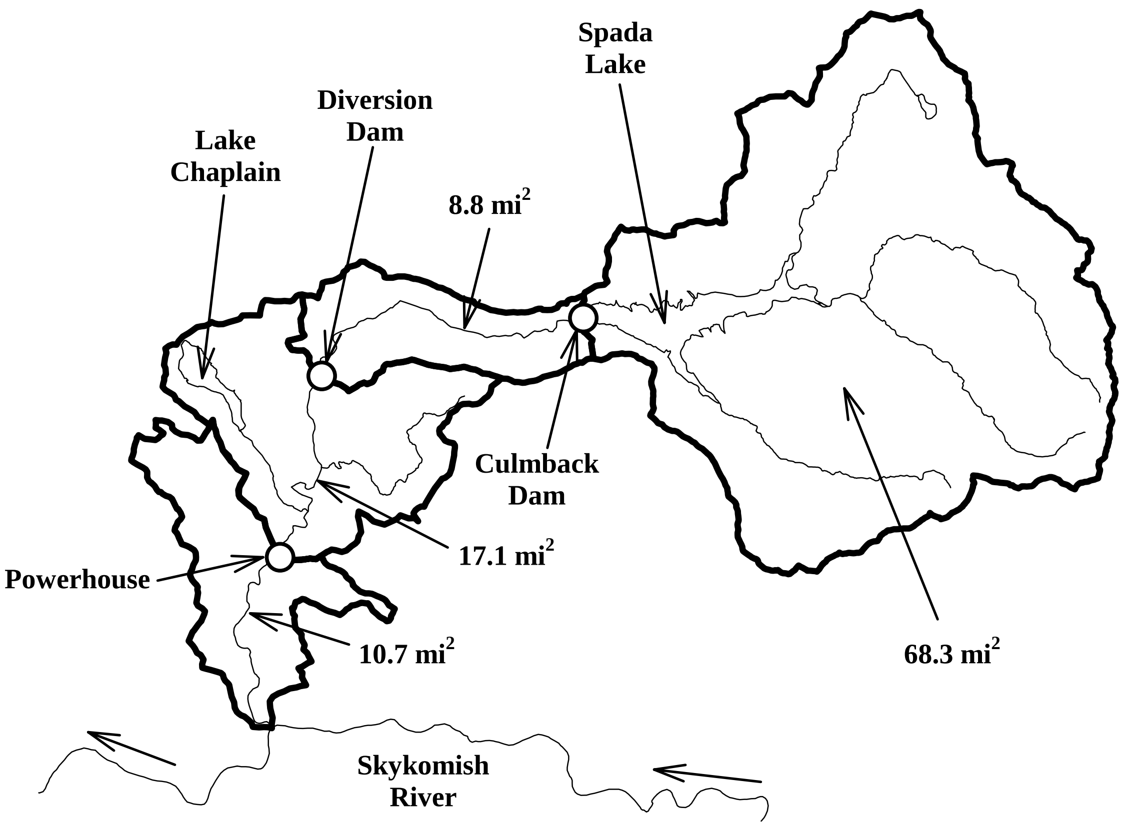

Figure 2-1 Four sub-basins of the Sultan River watershed.

The basin is bounded on the east by the Cascade Mountains, on the north and south by lateral ridges extending westward from the Cascade crest, and on the west by the Puget Sound lowlands. Elevations in the basin range from the 6,617-foot summit of Del Campo Peak to 130 feet at the confluence of the Sultan and Skykomish rivers. Major tributaries to the Sultan River above Culmback Dam include the South Fork Sultan River, North Fork Sultan River, Elk Creek, and Williamson Creek. Downstream of Culmback Dam, major tributaries include Marsh Creek, Chaplain Creek, Woods Creek (drains Woods Lake), Ames Creek, and Winters Creek.

In the headwaters upstream from Elk Creek (RM 22.8), the Sultan River flows through a narrow steep-sloped, densely forested valley. The river channel is relatively steep and narrow, containing numerous small falls, cascades, and rapids, and a few short pool-riffle stretches. From Elk Creek downstream to Spada Lake (formed by Culmback Dam), the channel gradient is moderate with only a few steep areas.

Downstream of Culmback Dam (RM 16.5), the Sultan River flows through a deep gorge for nearly 14 miles. The steep side slopes above the channel are densely forested with conifer and mixed deciduous growth. The river channel in this reach is relatively high gradient and confined, containing numerous cascades and rapids separated by short pool-riffle, stretches. Much of the streambank is sheer rock face or large rock cuts (Williams et al. 1975). The City's Diversion Dam at RM 9.7 historically directed a portion of the river's flow to its water supply reservoir, Lake Chaplain. While that method of diversion remains in place and is used when Project maintenance or other reasons require, water now is normally supplied to Lake Chaplain through the Lake Chaplain pipeline after passing through the Project Powerhouse. Near RM 3, the Sultan River emerges from the canyon reach onto a broad, relatively flat valley floor containing intermittent stands or strips of deciduous trees, underbrush, and some mixed conifers. The river channel in this reach has a moderate gradient with a number of split channel sections.

2.2 Climate

The climate of the area is influenced by the proximity of the Pacific Ocean and Puget Sound. Cool, dry summers and mild, rainy winters are characteristic of the area. Weather conditions within the Project area vary according to topography, distance from Puget Sound, and elevation. Spada Lake and the surrounding watershed, which rises up to 6,000 feet mean sea level (msl), receive heavier precipitation in the form of rain and snow and generally lower temperatures than the lower Sultan River near the powerhouse(280 feet msl).

Monthly average daily maximum and minimum temperatures, and monthly average daily precipitation observed at the District's station at Spada Lake (1,480 feet msl) are shown in Figure 2-2. The wettest months (November through March) coincide with the coldest months of the year. Some of the precipitation that falls during this period is stored in the snowpack at higher elevations, and subsequently released when temperatures warm up during the spring.

Prevailing winds in the Project area are from the south or southwest in the winter, and west or northwest in the summer. Both wind direction and speed near Spada Lake are influenced by the mountains surrounding the lake. Wind currents usually follow the east-west axis of the lake valley, and wind speeds are slowed by the terrain. A weather station at Spada Lake recorded monthly average speeds of 2.0 to 5.1 miles per hour (mph) from August 1978 to April 1979, with a maximum gust of 35 mph. Hurricane force winds (greater than 75 mph) rarely occur in the Project area (WRCC 2005).

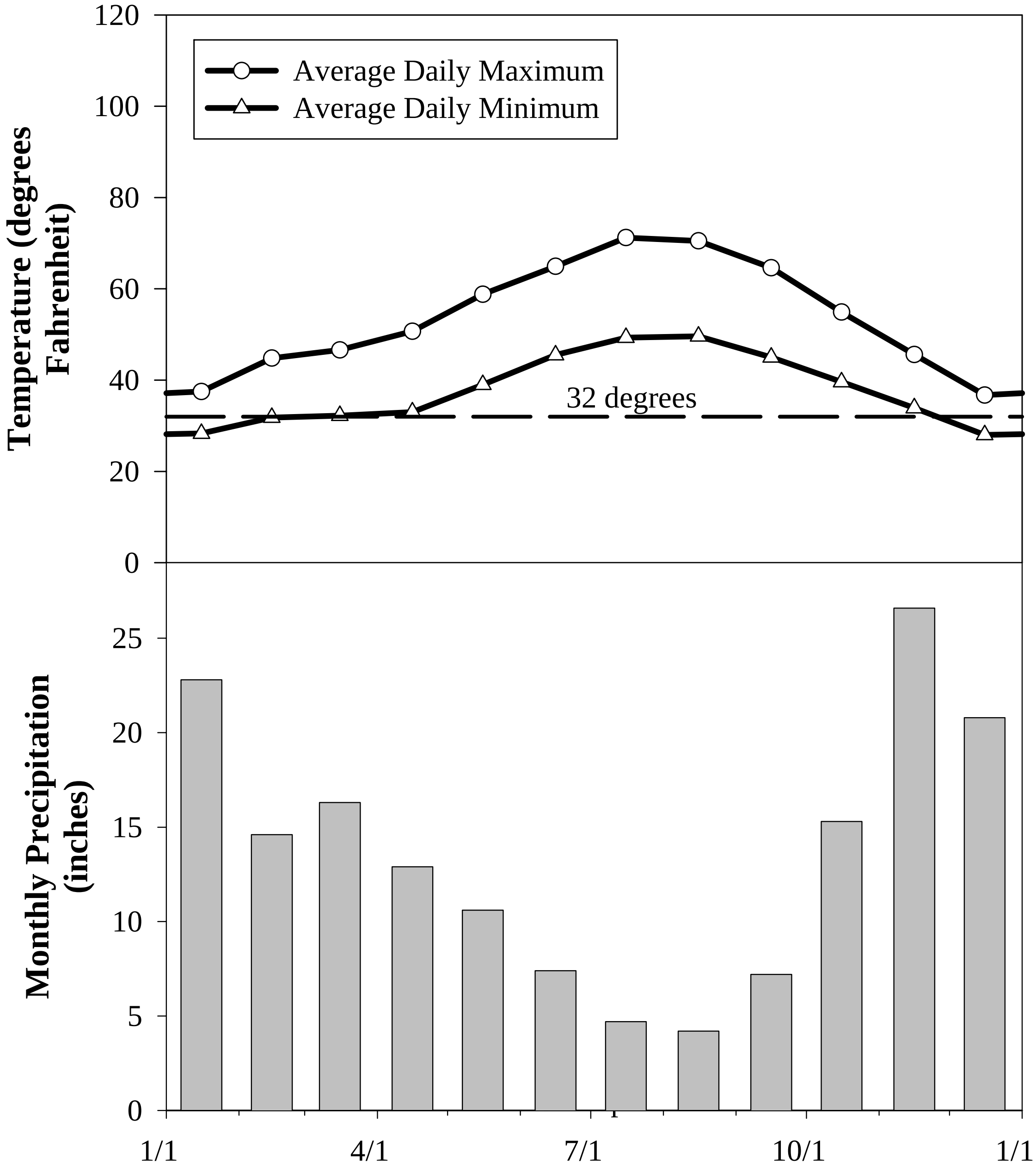

Figure 2-2 Monthly average daily maximum and minimum temperatures, and monthly average daily precipitation at Spada Lake, Washington (from data collected by the District).

2.3 Project Operations

In 1930, the City of Everett constructed, at RM 9.7, the Diversion Dam that exists today. This dam was used to divert water from the Sultan River, through a pipeline and tunnel, west to Lake Chaplain for municipal water supply storage. In 1965, Stage I of Culmback Dam was built at RM 16.5 for additional storage of municipal water supply, but the traditional operation of the Diversion Dam and tunnel to Lake Chaplain were essentially unchanged. With completion of the Stage II hydroelectric project facilities in 1984 (which included a raised Culmback Dam, a power tunnel and pipeline, a powerhouse, and a Lake Chaplain pipeline from the powerhouse to Lake Chaplain), the function of the Diversion Dam changed considerably. “Traditionally,” or prior to the completion of Stage II, water flowed west from the Diversion Dam through the tunnel to Lake Chaplain; post-Stage II, water now flows east through the tunnel between Lake Chaplain and the Diversion Dam. Some of the water diverted from Spada Lake at Culmback Dam is now returned to the Sultan River at the Diversion Dam to provide minimum instream flows below that point for fishery protection and enhancement.

Under current operations, 20 cfs of water is released from Culmback Dam into the river reach between Culmback Dam and the City’s Diversion Dam at all times. This 20 cfs, plus natural inflow from streams above the Diversion Dam, provides a constant flow for the fisheries in this reach. The rest of the water diverted from Spada Lake travels through the power tunnel and power pipeline to the powerhouse. Most of the water delivered to the powerhouse in this manner passes through the Pelton turbines for electrical generation and is returned to the river at the powerhouse. However, an amount of water necessary for municipal supply and maintenance of minimum instream flows in the reach below the Diversion Dam is routed through two Francis turbines in the powerhouse, and then through the Lake Chaplain pipeline to the “Portal 2” facilities on the shores of Lake Chaplain.

At Lake Chaplain, a portion of the water in the Lake Chaplain pipeline is diverted by means of the “Portal 2” facilities to the lake for municipal water supply. The remainder is transported east via the original water diversion tunnel back to the Sultan River at the Diversion Dam to provide minimum instream flows in the reach between the Diversion Dam and the powerhouse. In this manner, regulated fish flows are maintained for the full length of the Sultan River below Culmback Dam, with larger flows provided below the Diversion Dam and powerhouse where river conditions offer more suitable fish habitat than exists in the reach above the Diversion Dam. As noted above, prior to the Stage II raising of Culmback Dam and construction of the hydroelectric facilities completed in 1984, Sultan River flows were diverted by the City’s Diversion Dam in a westerly direction through the tunnel into Lake Chaplain to meet the City of Everett’s municipal water supply needs. Under current normal Project operations, flows through the diversion tunnel are now reversed from the original diversion flows. Water from Spada Lake can generate power and be transported by pipeline back up to Lake Chaplain and the Diversion Dam because Spada Lake is approximately 700 feet higher in elevation than Lake Chaplain and the Diversion Dam.

Occasionally, when storm events cause natural inflows within the reach between Culmback Dam and the City's Diversion Dam to exceed the combined total flows needed to meet both the City's water supply requirements and established minimum instream flows below the Diversion Dam, the Diversion Dam will be made to operate in its original manner. At these times, water for municipal supply will be diverted from the Sultan River by the Diversion Dam and routed westerly through the tunnel to Lake Chaplain. Remaining flows in the river are allowed to pass over the Diversion Dam to provide required instream flows. The Powerhouse then routes water diverted from Spada Lake through only the larger Pelton units for more efficient power generation, and then immediately returns the water to the river. This method of operation captures excess rainfall from storm events in Spada Lake and saves it for later generation, municipal water supply and fish flows, as needed. In this manner, available rainfall, whether in the reach above the Diversion Dam or above Spada Lake, is utilized with greatest efficiency and maximum benefit. This method of operation is used only when the water in the Sultan River from natural inflow meets the City's requirements regarding turbidity levels for water supply.

Should the Project power pipeline, power tunnel, or Powerhouse be shut down for any reason, the Diversion Dam and tunnel can be operated in their traditional (pre-Stage II) manner to divert and carry flows from the Sultan River to Lake Chaplain. During this shutdown operation, sufficient flows are released from Culmback Dam to supply the required instream flows at the powerhouse and water flows to Lake Chaplain.

The Project reservoir, Spada Lake, has a gross area of 1,870 acres at elevation 1,450 feet mean sea level (msl) with a gross storage capacity of 153,260 acre-feet. While the maximum operating pool is at elevation 1,450 feet msl, the normal full pool is 1,445 feet msl, typically occurring from June through mid-July. Annually, starting in late July, the District lowers the pool to elevation 1,415 feet msl by mid-September to avoid spill in the later fall. This measure provides approximately 58,500 acre-feet of incidental flood storage prior to the onset of the October to December wet season. There is no minimum normal operating pool elevation for the Project because operations vary depending on the winter hydrologic conditions. To date, the lowest operating pool, elevation 1,395.5 feet msl, occurred on January 20, 1993. To avoid vortex stresses in the power tunnel, diversion of water into the power tunnel ceases if the pool elevation drops to 1,380 feet or lower.

The Project uses all inflow to Spada Lake to generate power except for required minimum instream flow releases (to protect and enhance fisheries) and any spill at Culmback Dam. Water required to meet the City's municipal supply demands and to supplement instream flows for fisheries below the Diversion Dam generates power through two Francis turbine units installed at the Powerhouse, using the 700 feet of elevation difference (also known as "head") between Spada Lake and Lake Chaplain. Water in excess of the above requirements generates power through two Pelton units discharging directly into the Sultan River, utilizing the 1,000 feet of head between Spada Lake and the Powerhouse.

Project operations have altered the seasonal flow pattern in the Sultan River. The reservoir rule curves are shaped to minimize spill (uncontrolled release of water via the spillway) and provide storage of spring runoff for municipal water supply and instream flow augmentation later in the year during the driest months. This strategy provides significant incidental floodwater storage. With the same total volume of runoff from basin rainfall and snow melt, the historically higher peak flows in the lower Sultan River that occurred previously in late fall, early winter, and spring have been reduced in both amplitude and frequency. Total volume of flow below the Diversion Dam is reduced by withdrawals for municipal water supply, which averaged 130 cfs from water year 1996 through 2004. This pre-existing right for municipal water withdrawals is not an impact of Project operations.

The Project is operated to meet ramping rate restrictions in the Sultan River below the Diversion Dam and below the Powerhouse. The Project is also operated to meet minimum flow restrictions in the Sultan River below Culmback Dam, below the Diversion Dam, and below the Powerhouse, as listed in Table 2-1.

Table 2-1 Sultan River instream flow requirements

Date	Point of Discharge	Minimum Flow (cfs)
All Year	Culmback Dam	20
11/1 -–1/15	Diversion Dam	95
1/16 – 2/28	Diversion Dam	150
3/1– 6/15	Diversion Dam	175
6/16 – 9/14	Diversion Dam	95
9/15 – 9/21	Diversion Dam	145
9/22 – 10/31	Diversion Dam	155
6/16 – 9/14	Powerhouse	165
9/15 – 6/15	Powerhouse	200

3.0 METHODS

Available hydrologic records were obtained and used to derive a 20-year period of daily flows representative of pre-Project conditions and a 20-year period of daily flows representative of post-Project conditions. As previously mentioned in Section 2, the pre-existing right for municipal water withdrawals is not an impact of Project operations. Thus, the impact of Project operations is not assessed with respect to natural flows, but with respect to the flow regime associated with municipal water withdrawals.

3.1 Available Hydrologic Data

Available hydrologic data from the Sultan River Basin were obtained from the US Geological Survey (USGS), and from the District and the City. These flow records were measured or synthesized at different locations, during different periods, and under different phases of the Project. The flow records were reviewed to select appropriate data and an appropriate study period for these analyses.

Available hydrologic records in the Sultan River Basin from the USGS are summarized in Table 3-1. Flows have been measured in three tributaries of Spada Lake: Elk Creek; Williamson Creek; and the South Fork of the Sultan River. Flows have been measured at five locations on the Sultan River between River Miles 4.5 and 11.3. Water surface elevations have been measured in Spada Lake.

Monthly average water withdrawals for municipal water supply from the Sultan River Basin have been reported by the City of Everett from July 1995 through June 2005. Synthesized daily natural (unimpaired) flows were obtained from the District's relicensing website (http://www.snopud.com/water/relicensing/history/existing/water.ashx?p=2576). These daily flows span the 105-year period from July 1 1899 to June 30 2004. Daily synthesized flows are reported for the following five sub-basins of the Sultan River upstream from the Powerhouse:

1. Inflow to Spada Lake – 68.3 square miles.
2. Tributary flows to the Sultan River between Culmback Dam and the Diversion Dam – 8.8 square miles.
3. Tributary flows to the Sultan River between the Diversion Dam and just upstream from confluence with Chaplain Creek – 10.3 square miles.
4. Inflow to Lake Chaplain – 3.4 square miles.
5. Tributary flows to the Sultan River from confluence with Chaplain Creek (including Chaplain Creek but not including inflow to Lake Chaplain) to Powerhouse – 3.4 square miles.

Table 3-1. Current and historic USGS gaging stations within the Sultan River Basin

Site Name	USGS Gaging Station Number	River Mile	Drainage Area (mi^2)	Period of Record	Status	Comment
Elk Creek	12137200	22.8	11.4	11/24/76 to 11/10/83	Discontinued	
Williamson Creek	12137260	20.9	15.6	11/24/76 to 11/10/83	Discontinued	Missing records 10/15/83 to 10/17/83 10/22/83 to 10/23/83 10/31/83 11/2/83 to 11/6/83
South Fork Sultan River	12137290	18.2	11.6	10/1/91 to present	In current use	Missing record 11/6/06
Spada Lake	12137300	16.5	68.3	4/6/65 to 9/30/06	In current use	Missing records 10/1/93 to 9/30/94
Sultan River near Startup, WA	12137500	11.3	74.5	5/1/34 to 6/30/71	Discontinued	
Sultan River below Diversion Dam	12137800	9.7	77.1	5/1/83 to present	In current use	
Sultan River near Sultan	12138000	7.3	86.6	10/1/11 to 9/30/31	Discontinued	Missing records 11/1/26 to 2/28/29
Sultan River below Chaplain Creek	12138150	4.9	92.6	11/1/74 to 10/16/84	Discontinued	
Sultan River below Powerhouse	12138160	4.5	94.2	7/19/83 to present	In current use	

In reviewing all of the available records, it became obvious that the flows measured at the USGS Gages on the Sultan River below the Powerhouse and below the Diversion Dam (Gages 12138160 and 12137800) since 1983 could be utilized to represent post-Project conditions at the upstream ends of Reaches 1 and 2, respectively. These records could be combined with the natural flows synthesized by the District to estimate flows at the downstream ends of Reaches 1 and 2 by accounting for the appropriate drainage areas. Flows in Reach 3 could be estimated by comparing flows in the Sultan River below the Diversion Dam with the instream flow requirements listed in Table 2-1, and by accounting for the tributary inflow between Culmback Dam and the Diversion Dam. A 20-year period extending from July 1, 1984 to June 30, 2004 was selected for post-Project conditions, based on a common period that would include data from the different sources. A detailed description of these calculations will be provided herein.

In the Revised Study Plans (Public Utility District No. 1 of Snohomish County and City of Everett 2006), flow records from the Sultan River near Sultan (USGS Gage 12138000) were proposed for pre-Project conditions, because they covered a 20-year period extending from October 1, 1911 to September 30, 1931. However, closer inspection of records from this gage revealed missing records from a 28-month period extending from November 1926 through February 1929.

Furthermore, the use of records from different time periods for comparing pre-Project and post-Project conditions may be inappropriate because one period might be wetter or drier than the other period, or one period might have an extremely wet or dry year that is not represented in the other period. Therefore the period from July 1, 1984 to June 30, 2004 was selected to represent pre-Project conditions. Water use records during this period are available from the City from July 1995 to June 2004, and can be estimated for the other months. Synthesized flow records obtained from the District were reviewed, and modified as necessary, to represent pre-Project conditions.

3.2 Synthesis of Natural Conditions

Daily flow records synthesized by the District to represent natural (unimpaired) flow conditions from July 1, 1984 to June 30, 2004 were reviewed. These synthesized flows are based on estimates of total inflow to Spada Lake. Flows in downstream sub-basins were estimated by applying monthly flow ratios to the daily inflows to Spada Lake.

Synthesized inflows to Spada Lake were subsequently reviewed. While the daily inflows for the first five years (July 1, 1984 to June 30, 1989) appeared to be reasonable, the daily inflows for the next fifteen years (July 1, 1990 to June 30, 2004) had a total of 53 days with zero inflow. In contrast, flows measured by the USGS in one of the tributaries to Spada Lake (South Fork Sultan River, Gage No. 12137290) have never been reported to be zero. The days with zero flow reported for total inflow to Spada Lake were likely the result of the process used to synthesize those flows – reverse reservoir routing. This method of synthesizing inflows can result in flow fluctuations associated with small errors in measured water surface elevations in Spada Lake. Wind-generated waves can also introduce small errors in measured water surface elevations, which can translate into random errors of estimated inflow.

An approximate measure of this effect can be made by calculating the annual number of peak flows, defined as when the flow on any given day is greater than the flow on the preceding or following day. Results of these calculations are shown in Figure 3-1. From 1985 through 1989, there were an average of 52 peaks per year, and from 1990 through 2004, there were an average of 93 peaks per year. The increased number of peaks from 1990 through 2004 is associated with the random errors in the reverse routing calculations.

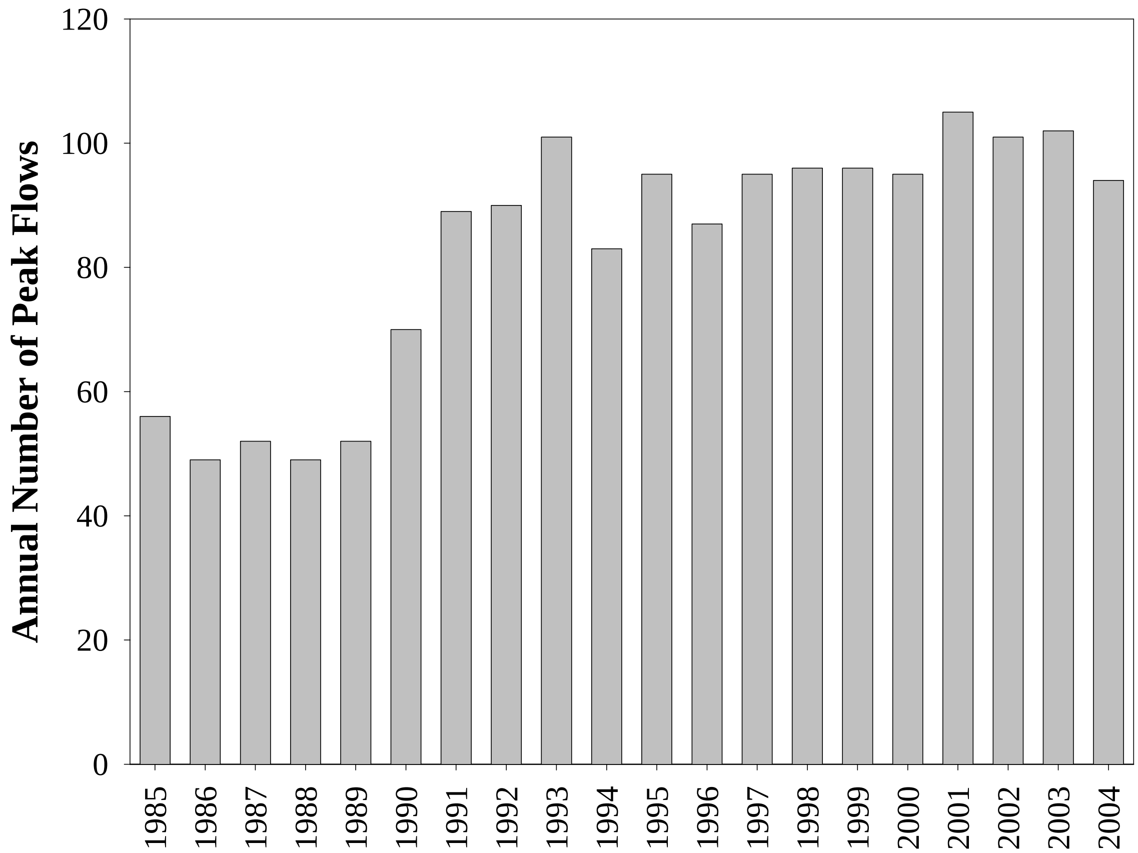

Figure 3-1 Annual number of peak flows from raw synthesized inflows to Spada Lake, 1985 through 2004.

The number of annual peaks was also calculated for the Sultan River near Startup (USGS Gage 12317500) from 1935 through 1961, prior to the construction of Culmback Dam. Results of these calculations are shown in Figure 3-2. The average number of annual peaks from 1935 through 2004 was 53, similar to the average number of peaks in the synthesized inflows to Spada Lake from 1985 through 1989, and much less than the average number of peaks in the synthesized inflows to Spada Lake from 1990 through 2004.

This suggested that the synthesized inflows to Spada Lake would need to be adjusted prior to further analysis. The synthesized inflows from 1990 through 2004 were adjusted by smoothing, while preserving the overall flow volume. The number of annual peak flows after adjustment is shown in Figure 3-3.

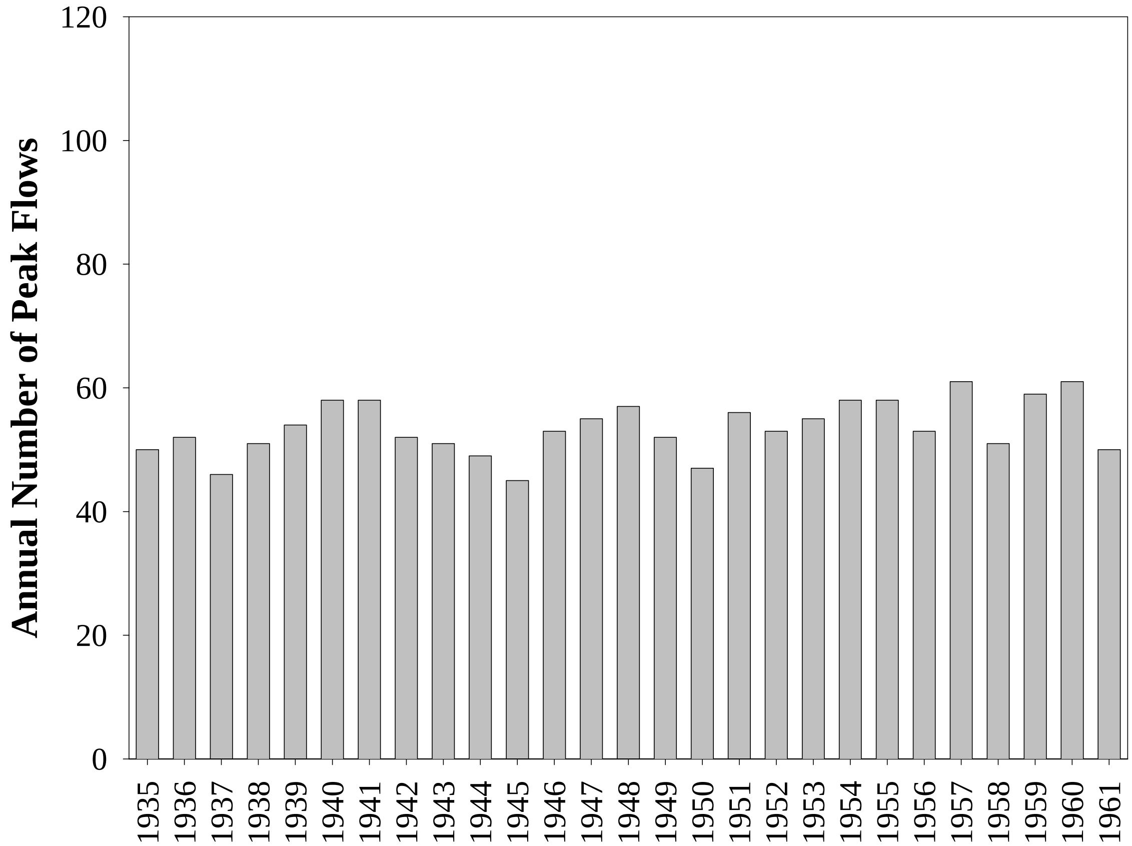

Figure 3-2 Annual number of peak flows from the Sultan River near Startup (USGS Gage 12137500), 1935 through 1961.

The average number of peaks from 1985 through 2004, after adjustments, was 53, the same as the average number of peaks from the Sultan River near Startup (USGS Gage 12137500). An example of the daily inflows to Spada Lake before and after adjustments is shown in Figure 3-4, based on the period extending from March 1 2001 to November 1 2001. The hydrograph, prior to adjustments, included eight days with zero flow during this 8-month period. There were no days with zero flow after the adjustments.

As previously mentioned, synthesized daily natural inflows to sub-basins downstream from Culmback Dam were estimated by the District by multiplying the daily inflows to Spada Lake by the drainage area ratio and by applying a monthly seasonal adjustment factor. The monthly seasonal adjustment factors used by the District were checked by performing a monthly flow balance from July 1995 to June 2004. Monthly average natural (unimpaired) tributary inflow to the Sultan River between Culmback Dam and the Powerhouse was calculated by subtracting the monthly average inflow to Spada Lake from the sum of the monthly averages of flow in the Sultan River below the Powerhouse (USGS Gage 12137500), plus the water withdrawal for municipal water supply plus the change in reservoir storage in Spada Lake. Changes in reservoir storage in Lake Chaplain were ignored in this assessment.

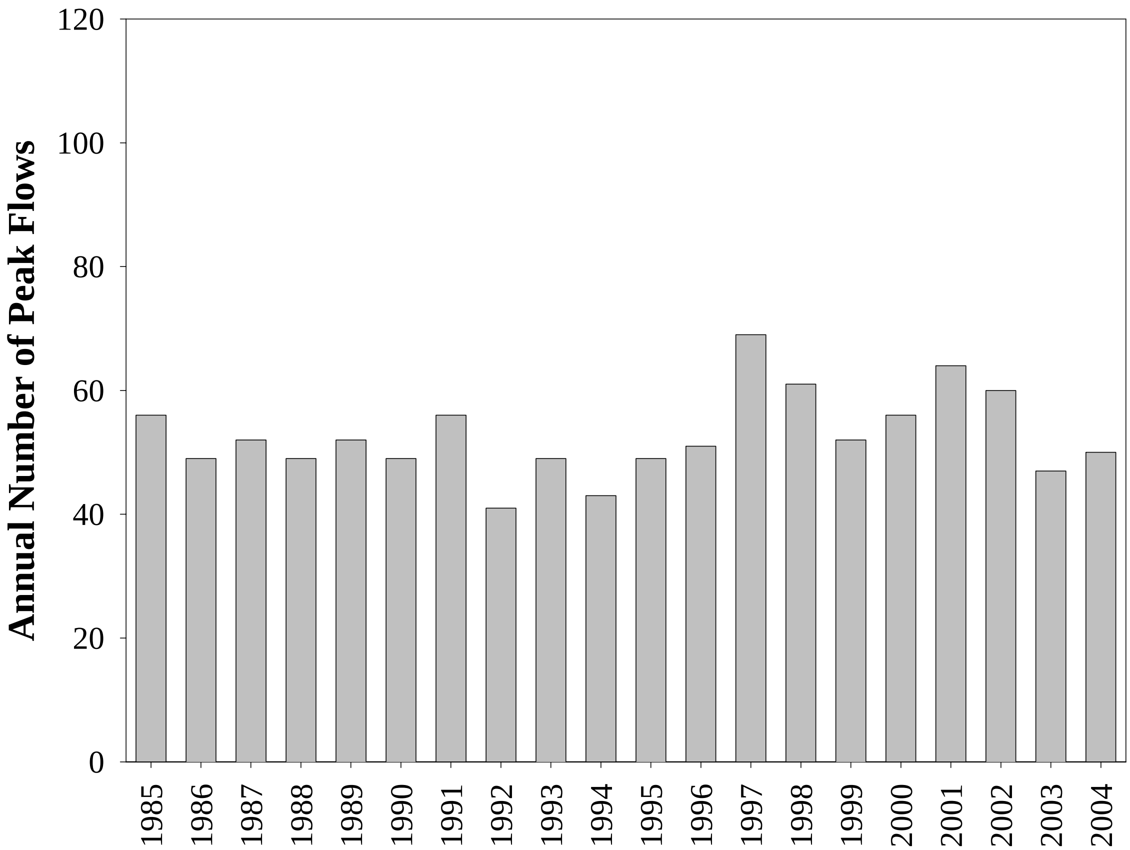

Figure 3-3 Annual number of peak flows from adjusted synthesized inflows to Spada Lake, 1985 through 2004.

Monthly seasonal adjustment factors to estimate natural tributary inflow to the Sultan River below Culmback Dam can be estimated by dividing the tributary inflow to the Sultan River between Culmback Dam and the Powerhouse (from Table 3-2) by the monthly inflow to Spada Lake (scaled down by the drainage area ratio of 25.9/63.3). These monthly seasonal adjustment factors are compared with the monthly seasonal adjustment factors used by the District in Figure 3-5. The monthly seasonal adjustment factors are all less than one from both sources of data, which indicates that the unit runoff from the portion of the Sultan River Basin downstream from Culmback Dam is less than the unit runoff from the portion of the basin upstream from Culmback Dam. Differences between the monthly seasonal adjustment factors from the two sources may be due to different periods of analysis, and the unaccounted for storage in Lake Chaplain in the analysis performed herein.

The monthly seasonal adjustment factors used by the District appear to be reasonable, and were utilized in this study. However, to avoid abrupt changes in flow when going from the end of one month to the beginning of the next, the monthly seasonal adjustment factors were converted to daily seasonal adjustment factors. The daily seasonal adjustment factors are illustrated in Figure 3-6. Therefore, to estimate natural unimpaired tributary inflows to the Sultan River in the three downstream sub-basins shown in Figure 2-1, the natural unimpaired inflow to Spada Lake was multiplied by the drainage area ratio and the seasonal adjustment factor shown in Figure 3-6.

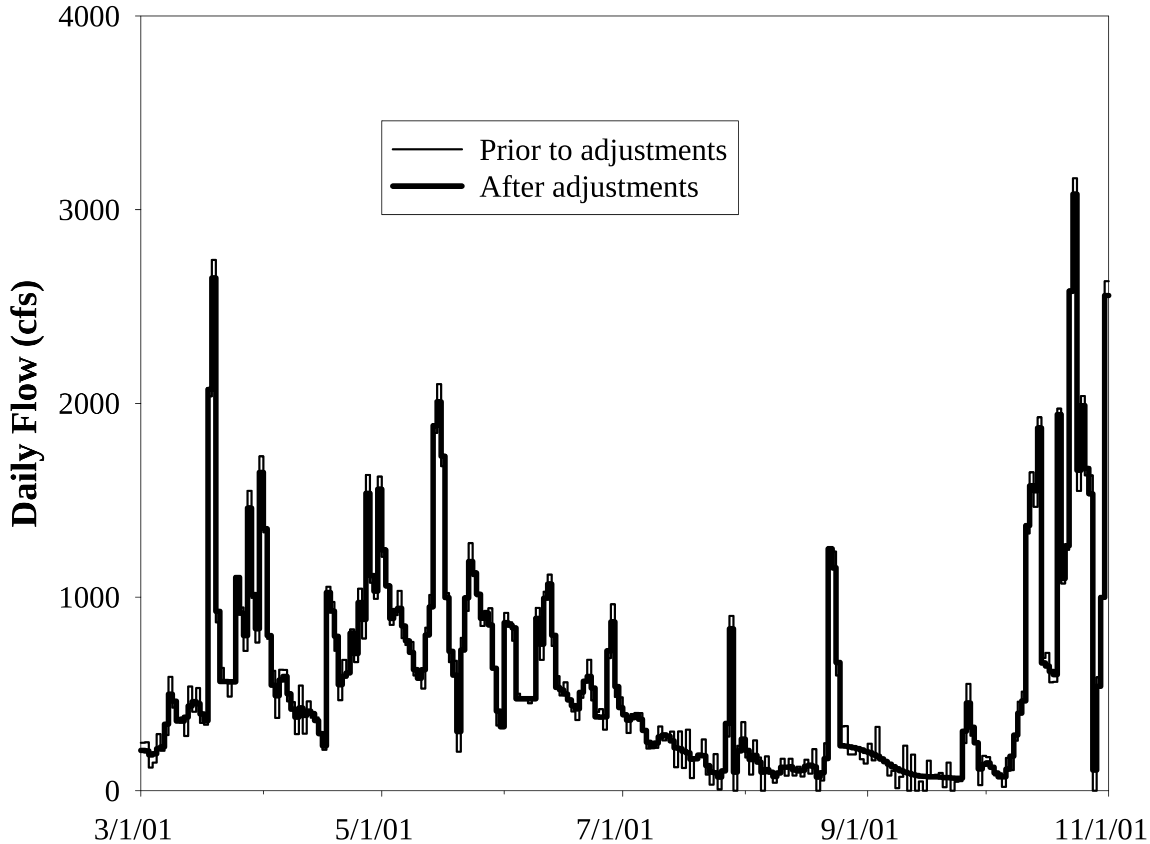

Figure 3-4 Synthesized inflows to Spada Lake, before and after adjustments, March 1 2001 to November 1 2001.

Table 3-2 Average monthly water balance in Sultan River Basin upstream from the Powerhouse, 1996 though 2004 (not accounting for storage in Lake Chaplain).

Month	Average Monthly Volume (acre-feet)				
	Inflow to Spada Lake (63.3 mi^2)	Change in Storage in Spada Lake	Water Withdrawal for Municipal Water Supply	Sultan River below Powerhouse (USGS Gage 12138160, 94.2 mi^2)	Unimpaired Tributary Inflow to Sultan River between Culmback Dam and Powerhouse (25.8 mi^2)
July	25,457	-9,694	9,831	29,065	3,745
August	11,550	-15,827	10,166	19,952	2,741
September	14,618	-13,937	8,707	21,983	2,135
October	56,832	11,583	7,631	48,445	10,827
November	76,669	3,762	7,048	80,242	14,383
December	59,373	-3,024	7,187	72,394	17,184
January	66,666	2,376	7,180	74,997	17,887
February	42,449	-4,209	6,481	53,594	13,417
March	47,761	6,337	7,139	46,531	12,246
April	49,569	10,223	7,008	42,304	9,966
May	60,353	14,700	7,706	46,613	8,666
June	51,686	-1,804	8,456	50,599	5,565

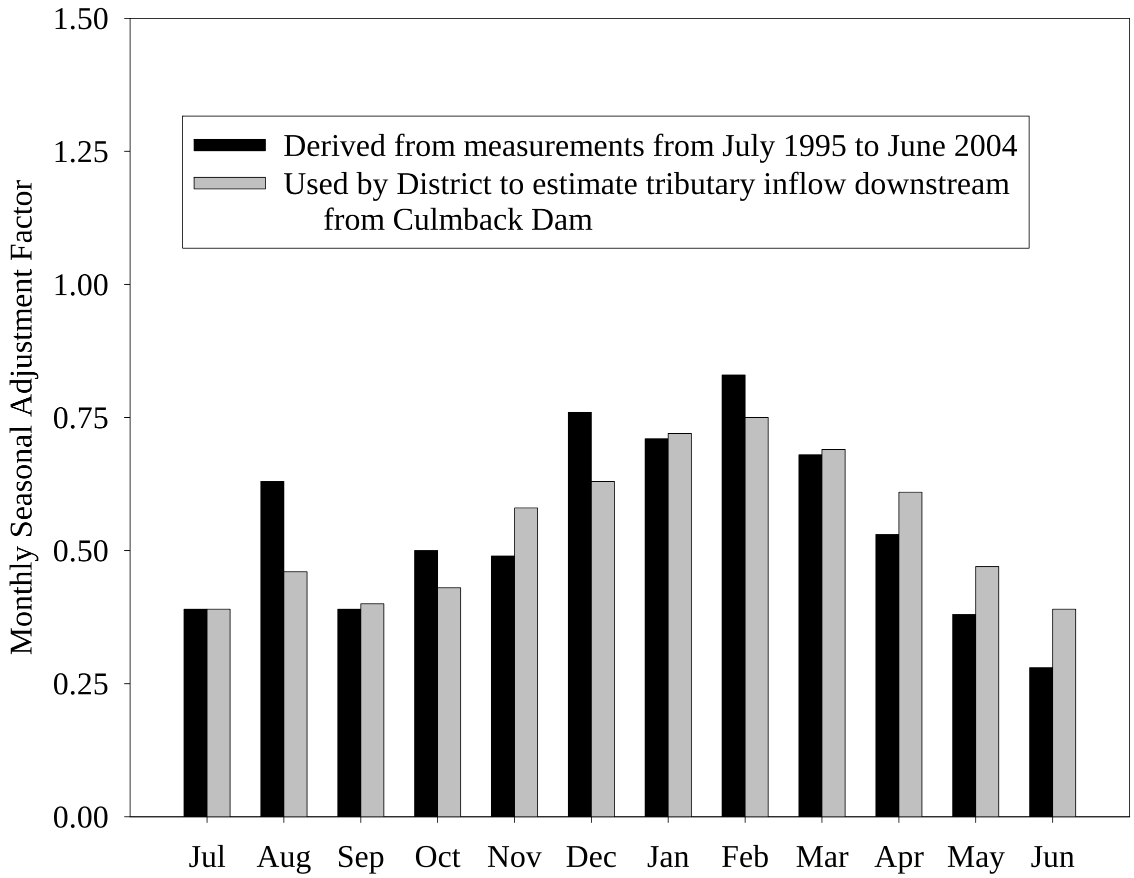

Figure 3-5 Comparison of monthly seasonal adjustment factors derived from data reported from July 1995 to June 2004 with monthly seasonal adjustment factors used by the District.

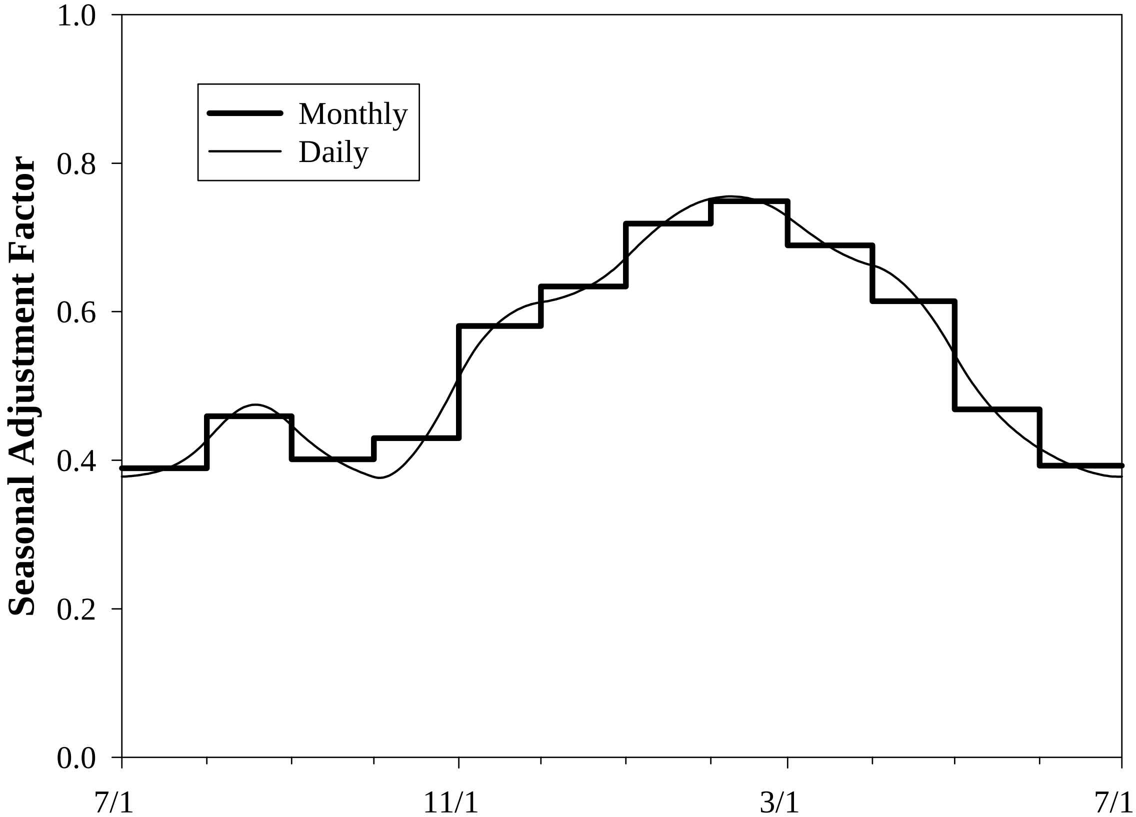

Figure 3-6 **Monthly seasonal adjustment factors used by the District, and daily seasonal adjustment factors used in this study.**

3.3 Synthesis of Pre-Project Conditions

The natural unimpaired flows discussed in Section 3.2 were used as the basis for determining pre-Project conditions. The natural flows developed for Reach 3 were used unaltered for pre-Project conditions. The natural flows developed for Reaches 1 and 2 were modified to account for water withdrawal for municipal water supply by the City.

Water demand from July 1995 to June 2004 was based on monthly water withdrawals reported by the City. Monthly water demand from July 1984 to June 1995 was estimated from the monthly averages of monthly water withdrawals from July 1995 to June 2004. Monthly water demand was converted to daily demand to avoid abrupt changes in flow from the end of one month to the beginning of the next, as shown in Figure 3-7.

The daily average water withdrawals shown in Figure 3-7 were assumed as the demand for municipal water supply from 1985 through 1995. Actual monthly water withdrawals from 1996 through 2004 were converted to daily withdrawals for assumed demand from 1996 through 2004.

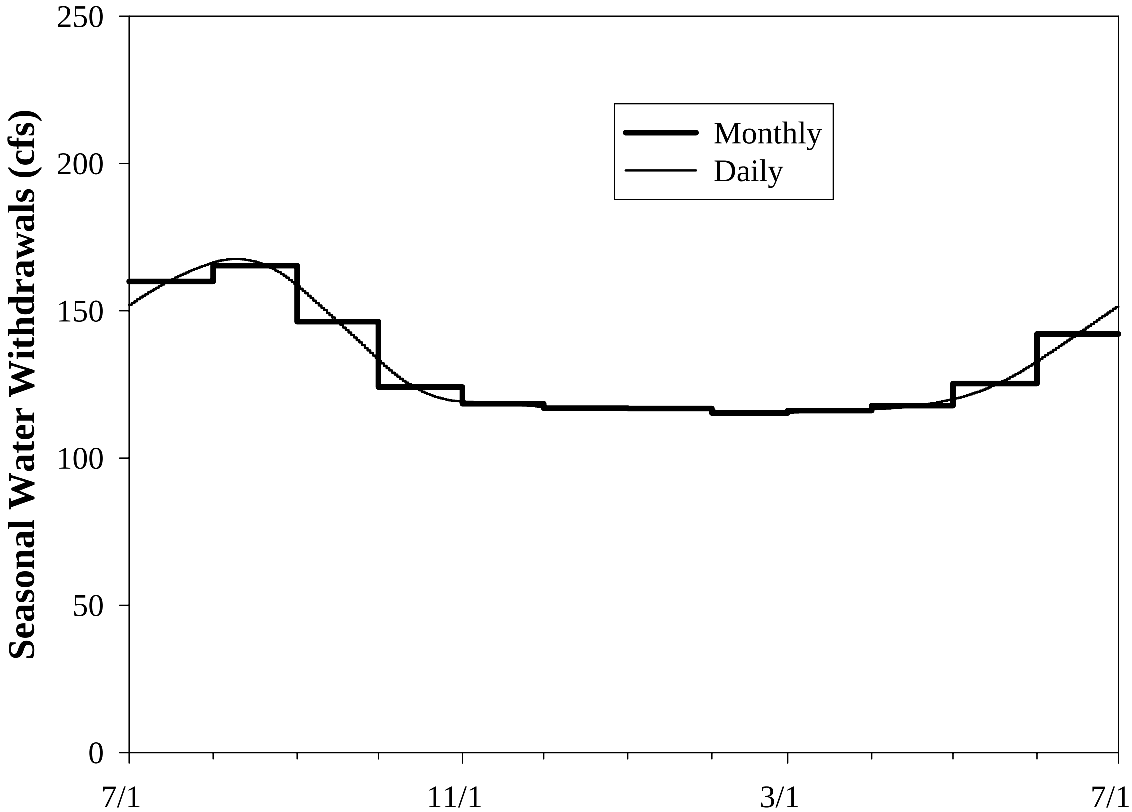

Figure 3-7 Average seasonal water withdrawals for municipal water supply from Sultan River Basin, 1996 to 2004.

For this analysis, it was assumed that the daily demand for water supply would be met by various sources in the following sequence:

1. Direct runoff into Lake Chaplain (3.4 square miles).
2. Diversion from Sultan River. Minimum release to the Sultan River from the Diversion Dam was assumed to be 3 cfs, consistent with the lowest measured flow in the Sultan River near Sultan (USGS Gage 12138000), 10/1/1911 to 9/30/1931.
3. Storage withdrawal from Lake Chaplain up to a limit of 13,200 acre-feet.

Flows at the upstream end of Reach 2 under pre-Project conditions were determined from the remaining flow in the Sultan River at the Diversion Dam, after accounting for diversion for water supply. Flows at the downstream end of Reach 2 and the upstream end of Reach 3 were determined from the sum of the flow at the upstream end of Reach 2 plus tributary inflow between the Diversion Dam and the Powerhouse, after accounting for the portion of direct runoff into Lake Chaplain used to meet the demand for water supply. The flows at the downstream end of Reach 3 were determined from the sum of the flow at the upstream end of Reach 3 plus tributary runoff between the Powerhouse and the confluence with the Skykomish River.

3.4 Synthesis of Post-Project Conditions

Under post-Project conditions, the flow at the upstream end of Reach 3 was 20 cfs most of the time, except for rare occasions when there was spill from Culmback Dam. To estimate flows at the upstream end of Reach 3 when spill occurred, flow records in the Sultan River below the Diversion Dam (USGS Gage 12137800) were compared with the seasonal minimum release requirements from the Diversion Dam (Table 2-1) and the tributary inflow between Culmback Dam and the Diversion Dam. The seasonal minimum flow release requirement and the tributary inflow between Culmback Dam and the Diversion Dam were subtracted from the flow in the Sultan River below the Diversion Dam (USGS 12317800). If the result exceeded 20 cfs, then this result was assumed to be the flow at the upstream end of Reach 3. Otherwise, the flow was assumed to be 20 cfs at the upstream end of Reach 3. The flow in the Sultan River at the downstream end of Reach 3 was determined by adding the flow at the upstream end of Reach 3 to the tributary inflow to the Sultan River between Culmback Dam and the Diversion Dam.

The flow at the upstream end of Reach 2 was determined directly from the flows measured in the Sultan River below the Diversion Dam (USGS Gage 12137800). The flow at the downstream end of Reach 2 was determined from the flow at the upstream end of Reach 2, plus tributary inflow between the Diversion Dam and the Powerhouse, after accounting for the portion of direct runoff into Lake Chaplain used to meet the daily demand for municipal water supply.

The flow at the upstream end of Reach 3 was determined directly for the flows measured in the Sultan River below the Powerhouse (USGS Gage 12138160). The flow at the downstream end of Reach 3 was determined from the flow at the upstream end of Reach 3 plus tributary inflow between the Powerhouse and the confluence with the Skykomish River.

3.5 IHA/RVA Analyses

The pre- and post-Project conditions were assessed by performing Index of Hydrologic Alteration (IHA)/Range of Variability Analysis (RVA) evaluations (The Nature Conservancy 2005). These analyses are based on 33 IHA hydrologic statistics defined in Table 3-3, and 34 Environmental Flow Components (EFC) defined in Table 3-4. These assessments were performed at the upstream and downstream ends of Reaches 1, 2, and 3.

The 33 hydrologic parameters listed in Table 3-3 are divided into five parameter groups: 1) magnitude of monthly water conditions; 2) magnitude and duration of annual extreme water conditions; 3) timing of annual extreme water conditions; 4) frequency and duration of high and low flow pulses; and 5) rate and frequency of water condition changes. The 34 hydrologic parameters listed in Table 3-4 are divided into five parameter groups: monthly low flows; extreme low flows; high flow pulses; small floods; and large floods.

In performing the IHA/RVA analyses, the two-period, non-parametric method was used. Default settings were used for all of the options.

Table 3-3 List of 33 Index of Hydrologic Alteration (IHA) parameters (The Nature Conservancy 2005).

IHA Parameter Group	Hydrologic Parameters	Ecosystem Influences
1. Magnitude of monthly water conditions	Mean or median value for each calendar month *Subtotal 12 parameters*	• Habitat availability for aquatic organisms • Soil moisture availability for plants • Availability of water for terrestrial animals • Availability of food/cover for forbearing mammals • Reliability of water supplies for terrestrial animals • Access by predators to nesting sites • Influences water temperature, oxygen levels, photosynthesis in water column
2. Magnitude and duration of annual extreme water conditions	Annual minima, 1-day mean Annual minima, 3-day means Annual minima, 7-day means Annual minima, 30-day means Annual minima, 90-day Means Annual maxima, 1-day mean Annual maxima, 3-day means Annual maxima, 7-day means Annual maxima, 30-day means Annual maxima, 90-day means Number of zero-flow days Base flow: 7-day minimum flow/mean flow for year *Subtotal 12 parameters*	• Balance of competitive, ruderal, and stress-tolerant organisms • Creation of sites for plant colonization • Structuring of aquatic ecosystems by abiotic vs. biotic factors • Structuring of river channel morphology and physical habitat conditions • Soil moisture stress in plants • Dehydration in animals • Anaerobic stress in plants • Volume of nutrient exchanges between rivers and floodplains • Duration of stressful conditions such as low oxygen and concentrated chemicals in aquatic environments • Distribution of plant communities in lakes, ponds, floodplains • Duration of high flows for waste disposal, aeration of spawning beds in channel sediments
3. Timing of annual extreme water conditions	Julian date of each annual 1-day maximum Julian date of each annual 1-day minimum *Subtotal 2 parameters*	• Compatibility with life cycles of organisms • Predictability/avoidability of stress for organisms • Access to special habitats during reproduction or to avoid predation • Spawning cues for migratory fish • Evolution of life history strategies, behavioral mechanisms
4. Frequency and duration of high and low pulses	Number of low pulses within each water year Mean or median duration of low pulses (days) Number of high pulses within each water year Mean or median duration of high pulses (days) *Subtotal 4 parameters*	• Frequency and magnitude of soil moisture stress for plants • Frequency and duration of anaerobic stress for plants • Availability of floodplain habitats for aquatic organisms • Nutrient and organic matter exchanges between river and floodplain • Soil mineral availability • Access for waterbirds to feeding, resting, reproduction sites • Influences bedload transport, channel sediment textures, and duration of substrate disturbance (high pulses)
5. Rate and frequency of water condition changes	Rise rates: Mean or median of all positive differences between consecutive daily values Fall rates: Mean or median of all negative differences between consecutive daily values Number of hydrologic reversals *Subtotal 3 parameters* *Grand total 33parameters*	• Drought stress on plants (falling levels) • Entrapment of organisms on islands, floodplains (rising levels) • Desiccation stress on low-mobility streamedge (varial zone) organisms

Table 3-4 List of 34 Environmental Flow Component (EFC) parameters (The Nature Conservancy 2005).

EFC Type	Hydrologic Parameters	Ecosystem Influences
1. Monthly low flows	Mean or median values of low flows during each calendar month *Subtotal 12 parameters*	• Provide adequate habitat for aquatic organisms • Maintain suitable water temperatures, dissolved oxygen, and water chemistry • Maintain water table levels in floodplain, soil moisture for plants • Provide drinking water for terrestrial animals • Keep fish and amphibian eggs suspended • Enable fish to move to feeding and spawning areas • Support hyporheic organisms (living in saturated sediments)
2. Extreme low flows	Frequency of extreme low flows during each water year or season Mean or median values of extreme low flow event: • Duration (days) • Peak flow (minimum flow during event) • Timing (Julian date of peak flow) *Subtotal 4 parameters*	• Enable recruitment of certain floodplain plant species • Purge invasive, introduced species from aquatic and riparian communities • Concentrate prey into limited areas to benefit predators
3. High flow pulses	Frequency of high flow pulses during each water year or season Mean or median values of high flow pulse event: • Duration (days) • Peak flow (maximum flow during event) • Timing (Julian date of peak flow) • Rise and fall rates *Subtotal 6 parameters*	• Shape physical character of river channel, including pools, riffles • Determine size of streambed substrates (sand, gravel, cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels, prevent siltation
4. Small floods	Frequency of small floods during each water year or season Mean or median values of small flood event: • Duration (days) • Peak flow (maximum flow during event) • Timing (Julian date of peak flow) • Rise and fall rates *Subtotal 6 parameters*	Applies to small and large floods: • Provide migration and spawning cues for fish • Trigger new phase in life cycle (i.e., insects) • Enable fish to spawn in floodplain, provide nursery area for juvenile fish • Provide new feeding opportunities for fish, waterfowl • Recharge floodplain water table • Maintain diversity in floodplain forest types through prolonged inundation (i.e., different plant species have different tolerances) • Control distribution and abundance of plants on floodplain • Deposit nutrients on floodplain
5. Large floods	Frequency of large floods during each water year or season Mean or median values of large flood event: • Duration (days) • Peak flow (maximum flow during event) • Timing (Julian date of peak flow) • Rise and fall rates *Subtotal 6 parameters* *Grand total 34 parameters*	Applies to small and large floods: • Maintain balance of species in aquatic and riparian communities • Create sites for recruitment of colonizing plants • Shape physical habitats of floodplain • Deposit gravel and cobbles in spawning areas • Flush organic materials (food) and woody debris (habitat structures) into channel • Purge invasive, introduced species from aquatic and riparian communities • Disburse seeds and fruits of riparian plants • Drive lateral movement of river channel, forming new habitats (secondary channels, oxbow lakes) • Provide plant seedlings with prolonged access to soil moisture

4.0 RESULTS

Detailed results of the IHA/RVA analyses are presented in Appendices A, B, C, D, E, and F for the upstream and downstream ends of Reaches 1, 2, and 3, respectively. A general summary of results is presented below.

4.1 Sultan River, Upstream End of Reach 1

Means and medians of average monthly flows in the Sultan River at the upstream end of Reach 1 under pre- and post-Project conditions are summarized in Table 4-1. The means of the average monthly flows were increased at the upstream end of Reach 1 by the Project in July, August, September, December, and February, and were decreased at the upstream end of Reach 1 by the Project in October, November, January, March, April, May, and June.

Table 4-1. Means and medians of average monthly flows in the Sultan River at the upstream end of Reach 1 under pre- and post-Project conditions.

Month	Mean of Average Monthly Flows (cfs)		Median of Average Monthly Flows (cfs)	
	Pre-Project Conditions	Post-Project Conditions	Pre-Project Conditions	Post-Project Conditions
July	255	423	163	308
August	62	264	13	207
September	132	335	11	286
October	697	645	231	368
November	1435	1331	784	1273
December	984	1099	485	1075
January	1110	1021	665	839
February	890	897	458	772
March	825	750	670	623
April	1021	747	799	612
May	963	744	868	688
June	731	685	542	496

The magnitudes and durations of annual extreme water conditions under pre- and post-Project conditions are summarized in Table 4-2. The magnitudes of annual minimum flows were increased by the Project for all durations ranging from 1 to 90 days. The magnitudes of annual maximum flows were decreased by the Project for all durations ranging from 1 to 90 days. There were no zero flow days under pre-and post-Project conditions. The base flow index, defined as the ratio of the annual 7-day minimum flow divided by the annual mean flow, was increased by the Project.

Table 4-2. Medians of magnitude and duration of annual extreme water conditions in the Sultan River at the upstream end of Reach 1 under pre- and post-Project conditions.

Parameter	Median	
	Pre-Project Conditions	Post-Project Conditions
1-day minimum flow (cfs)	7.6	189.5
3-day minimum flow (cfs)	7.8	190.2
7-day minimum flow (cfs)	8.2	195.2
30-day minimum flow (cfs)	9.9	206.0
90-day minimum flow (cfs)	83.9	270.4
1-day maximum flow (cfs)	10,320	2,385
3-day maximum flow (cfs)	6,790	1,985
7-day maximum flow (cfs)	4,231	1,850
30-day maximum flow (cfs)	2,033	1,630
90-day maximum flow (cfs)	1,402	1,293
Number of zero-flow days	0	0
Base flow index	0.010	0.271

The median date of the annual 1-day minimum flow was shifted earlier in the Water Year from September 14 to August 14 by the Project. The median date of the annual 1-day maximum flow was also shifted earlier in the Water Year from December 13 to November 28 by the Project.

Under pre-Project conditions, the median annual number of low flow pulses (defined for the upstream end of reach 1 to be flows less than 122 cfs) was 6 and the median duration of low flow pulses was 7 days. Under post-Project conditions, there were no low flow pulses.

The median annual number of high flow pulses (defined by for the upstream end of Reach 1 to be flows greater than 921 cfs) was reduced by the Project from 16 to 8, and the median duration of high flow pulses was increased by the Project from 3 to 6 days.

The median rate of rising flows was reduced by the Project from 76 to 28 cfs per day, and the median rate of falling flows was also reduced by the Project from 48 to 26 cfs per day. The median annual number of flow reversals was increased by the Project from 107 to 127.

The monthly median low flows under pre- and post-Project conditions are summarized in Table 4-3. The monthly median low flows were increased by the Project from July through March, and were decreased by the Project from April through June.

Table 4-3. Monthly median low flows in the Sultan River at the upstream end of Reach 1 under pre- and post-Project conditions.

Month	Monthly Median of Low Flows (cfs)	
	Pre-Project Conditions	Post-Project Conditions
July	151.6	293.5
August	13.6	206.5
September	14.2	278.0
October	87.0	332.8
November	277.4	337.5
December	297.0	580.8
January	303.7	436.5
February	322.9	512.0
March	368.6	384.0
April	555.3	505.3
May	580.9	535.5
June	454.2	362.3

Under pre-Project conditions, the median magnitude and duration of extreme low flow events (defined for the upstream end of Reach 1 to be flows less than 9.6 cfs) was 8.6 cfs and 3.5 days, respectively. Extreme low flows occurred on a median date within the Water Year on September 13 and there were a median number of 2.0 extreme low flow events per year. Under post-Project conditions there were no extreme low flow events.

The median magnitude of high flow pulses was reduced by the Project from 1,483 to 1,077 cfs. The median duration of high flow pulses was increased by the Project from 4.0 to 5.8 days. The median date of high flow pulses was shifted later in the Water Year from February 22 to February 27 by the Project. The median number of high flow pulses was reduced by the Project from 19.0 to 11.5. The median rate of rising flows during high flow pulses was reduced by the Project from 432 to 187 cfs per day, and the median rate of falling flows during high flow pulses was also reduced by the Project from 258 to 99 cfs per day.

Under pre-Project conditions, the median peak magnitude of small floods (defined for the upstream end of Reach 1 to be a flood with a peak in excess of 10,320 cfs) was 11,960 cfs. The median duration of small floods under pre-Project conditions was 13.5 days. The median date of a small flood during the Water Year was December 22 under pre-Project conditions. There were a total of 10 small floods during the 20-year period studied under pre-Project conditions. The median rise and fall rates during small magnitude floods were 1,878 and 1,576 cfs per day, respectively.

Under post-Project conditions, there was a single small flood during the 20-year period with a peak magnitude of 12,100 cfs, and a duration of 112 days. The peak occurred on

November 29. The median rise and fall rates during this flood were 257 and 165 cfs, respectively.

Under pre-Project conditions, the median peak magnitude of large floods (defined for the upstream end of Reach 1 to be a flood with a peak in excess of 16,610 cfs) was 17,900 cfs. The median duration of large floods under pre-Project conditions was 11.0 days. The median date of a large flood during the Water Year was November 7 under pre-Project conditions. There were a total of 2 large floods during the 20-year period studied under pre-Project conditions. The median rise and fall rates during large magnitude floods were 3,601 and 2,515 cfs per day, respectively.

Under post-Project conditions, there was a single large flood during the 20-year period with a peak magnitude of 20,100 cfs, and a duration of 82 days. The peak occurred on November 24. The median rise and fall rates during this flood were 492 and 457 cfs, respectively.

4.2 Sultan River, Downstream End of Reach 1

Means and medians of average monthly flows in the Sultan River at the downstream end of Reach 1 under pre- and post-Project conditions are summarized in Table 4-4. The means of the average monthly flows were increased at the downstream end of Reach 1 by the Project in July, August, September, December, and February, and were decreased at the downstream end of Reach 1 by the Project in October, November, January, March, April, May, and June.

The magnitudes and durations of annual extreme water conditions under pre- and post-Project conditions are summarized in Table 4-5. The magnitudes of annual minimum flows were increased by the Project for all durations ranging from 1 to 90 days. The magnitudes of annual maximum flows were decreased by the Project for all durations ranging from 1 to 90 days. There were no zero flow days under pre-and post-Project conditions. The base flow index, defined as the ratio of the annual 7-day minimum flow divided by the annual mean flow, was increased by the Project.

The median date of the annual 1-day minimum flow was shifted earlier in the Water Year from September 14 to August 26 by the Project. The median date of the annual 1-day maximum flow was also shifted earlier in the Water Year from December 13 to November 27 by the Project.

Under pre-Project conditions, the median annual number of low flow pulses (defined for the downstream end of reach 1 to be flows less than 141 cfs) was 6 and the median duration of low flow pulses was 8.5 days. Under post-Project conditions, there were no low flow pulses.

Table 4-4. Means and medians of average monthly flows in the Sultan River at the downstream end of Reach 1 under pre- and post-Project conditions.

Month	Mean of Average Monthly Flows (cfs)		Median of Average Monthly Flows (cfs)	
	Pre-Project Conditions	Post-Project Conditions	Pre-Project Conditions	Post-Project Conditions
July	276	445	180	327
August	73	275	21	217
September	146	349	17	305
October	746	695	255	406
November	1554	1450	853	1406
December	1073	1187	532	1148
January	1219	1130	732	1069
February	982	989	511	843
March	905	831	736	687
April	1110	836	870	682
May	1031	811	929	746
June	778	732	542	496

Table 4-5. Medians of magnitude and duration of annual extreme water conditions in the Sultan River at the downstream end of Reach 1 under pre- and post-Project conditions.

Parameter	Median	
	Pre-Project Conditions	Post-Project Conditions
1-day minimum flow (cfs)	11.1	195.5
3-day minimum flow (cfs)	11.5	197.0
7-day minimum flow (cfs)	12.3	201.4
30-day minimum flow (cfs)	15.2	214.2
90-day minimum flow (cfs)	96.7	282.2
1-day maximum flow (cfs)	11,200	3,075
3-day maximum flow (cfs)	7,353	2,576
7-day maximum flow (cfs)	4,609	2,144
30-day maximum flow (cfs)	2,193	1,758
90-day maximum flow (cfs)	1,522	1,404
Number of zero-flow days	0	0
Base flow index	0.014	0.252

The median annual number of high flow pulses (defined by for the downstream end of Reach 1 to be flows greater than 999 cfs) was reduced by the Project from 17 to 8, and the median duration of high flow pulses was increased by the Project from 3.0 to 6.0 days.

The median rate of rising flows was reduced by the Project from 82 to 31 cfs per day, and the median rate of falling flows was also reduced by the Project from 50 to 24 cfs per day. The median annual number of flow reversals was increased by the Project from 108 to 138.

The monthly median low flows under pre- and post-Project conditions are summarized in Table 4-6. The monthly median low flows were increased by the Project from July through March, and were decreased by the Project from April through June.

Table 4-6. Monthly median low flows in the Sultan River at the downstream end of Reach 1 under pre- and post-Project conditions.

Month	Monthly Median of Low Flows (cfs)	
	Pre-Project Conditions	Post-Project Conditions
July	168.3	310.3
August	21.9	216.5
September	22.9	304.7
October	100.5	360.6
November	307.2	438.0
December	330.5	624.0
January	341.0	522.3
February	355.5	555.2
March	402.7	489.0
April	610.3	593.4
May	640.4	609.3
June	485.4	407.8

Under pre-Project conditions the median magnitude and duration of extreme low flow events (defined for the upstream end of Reach 1 to be flows less than 14.8 cfs) was 13.0 cfs and 3.5 days, respectively. Extreme low flows occurred on a median date within the Water Year on September 13 and there were a median number of 2.0 extreme low flow events per year. Under post-Project conditions there were no extreme low flow events.

The median magnitude of high flow pulses was reduced by the Project from 1,538 to 1,194 cfs. The median duration of high flow pulses was increased by the Project from 4.5 to 6.3 days. The median date of high flow pulses was February 23 under both pre- and post-Project conditions. The median number of high flow pulses was reduced by the

Project from 19.0 to 10.0. The median rate of rising flows during high flow pulses was reduced by the Project from 434 to 221 cfs per day, and the median rate of falling flows during high flow pulses was also reduced by the Project from 280 to 112 cfs per day.

Under pre-Project conditions, the median peak magnitude of small floods (defined for the downstream end of Reach 1 to be a flood with a peak in excess of 11,200 cfs) was 12,970 cfs. The median duration of small floods under pre-Project conditions was 14.0 days. The median date of a small flood during the Water Year was December 22 under pre-Project conditions. There were a total of 10 small floods during the 20-year period studied under pre-Project conditions. The median rise and fall rates during small magnitude floods were 2,039 and 1,589 cfs per day, respectively.

Under post-Project conditions, there was a single small flood during the 20-year period with a peak magnitude of 12,340 cfs, and a duration of 111 days. The peak occurred on November 29. The median rise and fall rates during this flood were 261 and 172 cfs, respectively.

Under pre-Project conditions, the median peak magnitude of large floods (defined for the downstream end of Reach 1 to be a flood with a peak in excess of 17,660 cfs) was 19,150 cfs. The median duration of large floods under pre-Project conditions was 11.0 days. The median date of a large flood during the Water Year was November 7 under pre-Project conditions. There were a total of 2 large floods during the 20-year period studied under pre-Project conditions. The median rise and fall rates during large magnitude floods were 3,856 and 2,685 cfs per day, respectively.

Under post-Project conditions, there was a single large flood during the 20-year period with a peak magnitude of 21,560 cfs, and a duration of 82 days. The peak occurred on November 24. The median rise and fall rates during this flood were 516 and 502 cfs, respectively.

4.3 Sultan River, Upstream End of Reach 2

Means and medians of average monthly flows in the Sultan River at the upstream end of Reach 2 under pre- and post-Project conditions are summarized in Table 4-7. The means of the average monthly flows were increased at the upstream end of Reach 2 by the Project in August and September, and were decreased at the upstream end of Reach 2 by the Project from October through July.

The magnitudes and durations of annual extreme water conditions under pre- and post-Project conditions are summarized in Table 4-8. The magnitudes of annual minimum flows were increased by the Project for all durations ranging from 1 to 90 days. The magnitudes of annual maximum flows were decreased by the Project for all durations ranging from 1 to 90 days. There were no zero flow days under pre-and post-Project conditions. The base flow index, defined as the ratio of the annual 7-day minimum flow divided by the annual mean flow, was increased by the Project.

Table 4-7. Means and medians of average monthly flows in the Sultan River at the upstream end of Reach 2 under pre- and post-Project conditions.

Month	Mean of Average Monthly Flows (cfs)		Median of Average Monthly Flows (cfs)	
	Pre-Project Conditions	Post-Project Conditions	Pre-Project Conditions	Post-Project Conditions
July	227	125	141	114
August	48	122	3	117
September	114	152	3	166
October	633	226	200	178
November	1280	365	697	142
December	869	173	424	122
January	968	186	580	172
February	769	202	391	176
March	721	215	586	198
April	907	206	709	197
May	877	200	789	196
June	671	158	495	171

Table 4-8. Medians of magnitude and duration of annual extreme water conditions in the Sultan River at the upstream end of Reach 2 under pre- and post-Project conditions.

Parameter	Median	
	Pre-Project Conditions	Post-Project Conditions
1-day minimum flow (cfs)	3.0	101.0
3-day minimum flow (cfs)	3.0	103.0
7-day minimum flow (cfs)	3.0	106.0
30-day minimum flow (cfs)	3.0	112.4
90-day minimum flow (cfs)	67.5	129.1
1-day maximum flow (cfs)	9,011	924
3-day maximum flow (cfs)	6,037	607
7-day maximum flow (cfs)	3,710	387
30-day maximum flow (cfs)	1,820	253
90-day maximum flow (cfs)	1,233	227
Number of zero-flow days	0	0
Base flow index	0.004	0.589

The median date of the annual 1-day minimum flow was shifted earlier in the Water Year from July 27 to July 12 by the Project. The median date of the annual 1-day maximum flow was also shifted earlier in the Water Year from December 13 to November 30 by the Project.

Under pre-Project conditions, the median annual number of low flow pulses (defined for the upstream end of Reach 2 to be flows less than 99 cfs) was 6 and the median duration of low flow pulses was 7.0 days. Under post-Project conditions, there were no low flow pulses.

The median annual number of high flow pulses (defined for the downstream end of Reach 2 to be flows greater than 822 cfs) was reduced by the Project from 16.5 to 1.0, and the median duration of high flow pulses was reduced by the Project from 3.0 to 1.3 days.

The median rate of rising flows was reduced by the Project from 102 to 5 cfs per day, and the median rate of falling flows was also reduced by the Project from 67 to 5 cfs per day. The median annual number of flow reversals was increased by the Project from 99 to 153.

The monthly median low flows under pre- and post-Project conditions are summarized in Table 4-9. The monthly median low flows were increased by the Project from August through October, and were decreased by the Project from November through July.

Table 4-9. Monthly median low flows in the Sultan River at the upstream end of Reach 2 under pre- and post-Project conditions.

Month	Monthly Median of Low Flows (cfs)	
	Pre-Project Conditions	Post-Project Conditions
July	176.7	114.0
August	71.2	117.0
September	95.1	166.0
October	154.7	178.0
November	232.7	136.5
December	252.2	121.0
January	262.9	171.8
February	275.5	173.5
March	326.0	197.5
April	486.3	196.8
May	521.6	196.0
June	412.6	170.8

Under pre-Project conditions the median magnitude and duration of extreme low flow events (defined for the upstream end of Reach 2 to be flows less than or equal to 3 cfs) was 3.0 cfs and 9.0 days, respectively. Extreme low flows occurred on a median date within the Water Year on September 2 and there were a median number of 4.0 extreme low flow events per year. Under post-Project conditions there were no extreme low flow events.

The median magnitude of high flow pulses was reduced by the Project from 1,218 to 530 cfs. The median duration of high flow pulses was reduced by the Project from 4.5 to 1.3 days. The median date of high flow pulses was shifted earlier in the Water Year from February 25 to December 17 by the Project. The median number of high flow pulses was reduced by the Project from 18.0 to 4.0. The median rate of rising flows during high flow pulses was reduced by the Project from 385 to 315 cfs per day, and the median rate of falling flows during high flow pulses was increased by the Project from 222 to 238 cfs per day.

Under pre-Project conditions, the median peak magnitude of small floods (defined for the upstream end of Reach 2 to be a flood with a peak in excess of 9,011 cfs) was 10,320 cfs. The median duration of small floods under pre-Project conditions was 14.3 days. The median date of a small flood during the Water Year was December 22 under pre-Project conditions. There were a total of 10 small floods during the 20-year period studied under pre-Project conditions. The median rise and fall rates during small magnitude floods were 1,638 and 1,384 cfs per day, respectively.

Under post-Project conditions, there was a single small flood during the 20-year period with a peak magnitude of 11,600 cfs, and a duration of 9 days. The peak occurred on November 29. The median rise and fall rates during this flood were 1,890 and 2,805 cfs, respectively.

Under pre-Project conditions, the median peak magnitude of large floods (defined for the upstream end of Reach 2 to be a flood with a peak in excess of 15,300 cfs) was 16,130 cfs. The median duration of large floods under pre-Project conditions was 13.0 days. The median date of a large flood during the Water Year was November 7 under pre-Project conditions. There were a total of 2 large floods during the 20-year period studied under pre-Project conditions. The median rise and fall rates during large magnitude floods were 2,766 and 2,275 cfs per day, respectively.

Under post-Project conditions, there was a single large flood during the 20-year period with a peak magnitude of 16,600 cfs, and a duration of 6 days. The peak occurred on November 24. The median rise and fall rates during this flood were 5,455 and 4,105 cfs, respectively.

4.4 Sultan River, Downstream End of Reach 2

Means and medians of average monthly flows in the Sultan River at the downstream end of Reach 2 under pre- and post-Project conditions are summarized in Table 4-10. The means of the average monthly flows were increased at the downstream end of Reach 2 by the Project in August and September, and were decreased at the downstream end of Reach 2 by the Project from October through July.

The magnitudes and durations of annual extreme water conditions under pre- and post-Project conditions are summarized in Table 4-11. The magnitudes of annual minimum flows were increased by the Project for all durations ranging from 1 to 90 days. The magnitudes of annual maximum flows were decreased by the Project for all durations ranging from 1 to 90 days. There were no zero flow days under pre-and post-Project conditions. The base flow index, defined as the ratio of the annual 7-day minimum flow divided by the annual mean flow, was increased by the Project.

Table 4-10. Means and medians of average monthly flows in the Sultan River at the downstream end of Reach 2 under pre- and post-Project conditions.

Month	Mean of Average Monthly Flows (cfs)		Median of Average Monthly Flows (cfs)	
	Pre-Project Conditions	Post-Project Conditions	Pre-Project Conditions	Post-Project Conditions
July	255	153	163	139
August	62	136	13	130
September	132	169	11	177
October	697	290	231	205
November	1435	521	784	243
December	984	288	485	186
January	1110	329	665	252
February	890	323	458	246
March	825	319	670	289
April	1021	320	799	291
May	963	287	868	275
June	731	218	542	227

The median date of the annual 1-day minimum flow was shifted earlier in the Water Year from September 14 to August 29 by the Project. The median date of the annual 1-day maximum flow was also shifted earlier in the Water Year from December 13 to December 7 by the Project.

Under pre-Project conditions, the median annual number of low flow pulses (defined for the downstream end of Reach 2 to be flows less than 122 cfs) was 6 and the median duration of low flow pulses was 7.0 days. Under post-Project conditions, there were no low flow pulses.

Table 4-11. Medians of magnitude and duration of annual extreme water conditions in the Sultan River at the downstream end of Reach 2 under pre- and post-Project conditions.

Parameter	Median	
	Pre-Project Conditions	Post-Project Conditions
1-day minimum flow (cfs)	7.6	115.2
3-day minimum flow (cfs)	7.8	116.4
7-day minimum flow (cfs)	8.2	118.6
30-day minimum flow (cfs)	9.9	126.1
90-day minimum flow (cfs)	83.9	147.6
1-day maximum flow (cfs)	10,320	1,945
3-day maximum flow (cfs)	6,790	1,383
7-day maximum flow (cfs)	4,231	843
30-day maximum flow (cfs)	2,033	472
90-day maximum flow (cfs)	1,402	347
Number of zero-flow days	0	0
Base flow index	0.010	0.444

The median annual number of high flow pulses (defined by for the downstream end of Reach 2 to be flows greater than 921 cfs) was reduced by the Project from 16.0 to 3.5, and the median duration of high flow pulses was reduced by the Project from 3.0 to 1.5 days.

The median rate of rising flows was reduced by the Project from 76 to 10 cfs per day, and the median rate of falling flows was also reduced by the Project from 48 to 8 cfs per day. The median annual number of flow reversals was increased by the Project from 107 to 140.

The monthly median low flows under pre- and post-Project conditions are summarized in Table 4-12. The monthly median low flows were increased by the Project from August through October, and were decreased by the Project from November through July.

Under pre-Project conditions the median magnitude and duration of extreme low flow events (defined for the downstream end of Reach 2 to be flows less than or equal to 9.6 cfs) was 8.6 cfs and 3.5 days, respectively. Extreme low flows occurred on a median date within the Water Year on September 13 and there were a median number of 2.0 extreme low flow events per year. Under post-Project conditions there were no extreme low flow events.

Table 4-12. Monthly median low flows in the Sultan River at the downstream end of Reach 2 under pre- and post-Project conditions.

Month	Monthly Median of Low Flows (cfs)	
	Pre-Project Conditions	Post-Project Conditions
July	151.6	139.4
August	13.6	129.8
September	14.2	177.0
October	87.0	204.9
November	277.4	208.2
December	297.0	176.6
January	303.7	243.3
February	322.9	245.0
March	368.6	285.7
April	555.3	290.4
May	580.9	275.3
June	454.2	225.5

The median magnitude of high flow pulses was reduced by the Project from 1,483 to 726 cfs. The median duration of high flow pulses was reduced by the Project from 4.0 to 2.0 days. The median date of high flow pulses was shifted earlier in the Water Year from February 22 to January 13 by the Project. The median number of high flow pulses was reduced by the Project from 19.0 to 9.5. The median rate of rising flows during high flow pulses was reduced by the Project from 432 to 309 cfs per day, and the median rate of falling flows during high flow pulses was increased by the Project from 258 to 217 cfs per day.

Under pre-Project conditions, the median peak magnitude of small floods (defined for the downstream end of Reach 2 to be a flood with a peak in excess of 10,320 cfs) was 11,960 cfs. The median duration of small floods under pre-Project conditions was 13.5 days. The median date of a small flood during the Water Year was December 22 under pre-Project conditions. There were a total of 10 small floods during the 20-year period studied under pre-Project conditions. The median rise and fall rates during small magnitude floods were 1,878 and 1,576 cfs per day, respectively.

Under post-Project conditions, there was a single small flood during the 20-year period with a peak magnitude of 11,910 cfs, and a duration of 11.0 days. The peak occurred on November 29. The median rise and fall rates during this flood were 1,666 and 2,309 cfs, respectively.

Under pre-Project conditions, the median peak magnitude of large floods (defined for the downstream end of Reach 2 to be a flood with a peak in excess of 16,610 cfs) was 17,900 cfs. The median duration of large floods under pre-Project conditions was 11.0 days. The median date of a large flood during the Water Year was November 7 under pre-

Project conditions. There were a total of 2 large floods during the 20-year period studied under pre-Project conditions. The median rise and fall rates during large magnitude floods were 3,601 and 2,515 cfs per day, respectively.

Under post-Project conditions, there was a single large flood during the 20-year period with a peak magnitude of 18,810 cfs, and a duration of 7 days. The peak occurred on November 24. The median rise and fall rates during this flood were 4,640 and 4,630 cfs, respectively.

4.5 Sultan River, Upstream End of Reach 3

Means and medians of average monthly flows in the Sultan River at the upstream end of Reach 3 under pre- and post-Project conditions are summarized in Table 4-13. The means of the average monthly flows were decreased at the upstream end of Reach 3 by the Project for all 12 months of the year.

The magnitudes and durations of annual extreme water conditions under pre- and post-Project conditions are summarized in Table 4-14. The magnitudes of annual minimum and maximum flows were decreased by the Project for all durations ranging from 1 to 90 days. There were no zero flow days under pre-and post-Project conditions. The base flow index, defined as the ratio of the annual 7-day minimum flow divided by the annual mean flow, was increased by the Project.

The median date of the annual 1-day minimum flow was shifted earlier in the Water Year from September 10 to July 1 by the Project. The median date of the annual 1-day maximum flow was also shifted earlier in the Water Year from December 13 to November 24 by the Project.

Under pre-Project conditions, the median annual number of low flow pulses (defined for the upstream end of Reach 3 to be flows less than 226 cfs) was 7.0 and the median duration of low flow pulses was 7.0 days. Under post-Project conditions, the median annual number of low flow pulses was 1.0 and the median duration of low flow pulses was 253.0 days

The median annual number of high flow pulses (defined by for the upstream end of Reach 3 to be flows greater than 869 cfs) was reduced by the Project from 16.5 to zero, and the median duration of high flow pulses was reduced by the Project from 3.0 to 2.5 days.

The median rate of rising flows was reduced by the Project from 65 to 9 cfs per day, and the median rate of falling flows was also reduced by the Project from 41 to 11 cfs per day. The median annual number of flow reversals was reduced by the Project from 106 to 42.

Table 4-13. Means and medians of average monthly flows in the Sultan River at the upstream end of Reach 3 under pre- and post-Project conditions.

Month	Mean of Average Monthly Flows (cfs)		Median of Average Monthly Flows (cfs)	
	Pre-Project Conditions	Post-Project Conditions	Pre-Project Conditions	Post-Project Conditions
July	354	27	282	20
August	153	27	110	20
September	220	25	96	20
October	728	52	336	20
November	1312	209	747	20
December	888	44	489	20
January	970	29	600	20
February	780	28	446	20
March	748	25	570	20
April	923	23	742	20
May	922	21	846	20
June	760	21	597	20

Table 4-14. Medians of magnitude and duration of annual extreme water conditions in the Sultan River at the upstream end of Reach 3 under pre- and post-Project conditions.

Parameter	Median	
	Pre-Project Conditions	Post-Project Conditions
1-day minimum flow (cfs)	57.6	20.0
3-day minimum flow (cfs)	58.3	20.0
7-day minimum flow (cfs)	61.9	20.0
30-day minimum flow (cfs)	78.7	20.0
90-day minimum flow (cfs)	182.2	20.2
1-day maximum flow (cfs)	8,539	300
3-day maximum flow (cfs)	5,736	175
7-day maximum flow (cfs)	3,437	107
30-day maximum flow (cfs)	1,735	46
90-day maximum flow (cfs)	1,238	35
Number of zero-flow days	0	0
Base flow index	0.083	0.759

The monthly median low flows under pre- and post-Project conditions are summarized in Table 4-15. The monthly median low flows were decreased by the Project for all 12 months of the year.

The median magnitude of low flow events (defined for the upstream end of Reach 3 to be flows less than or equal to 76 cfs) was reduced by the Project from 58.9 to 20.0 cfs, and the median duration of extreme low flow events was increased by the Project from 5.3 to 40.0 days. The median date of extreme low flows was shifted later in the Water Year from September 14 to December 9. The median number of extreme low flows was increased by the Project from 1.3 to 6.0 per year.

Table 4-15. Monthly median low flows in the Sultan River at the upstream end of Reach 3 under pre- and post-Project conditions.

Month	Monthly Median of Low Flows (cfs)	
	Pre-Project Conditions	Post-Project Conditions
July	272.4	115.5
August	114.0	90.1
September	134.0	89.3
October	218.0	126.9
November	350.5	163.9
December	333.5	134.2
January	354.1	144.2
February	381.2	244.3
March	426.0	116.2
April	544.0	85.1
May	596.0	128.0
June	520.9	91.7

The median magnitude of high flow pulses was increased by the Project from 1,314 to 2,723 cfs. The median duration of high flow pulses was reduced by the Project from 4.5 to 3.5 days. The median date of high flow pulses was shifted earlier in the Water Year from February 22 to November 25 by the Project. The median number of high flow pulses was reduced by the Project from 18.0 to zero. The median rate of rising flows during high flow pulses was increased by the Project from 388 to 1,271 cfs per day, and the median rate of falling flows during high flow pulses was increased by the Project from 202 to 671 cfs per day.

Under pre-Project conditions, the median peak magnitude of small floods (defined for the upstream end of Reach 3 to be a flood with a peak in excess of 8,539 cfs) was 9,593 cfs.

The median duration of small floods under pre-Project conditions was 14.0 days. The median date of a small flood during the Water Year was December 22 under pre-Project conditions. There were a total of 10 small floods during the 20-year period studied under pre-Project conditions. The median rise and fall rates during small magnitude floods were 1,558 and 1,313 cfs per day, respectively.

Under post-Project conditions, there was a single small flood during the 20-year period with a peak magnitude of 10,650 cfs, and a duration of 8.0 days. The peak occurred on November 29. The median rise and fall rates during this flood were 2,059and 2,613 cfs, respectively.

Under pre-Project conditions, the median peak magnitude of large floods (defined for the upstream end of Reach 3 to be a flood with a peak in excess of 14,660 cfs) was 15,200 cfs. The median duration of large floods under pre-Project conditions was 13.0 days. The median date of a large flood during the Water Year was November 7 under pre-Project conditions. There were a total of 2 large floods during the 20-year period studied under pre-Project conditions. The median rise and fall rates during large magnitude floods were 2,569 and 2,129 cfs per day, respectively.

Under post-Project conditions, there was a single large flood during the 20-year period with a peak magnitude of 15,310 cfs, and a duration of 5 days. The peak occurred on November 24. The median rise and fall rates during this flood were 5,095 and 4,949 cfs, respectively.

4.6 Sultan River, Downstream End of Reach 3

Means and medians of average monthly flows in the Sultan River at the downstream end of Reach 3 under pre- and post-Project conditions are summarized in Table 4-16. The means of the average monthly flows were decreased at the downstream end of Reach 3 by the Project for all 12 months of the year.

The magnitudes and durations of annual extreme water conditions under pre- and post-Project conditions are summarized in Table 4-17. The magnitudes of annual minimum and maximum flows were decreased by the Project for all durations ranging from 1 to 90 days. There were no zero flow days under pre-and post-Project conditions. The base flow index, defined as the ratio of the annual 7-day minimum flow divided by the annual mean flow, was increased by the Project.

The median date of the annual 1-day minimum flow was shifted later in the Water Year from September 10 to September 14 by the Project. The median date of the annual 1-day maximum flow was also shifted earlier in the Water Year from December 13 to December 5 by the Project.

Table 4-16. Means and medians of average monthly flows in the Sultan River at the downstream end of Reach 3 under pre- and post-Project conditions.

Month	Mean of Average Monthly Flows (cfs)		Median of Average Monthly Flows (cfs)	
	Pre-Project Conditions	Post-Project Conditions	Pre-Project Conditions	Post-Project Conditions
July	372	46	296	37
August	162	37	117	29
September	231	38	101	30
October	769	96	354	39
November	1404	305	841	87
December	967	115	528	60
January	1055	116	675	76
February	859	100	489	64
March	812	90	678	74
April	997	96	800	79
May	981	77	896	71
June	798	61	627	53

Table 4-17. Medians of magnitude and duration of annual extreme water conditions in the Sultan River at the downstream end of Reach 3 under pre- and post-Project conditions.

Parameter	Median	
	Pre-Project Conditions	Post-Project Conditions
1-day minimum flow (cfs)	60.8	23.5
3-day minimum flow (cfs)	61.6	23.8
7-day minimum flow (cfs)	65.4	24.1
30-day minimum flow (cfs)	82.9	26.2
90-day minimum flow (cfs)	192.0	34.4
1-day maximum flow (cfs)	9,094	827
3-day maximum flow (cfs)	6,132	582
7-day maximum flow (cfs)	3,743	343
30-day maximum flow (cfs)	1,894	184
90-day maximum flow (cfs)	1,339	140
Number of zero-flow days	0	0
Base flow index	0.082	0.300

Under pre-Project conditions, the median annual number of low flow pulses (defined for the downstream end of Reach 3 to be flows less than 242 cfs) was 7.5 and the median duration of low flow pulses was 6.3 days. Under post-Project conditions, the median annual number of low flow pulses was 6.5 and the median duration of low flow pulses was 21.3 days

The median annual number of high flow pulses (defined by for the downstream end of Reach 3 to be flows greater than 931 cfs) was reduced by the Project from 17.0 to zero, and the median duration of high flow pulses was reduced by the Project from 3.0 to 2.5 days.

The median rate of rising flows was reduced by the Project from 70 to 7 cfs per day, and the median rate of falling flows was also reduced by the Project from 42 to 4 cfs per day. The median annual number of flow reversals was increased by the Project from 106 to 117.

The monthly median low flows under pre- and post-Project conditions are summarized in Table 4-18. The monthly median low flows were decreased by the Project for all 12 months of the year.

The median magnitude of low flow events (defined for the downstream end of Reach 3 to be flows less than or equal to 80 cfs) was reduced by the Project from 62.1 to 54.2 cfs, and the median duration of extreme low flow events was reduced by the Project from 6.0 to 5.5 days. The median date of extreme low flows was shifted later in the Water Year from September 14 to January 28. The median number of extreme low flows was increased by the Project from 2.0 to 21.0 per year.

Table 4-18. Monthly median low flows in the Sultan River at the downstream end of Reach 3 under pre- and post-Project conditions.

Month	Monthly Median of Low Flows (cfs)	
	Pre-Project Conditions	Post-Project Conditions
July	286.1	123.3
August	121.0	99.0
September	139.9	101.0
October	229.3	120.2
November	371.1	128.6
December	360.5	147.1
January	382.6	129.9
February	414.7	108.6
March	464.2	116.2
April	586.9	107.2
May	645.1	103.2
June	547.8	96.7

The median magnitude of high flow pulses was reduced by the Project from 1,376 to 713 cfs. The median duration of high flow pulses was reduced by the Project from 4.8 to 1.0 days. The median date of high flow pulses was shifted earlier in the Water Year from February 23 to December 11 by the Project. The median number of high flow pulses was reduced by the Project from 18.5 to 2.5. The median rate of rising flows during high flow pulses was increased by the Project from 400 to 482 cfs per day, and the median rate of falling flows during high flow pulses was increased by the Project from 228 to 422 cfs per day.

Under pre-Project conditions, the median peak magnitude of small floods (defined for the downstream end of Reach 3 to be a flood with a peak in excess of 9,094 cfs) was 10,410 cfs. The median duration of small floods under pre-Project conditions was 14.0 days. The median date of a small flood during the Water Year was December 22 under pre-Project conditions. There were a total of 10 small floods during the 20-year period studied under pre-Project conditions. The median rise and fall rates during small magnitude floods were 1,697 and 1,426 cfs per day, respectively.

Under post-Project conditions, there was a single small flood during the 20-year period with a peak magnitude of 10,850 cfs, and a duration of 9.0 days. The peak occurred on November 29. The median rise and fall rates during this flood were 1,755and 2,641 cfs, respectively.

Under pre-Project conditions, the median peak magnitude of large floods (defined for the downstream end of Reach 3 to be a flood with a peak in excess of 15,490 cfs) was 16,230 cfs. The median duration of large floods under pre-Project conditions was 13.0 days. The median date of a large flood during the Water Year was November 7 under pre-Project conditions. There were a total of 2 large floods during the 20-year period studied under pre-Project conditions. The median rise and fall rates during large magnitude floods were 2,754 and 2,269 cfs per day, respectively.

Under post-Project conditions, there was a single large flood during the 20-year period with a peak magnitude of 16,510 cfs, and a duration of 7 days. The peak occurred on November 24. The median rise and fall rates during this flood were 4,107 and 4,104 cfs, respectively.

5.0 DISCUSSION AND CONCLUSIONS

An Indicators of Hydrologic Alteration/Range of Variability Analysis (IHA/RVA) was performed to assess the effects of Project operations on the hydrology of the Sultan River between Culmback Dam and the confluence with the Sultan River. Three study reaches were assessed: Reach 1 (from the Powerhouse to the confluence with the Skykomish River; Reach 2 (from the Diversion Dam to the Powerhouse); and Reach 3 (from Culmback Dam to the Diversion Dam). The IHA/RVA assessments were performed at the upstream and downstream ends of each of the three study reaches.

A common period was selected to perform this study, from July 1, 1984 to June 30, 2004 representing Water Years from 1985 to 2004. This 20-year period is representative of current Project operations. Pre-Project hydrology was synthesized using hydrologic records obtained from the US Geological Survey (USGS), the District, and the City. The selection of a common study period for comparing pre- and post-Project conditions enabled a direct assessment of Project-related effects without the confounding factors that would be associated with different study periods with differing hydrology.

To place the results of this analysis that was based on the 20-year study period (1985 to 2004) in perspective, 77 years of flows measured in the nearby Skykomish River near Gold Bar (USGS Gage 12134500) were examined to see how representative this period was with respect to long-term hydrology. Results of these analyses are shown in Figure 5-1. The long-term average flow in the Skykomish River near Gold Bar is 3,960 cfs. Within the 77-year period from 1930 to 2006, several extended wet and dry periods can be seen in Figure 5-1. For example, the period from 1947 to 1976 was relatively wet with an average flow of 4,270 cfs, while the period from 1936 to 1946 was relatively dry with an average flow of 3,300 cfs. The average flow during the study period selected for the IHA/RVA assessments was 3,930 cfs, remarkably close to the long-term average flow.

Furthermore, the wettest year during the selected study period (1996 with and average flow of 5,390 cfs) would rank as the third wettest year during the 77-year long-term period. In addition, the driest year during the selected study period (1994 with and average flow of 2,750 cfs) would rank as the third driest year during the long-term period. Thus, based on long-term flow records from the nearby gage on the Skykomish River near Gold Bar, the study period selected for the IHA/RVA analysis from 1985 to 2004 should provide a reasonable representation of long-term hydrology.

Results of the analyses reported herein can be summarized on a reach by reach basis with respect to the five IHA parameter groups (magnitude of monthly water conditions, magnitude and duration of annual extreme water conditions, timing of annual extreme water conditions, frequency and duration of high and low pulses, rate and frequency of water condition changes), and with respect to the five Environmental Flow Component (EFC) parameter groups (monthly low flows, extreme low flows, high flow pulses, small floods, and large floods).

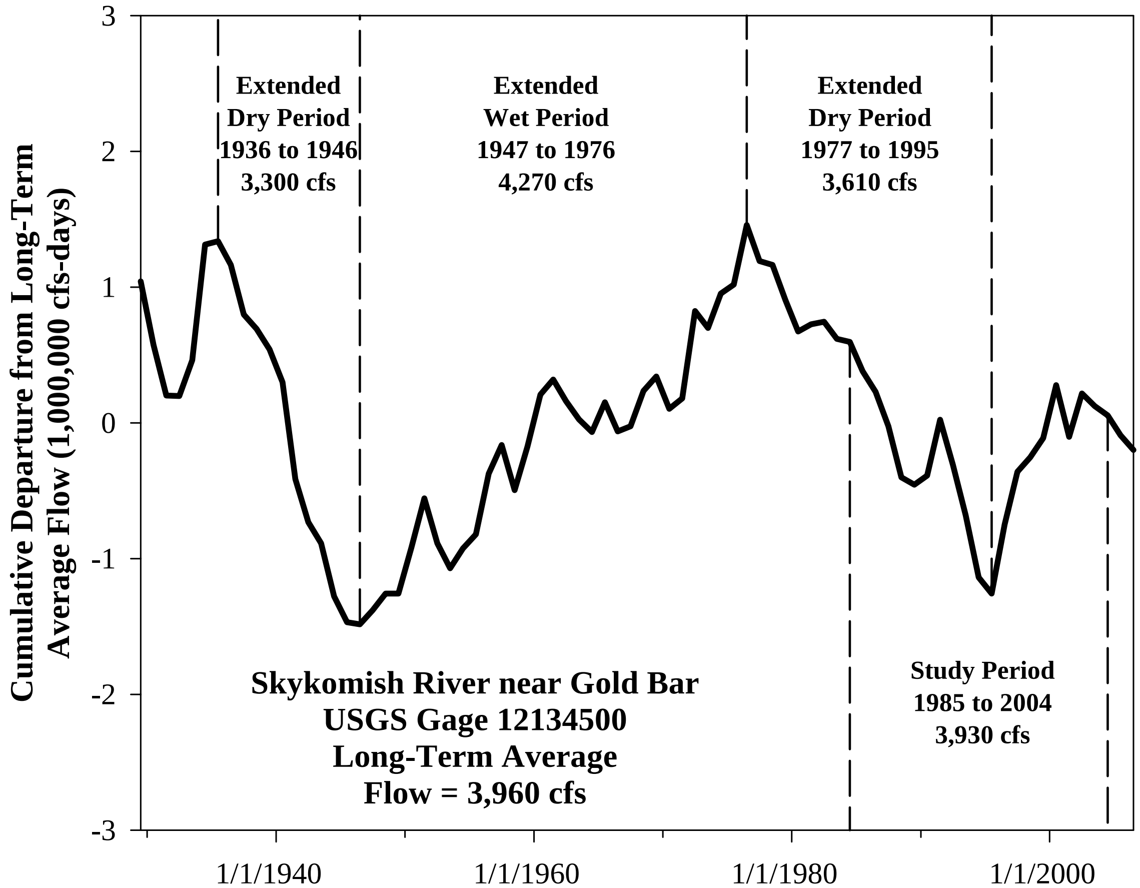

Figure 5-1. Cumulative departure of flow from long-term average flow in Skykomish River near Gold Bar, USGS Gage 12134500, 1930 to 2006.

Summary results from Reach 1 of the Sultan River extending from the Powerhouse to the confluence with the Skykomish River are as follows:

1. ***Magnitude of monthly water conditions.*** Average monthly flows were increased in Reach 1 by the Project in July, August, September, December, and February, and were decreased in Reach 1 by the Project in October, November, January, March, April, May, and June.

2. ***Magnitude and duration of annual extreme water conditions.*** The magnitudes of annual minimum flows were increased in Reach 1 by the Project for all durations ranging from 1 to 90 days, and the magnitudes of annual maximum flows were decreased in Reach 1 by the Project for all durations ranging from 1 to 90 days. There were no zero flow days in Reach 1 under pre-and post-Project conditions. The base flow index, defined as the ratio of the annual 7-day minimum flow divided by the annual mean flow, was increased in Reach 1 by the Project.

3. ***Timing of annual extreme water conditions.*** The annual 1-day minimum flow was shifted in Reach 1 by the Project earlier in the Water Year from September to August, and the annual 1-day maximum flow was also shifted in Reach 1 by the Project earlier in the Water Year from December to November.

4. ***Frequency and duration of high and low pulses.*** The occurrence of low flow pulses has been eliminated in Reach 1 by the Project. The frequency of high flow pulses has decreased in Reach 1, and the duration of high flow pulses has increased in Reach 1, as a result of Project operations.

5. ***Rate and frequency of water condition changes.*** The rates of change of rising and falling flows have both been reduced in Reach 1 by the Project, while the number of flow reversals in Reach 1 has increased.

6. ***Monthly low flows.*** The monthly median low flows were increased in Reach 1 by the Project from July through March, and were decreased in Reach 1 by the Project from April through June.

7. ***Extreme low flows.*** The occurrence of extreme low flows has been eliminated in Reach 1 by the Project.

8. ***High flow pulses.*** The median magnitude of high flow pulses was reduced, and the median duration of high flow pulses was increased in Reach 1 by the Project. High flow pulses typically occurred in February under both pre- and post-Project conditions. The frequency of high flow pulses has been reduced in Reach 1 by the Project. The rates of change of rising and falling flows during high flow pulses have both been reduced in Reach 1 by the Project.

9. ***Small floods.*** The recurrence interval of small magnitude flows has been increased from 2 years to about 20 years in Reach 1 by the Project. The peak magnitude of small magnitude floods has been reduced and the duration of small magnitude floods has been increased in Reach 1 by the Project. The rates of change of rising and falling flows during small magnitude floods have both been reduced in Reach 1 by the Project.

10. ***Large floods.*** The recurrence interval of large magnitude flows has been increased from 10 years to about 20 years in Reach 1 by the Project. The peak magnitude of large magnitude floods and the duration of large magnitude floods have both been increased in Reach 1 by the Project. The rates of change of rising and falling flows during large magnitude floods have both been reduced in Reach 1 by the Project.

Summary results from Reach 2 of the Sultan River extending from the Diversion Dam to the Powerhouse are as follows:

1. ***Magnitude of monthly water conditions.*** Average monthly flows were increased in Reach 2 by the Project in August and September, and were decreased in Reach 2 by the Project from October through July.

2. ***Magnitude and duration of annual extreme water conditions.*** The magnitudes of annual minimum flows were increased in Reach 2 by the Project for all durations ranging from 1 to 90 days, and the magnitudes of annual maximum flows were decreased in Reach 2 by the Project for all durations ranging from 1 to 90 days. There were no zero flow days in Reach 2 under pre-and post-Project conditions. The base flow index, defined as the ratio of the annual 7-day minimum flow divided by the annual mean flow, was increased in Reach 2 by the Project.

3. ***Timing of annual extreme water conditions.*** The annual 1-day minimum flow at the upstream end of Reach 2 typically occurred in July under both pre-and post-Project conditions. The annual 1-day minimum flow was shifted at the downstream end of Reach 2 by the Project earlier in the Water Year from September to August. The annual 1-day maximum flow was shifted at the upstream end of Reach 2 by the Project earlier in the Water Year from December to November. The annual 1-day maximum flow at the downstream end of Reach 2 typically occurred in December under both pre-and post-Project conditions.

4. ***Frequency and duration of high and low pulses.*** The occurrence of low flow pulses has been eliminated in Reach 2 by the Project. The frequency and duration of high flow pulses have both been decreased in Reach 2, as a result of Project operations.

5. ***Rate and frequency of water condition changes.*** The rates of change of rising and falling flows have both been reduced in Reach 2 by the Project, while the number of flow reversals in Reach 2 has increased.

6. ***Monthly low flows.*** The monthly median low flows were increased in Reach 2 by the Project from August through October, and were decreased in Reach 2 by the Project from November through July.

7. ***Extreme low flows.*** The occurrence of extreme low flows has been eliminated in Reach 2 by the Project.

8. ***High flow pulses.*** The magnitude and duration of high flow pulses have both been reduced by the Project. High flow pulses were shifted at the upstream end of Reach 2 by the Project earlier in the Water Year from February to December. High flow pulses were shifted at the downstream end of Reach 2 by the Project earlier in the Water Year from February to January. The frequency of high flow pulses has been reduced in Reach 2 by the Project. The rate of change of rising flows during high flow pulses has been reduced in Reach 2 by the Project. The rate of change of falling flows has been increased at the upstream end of Reach 2 and reduced at the downstream end of Reach 2 by the Project.

9. ***Small floods.*** The recurrence interval of small magnitude flows has been increased from 2 years to about 20 years in Reach 2 by the Project. The peak magnitude of small magnitude floods has been increased at the upstream end of

Reach 2 and decreased at the downstream end of Reach 2 by the Project. The duration of small magnitude floods has been reduced in Reach 2 by the Project. The rate of change of rising flows during small magnitude flows was increased and the upstream end of Reach 2 and reduced at the downstream end of Reach 2 by the Project. The rate of change of falling flows during small magnitude floods has been increased in Reach 2 by the Project.

10. ***Large floods.*** The recurrence interval of large magnitude flows has been increased from 10 years to about 20 years in Reach 2 by the Project. The peak magnitude of large magnitude floods has been increased in Reach 2 by the Project. The duration of large magnitude floods has been reduced in Reach 2 by the Project. The rates of change of rising and falling flows during large magnitude floods have both been increased in Reach 2 by the Project.

Summary results from Reach 3 of the Sultan River extending from Culmback Dam to the Diversion Dam are as follows:

1. ***Magnitude of monthly water conditions.*** Average monthly flows were decreased in Reach 3 by the Project for all 12 months of the year.

2. ***Magnitude and duration of annual extreme water conditions.*** The magnitudes of annual minimum flows and annual maximum were both decreased in Reach 3 by the Project for all durations ranging from 1 to 90 days. There were no zero flow days in Reach 3 under pre-and post-Project conditions. The base flow index, defined as the ratio of the annual 7-day minimum flow divided by the annual mean flow, was increased in Reach 3 by the Project.

3. ***Timing of annual extreme water conditions.*** The annual 1-day minimum flow was shifted at the upstream end of Reach 3 by the Project earlier in the Water Year from September to July. The annual 1-day minimum flow at the downstream end of Reach 3 typically occurred in September under both pre-and post-Project conditions. The annual 1-day maximum flow was shifted at the upstream end of Reach 3 by the Project earlier in the Water Year from December to November. The annual 1-day maximum flow at the downstream end of Reach 3 typically occurred in December under both pre-and post-Project conditions.

4. ***Frequency and duration of high and low pulses.*** The frequency of low flow pulses has been reduced and the duration has been increased in Reach 3 by the Project. The occurrence of low flow pulses has been eliminated in Reach 2 by the Project. The frequency and duration of high flow pulses have both been decreased in Reach 3, as a result of Project operations.

5. ***Rate and frequency of water condition changes.*** The rates of change of rising and falling flows have both been reduced in Reach 3 by the Project. The number of flow reversals has been reduced at the upstream end of Reach 3 and increased at the downstream end of Reach 3 by the Project.

6. ***Monthly low flows.*** The monthly median low flows were decreased in Reach 3 by the Project for all 12 months of the year.

7. ***Extreme low flows.*** The median magnitude of extreme low flows has been reduced in Reach 3 by the Project. The duration of extreme low flows has been increased at the upstream end of Reach 3 and reduced at the downstream end of Reach 3 by the Project. Extreme low flows have been shifted at the upstream end of Reach 3 by the Project later in the Water Year from September to December. Extreme low flows have been shifted at the downstream end of Reach 3 by the Project later in the Water Year from September to January. The frequency of extreme low flows has been reduced at the upstream end of Reach 3 and increased at the downstream end of Reach 3 by the Project.

8. ***High flow pulses.*** The magnitude of high flow pulses has been increased at the upstream end of Reach 3 and reduced at the downstream end of Reach 3 by the Project. The duration of high flow pulses has been reduced in Reach 3 by the Project. High flow pulses were shifted at the upstream end of Reach 3 by the Project earlier in the Water Year from February to November. High flow pulses were shifted at the downstream end of Reach 3 by the Project earlier in the Water Year from February to December. The frequency of high flow pulses has been reduced in Reach 3 by the Project. The rates of change of rising and falling flows during high flow pulses have both been increased in Reach 3 by the Project.

9. ***Small floods.*** The recurrence interval of small magnitude flows has been increased from 2 years to about 20 years in Reach 2 by the Project. The peak magnitude of small magnitude floods has been increased Reach 3 by the Project. The duration of small magnitude floods has been reduced in Reach 3 by the Project. The rates of change of rising and falling flows during small magnitude floods have both been increased in Reach 3 by the Project.

10. ***Large floods.*** The recurrence interval of large magnitude flows has been increased from 10 years to about 20 years in Reach 3 by the Project. The peak magnitude of large magnitude floods has been increased in Reach 3 by the Project. The duration of large magnitude floods has been reduced in Reach 3 by the Project. The rates of change of rising and falling flows during large magnitude floods have both been increased in Reach 3 by the Project.

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Appendix A
Results of IHA/RVA Analyses of

Sultan River,
Upstream End of Reach 1

Table A-1. Percentile distribution of average monthly flows in Sultan River at the upstream end of Reach 1 under pre- and post-Project conditions.

Month	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
July	14.3	33.9	162.6	313.4	511.9	192.4	212.8	307.5	448.8	787.6
August	8.0	10.2	13.3	16.0	164.6	179.2	193.8	207.0	273.8	317.7
September	8.0	9.0	11.0	24.3	92.2	204.6	232.6	285.5	383.5	415.3
October	7.8	15.7	231.0	639.5	970.3	235.7	276.5	368.0	727.0	1,379.0
November	175.3	530.7	784.2	1,213.0	1,361.0	260.8	711.0	1,273.0	1,538.0	1,703.0
December	271.6	412.7	484.5	664.0	992.8	435.8	702.0	1,075.0	1,498.0	1,638.0
January	185.5	337.3	665.1	965.3	1,029.0	369.1	512.8	838.5	1,505.0	1,673.0
February	171.7	335.7	458.0	574.7	886.4	344.7	455.8	771.5	1,133.0	1,529.0
March	202.2	447.2	669.9	899.1	987.7	307.6	394.8	623.0	919.3	1,390.0
April	464.5	537.9	799.1	1,002.0	1,556.0	288.2	404.6	611.5	938.1	1,408.0
May	496.2	636.0	867.5	1,093.0	1,238.0	309.1	430.3	688.0	873.3	1,091.0
June	249.0	330.9	541.6	1,015.0	1,118.0	277.1	360.4	495.8	986.3	1,285.0

Table A-2. Results of range of variability analyses of average monthly flows in Sultan River at the upstream end of Reach 1.

Month	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
July	6	0	-1.0	8	6	-0.3	6	14	1.3
August	6	0	-1.0	9	0	-1.0	5	20	3.0
September	6	0	-1.0	8	0	-1.0	6	20	2.3
October	6	0	-1.0	8	12	0.5	6	8	0.3
November	6	5	-0.2	8	2	-0.8	6	13	1.2
December	6	2	-0.7	8	1	-0.9	6	17	1.8
January	6	4	-0.3	8	7	-0.1	6	9	0.5
February	6	4	-0.3	8	1	-0.9	6	15	1.5
March	6	6	0.0	8	9	0.1	6	5	-0.2
April	6	10	0.7	8	5	-0.4	6	5	-0.2
May	6	13	1.2	8	5	-0.4	6	2	-0.7
June	6	9	0.5	8	5	-0.4	6	6	0.0

Table A-3. Percentile distribution of magnitude and duration of annual extreme water conditions in Sultan River at the upstream end of Reach 1 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
1-day minimum	4.8	6.5	7.6	8.7	11.0	166.3	177.5	189.5	195.5	238.6
3-day minimum	4.9	6.5	7.8	9.0	11.4	167.6	182.0	190.2	197.0	246.5
7-day minimum	5.0	7.1	8.2	9.4	12.3	169.3	187.7	195.2	203.4	252.7
30-day minimum	6.3	8.2	9.9	14.7	23.7	172.0	193.4	206.0	240.3	307.9
90-day minimum	20.2	50.0	83.9	132.5	228.3	204.5	222.5	270.4	373.5	470.7
1-day maximum	4,544	5,895	10,320	12,390	16,610	1,731	2,025	2,385	4,580	11,680
3-day maximum	2,454	4,163	6,790	8,691	9,893	1,596	1,806	1,985	3,270	7,665
7-day maximum	2,181	2,838	4,231	5,041	5,988	1,535	1,646	1,850	2,508	4,910
30-day maximum	1,276	1,628	2,033	2,413	3,426	1,028	1,422	1,630	1,831	2,879
90-day maximum	941	1,239	1,402	1,581	2,081	857	1,098	1,293	1,471	2,012
Number of zero-flow days	0	0	0	0	0	0	0	0	0	0
Base flow index	0.007	0.009	0.010	0.013	0.021	0.193	0.226	0.271	0.329	0.430

Table A-4. Results of range of variability analyses of magnitude and duration of annual extreme water conditions in Sultan River at the upstream end of Reach 1.

Parameter	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
1-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
3-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
7-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
30-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
90-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
1-day maximum	6	18	2.0	8	0	-1.0	6	2	-0.7
3-day maximum	6	17	1.8	8	2	-0.8	6	1	-0.8
7-day maximum	6	17	1.8	8	1	-0.9	6	2	-0.7
30-day maximum	6	13	1.2	8	4	-0.5	6	3	-0.5
90-day maximum	6	11	0.8	8	5	-0.4	6	4	-0.3
Number of zero-flow days	0	0		20	20	0.0	0	0	
Base flow index	6	0	-1.0	8	0	-1.0	6	20	2.3

Table A-5. Percentile distribution of timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes in Sultan River at the upstream end of Reach 1 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Date of annual 1-day minimum	Aug 29	Sep 5	Sep 14	Sep 30	Oct 8	Jul 14	Jul 26	Aug 14	Aug 23	Sep 11
Date of annual 1-day maximum	Sep 30	Oct 25	Dec 13	Feb 17	Mar 2	Jun 19	Nov 5	Nov 28	Jan 28	Mar 11
Annual number of low pulses	3	4	6	8	12	0	0	0	0	0
Annual median duration of low pulses (days)	2.7	4.6	7	11.5	23.4					
Annual number of high pulses	12	14	16	22	28	4	5	8	11	14
Annual median duration of high pulses (days)	2.1	2.5	3	3.9	4.5	3.1	5	6.3	12	15.4
Median rate of rising flows (cfs/day)	46	60	76	107	131	10	16	28	40	59
Median rate of falling flows (cfs/day)	-90	-79	-48	-36	-29	-44	-33	-26	-16	-10
Number of flow reversals	92	100	107	122	126	111	121	127	138	147

Table A-6. Results of range of variability analyses of timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes in Sultan River at the upstream end of Reach 1.

Parameter	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
Date of annual 1-day minimum	5	17	2.4	9	3	-0.7	6	0	-1.0
Date of annual 1-day maximum	6	6	0.0	8	7	-0.1	6	7	0.2
Annual number of low pulses	6	20	2.3	8	0	-1.0	6	0	-1.0
Annual median duration of low pulses (days)	0	0		0	0		0	0	
Annual number of high pulses	6	19	2.2	10	1	-0.9	4	0	-1.0
Annual median duration of high pulses (days)	6	0	-1.0	9	3	-0.7	5	17	2.4
Median rate of rising flows (cfs/day)	6	20	2.3	8	0	-1.0	6	0	-1.0
Median rate of falling flows (cfs/day)	6	0	-1.0	8	2	-0.8	6	18	2.0
Number of flow reversals	5	0	-1.0	9	2	-0.8	6	18	2.0

Table A-7. Percentile distribution of monthly median low flows in Sultan River at the upstream end of Reach 1 under pre- and post-Project conditions.

Month	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
July	14.2	39.2	151.6	300.8	392.9	192.0	203.5	293.5	331.3	613.7
August	10.1	11.4	13.6	15.9	123.1	179.2	193.8	206.5	272.6	317.7
September	10.3	10.9	14.2	58.9	80.6	204.6	232.6	278.0	373.8	408.3
October	11.9	22.1	87.0	209.3	332.7	234.5	276.4	332.8	375.8	450.6
November	80.2	178.4	277.4	509.3	643.9	236.2	260.5	337.5	643.5	872.1
December	158.0	214.7	297.0	367.7	444.5	209.8	387.5	580.8	698.3	810.4
January	148.2	206.4	303.7	403.6	445.2	251.8	351.5	436.5	667.5	775.2
February	138.4	204.9	322.9	379.6	465.0	340.0	364.0	512.0	744.0	791.0
March	196.3	295.1	368.6	463.3	553.1	304.0	361.0	384.0	549.0	637.0
April	262.4	367.2	555.3	703.4	792.8	265.3	364.3	505.3	626.5	741.5
May	367.2	428.9	580.9	702.8	750.0	294.7	347.1	535.5	697.0	804.6
June	244.8	297.2	454.2	570.8	742.4	251.3	292.8	362.3	690.8	831.0

Table A-8. Percentile distribution of extreme low flow characteristics and high flow pulse parameters in Sultan River at the upstream end of Reach 1 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Extreme low magnitude (cfs)	7.0	7.2	8.6	9.1	9.3					
Extreme low duration (days)	1.0	1.4	3.5	18.1	26.8					
Date of extreme low	Aug 28	Sep 4	Sep 13	Sep 21	Oct 20					
Extreme low frequency	0.1	2.0	2.0	3.8	5.0	0	0	0	0	0
High flow pulse magnitude (cfs)	1,048	1,185	1,483	1,726	1,915	671	832	1,077	1,405	1,662
High flow pulse duration (days)	3.6	4.0	4.0	5.8	7.0	2.6	3.3	5.8	10.1	14.0
Date of high flow pulse	Dec 23	Jan 18	Feb 22	Mar 22	Apr 2	Jan 5	Jan 25	Feb 27	Apr 12	May 17
High flow pulse frequency	14.1	16.3	19.0	22.8	25.0	7.1	9.0	11.5	14.0	18.9
High flow pulse rise rate (cfs/day)	317	363	432	571	683	135	162	187	232	300
High flow pulse fall rate (cfs/day)	-395	-302	-258	-179	-153	-150	-135	-99	-83	-63

Table A-9. Percentile distribution of small flood and large flood characteristics in Sultan River at the upstream end of Reach 1 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Small flood magnitude (cfs)	10,600	11,390	11,960	12,560	12,970			12,100		
Small flood duration (days)	4.6	11.5	13.5	18.6	22.6			112.0		
Date of small flood	Oct 19	Nov 22	Dec 22	Jan 11	Mar 14			Nov 29		
Small flood frequency	0.0	0.0	0.5	1.0	2.0	0.0	0.0	0.0	0.0	0.0
Small flood rise rate (cfs/day)	692	1,538	1,878	3,805	5,637			257		
Small flood fall rate (cfs/day)	-5,190	-1,857	-1,576	-1,078	-904			-165		
Large flood magnitude (cfs)	17,040	17,040	17,900	18,770	18,770			20,100		
Large flood duration (days)	11.0	11.0	11.0	11.0	11.0			82.0		
Date of large flood	Oct 21	Oct 21	Nov 7	Nov 24	Nov 24			Nov 24		
Large flood frequency	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0
Large flood rise rate (cfs/day)	2,689	2,689	3,601	4,512	4,512			492		
Large flood fall rate (cfs/day)	-2,783	-2,783	-2,515	-2,246	-2,246			-457		

Appendix B

Results of IHA/RVA Analyses of

Sultan River,

Downstream End of Reach 1

Table B-1. Percentile distribution of average monthly flows in Sultan River at the downstream end of Reach 1 under pre- and post-Project conditions.

Month	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
July	23.0	44.6	179.8	339.1	545.7	202.4	225.0	326.9	469.4	819.4
August	11.9	15.7	21.3	26.2	187.1	183.8	200.7	216.6	287.1	326.6
September	11.9	13.6	17.3	36.1	107.6	209.6	241.0	304.7	395.9	439.7
October	11.6	25.7	255.0	687.5	1,039.0	243.9	312.3	405.6	795.7	1,507.0
November	202.9	585.5	852.8	1,316.0	1,472.0	295.9	775.4	1,406.0	1,638.0	1,824.0
December	309.3	454.2	532.1	724.9	1,085.0	483.0	753.7	1,148.0	1,540.0	1,718.0
January	213.1	378.1	731.6	1,059.0	1,131.0	406.5	563.2	1,069.0	1,528.0	1,743.0
February	197.8	377.1	510.6	637.8	977.7	367.7	511.4	843.0	1,204.0	1,586.0
March	228.7	494.5	735.9	985.2	1,081.0	354.7	490.6	686.8	1,044.0	1,408.0
April	512.0	590.1	869.8	1,090.0	1,684.0	336.7	450.4	682.1	1,098.0	1,538.0
May	535.0	682.1	928.8	1,174.0	1,329.0	346.9	490.6	745.8	945.6	1,168.0
June	269.7	356.0	578.2	1,075.0	1,186.0	301.8	387.0	555.6	1,048.0	1,389.0

Table B-2. Results of range of variability analyses of average monthly flows in Sultan River at the downstream end of Reach 1.

Month	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
July	6	0	-1.0	8	6	-0.3	6	14	1.3
August	6	0	-1.0	8	0	-1.0	6	20	2.3
September	6	0	-1.0	8	0	-1.0	6	20	2.3
October	6	0	-1.0	8	12	0.5	6	8	0.3
November	6	5	-0.2	8	2	-0.8	6	13	1.2
December	6	2	-0.7	8	2	-0.8	6	16	1.7
January	6	3	-0.5	8	6	-0.3	6	11	0.8
February	6	4	-0.3	8	1	-0.9	6	15	1.5
March	6	6	0.0	8	8	0.0	6	6	0.0
April	6	9	0.5	8	4	-0.5	6	7	0.2
May	6	13	1.2	8	4	-0.5	6	3	-0.5
June	6	9	0.5	8	5	-0.4	6	6	0.0

Table B-3. Percentile distribution of magnitude and duration of annual extreme water conditions in Sultan River at the downstream end of Reach 1 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
1-day minimum	6.2	9.2	11.1	13.1	17.3	171.3	185.8	195.5	200.9	275.8
3-day minimum	6.3	9.3	11.5	13.7	18.1	172.6	189.7	197.0	203.0	281.7
7-day minimum	6.6	10.3	12.3	14.5	19.5	173.6	193.9	201.4	210.6	291.7
30-day minimum	8.9	12.2	15.2	21.2	32.4	176.7	202.9	214.2	258.2	321.7
90-day minimum	26.6	58.5	96.7	148.5	249.3	213.4	239.6	282.2	386.5	504.5
1-day maximum	4,898	6,408	11,200	13,190	17,660	1,884	2,483	3,075	4,859	11,950
3-day maximum	2,663	4,513	7,353	9,398	10,610	1,726	2,032	2,576	3,630	8,208
7-day maximum	2,387	3,082	4,609	5,448	6,462	1,676	1,847	2,144	2,853	5,320
30-day maximum	1,395	1,769	2,193	2,613	3,694	1,146	1,574	1,758	2,028	3,135
90-day maximum	1,032	1,346	1,522	1,729	2,253	929	1,213	1,404	1,596	2,187
Number of zero-flow days	0	0	0	0	0	0	0	0	0	0
Base flow index	0.009	0.011	0.014	0.017	0.030	0.184	0.212	0.252	0.314	0.418

Table B-4. Results of range of variability analyses of magnitude and duration of annual extreme water conditions in Sultan River at the downstream end of Reach 1.

Parameter	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
1-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
3-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
7-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
30-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
90-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
1-day maximum	6	18	2.0	8	1	-0.9	6	1	-0.8
3-day maximum	6	17	1.8	8	2	-0.8	6	1	-0.8
7-day maximum	6	17	1.8	8	1	-0.9	6	2	-0.7
30-day maximum	6	13	1.2	8	4	-0.5	6	3	-0.5
90-day maximum	6	11	0.8	8	5	-0.4	6	4	-0.3
Number of zero-flow days	0	0		20	20	0.0	0	0	
Base flow index	6	0	-1.0	8	0	-1.0	6	20	2.3

Table B-5. Percentile distribution of timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes in Sultan River at the downstream end of Reach 1 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Date of annual 1-day minimum	Aug 29	Sep 5	Sep 14	Sep 30	Oct 8	Jul 6	Aug 7	Aug 26	Sep 4	Sep 16
Date of annual 1-day maximum	Sep 30	Oct 25	Dec 13	Feb 17	Mar 2	Jun 19	Oct 24	Nov 27	Jan 26	Mar 17
Annual number of low pulses	3	4	6	8	12	0	0	0	0	0
Annual median duration of low pulses (days)	2.7	4.6	8.5	12.8	27.7					
Annual number of high pulses	12	14	17	22	26	4	6	8	12	14
Annual median duration of high pulses (days)	2	2.6	3	4	4.9	2.1	3.8	6	13.8	14.5
Median rate of rising flows (cfs/day)	43	63	82	114	137	13	21	31	41	47
Median rate of falling flows (cfs/day)	-94	-84	-50	-40	-30	-45	-36	-24	-17	-12
Number of flow reversals	93	100	108	122	126	122	129	138	146	154

Table B-6. Results of range of variability analyses of timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes in Sultan River at the downstream end of Reach 1.

Parameter	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
Date of annual 1-day minimum	5	16	2.2	9	3	-0.7	6	1	-0.8
Date of annual 1-day maximum	6	5	-0.2	8	8	0.0	6	7	0.2
Annual number of low pulses	6	20	2.3	8	0	-1.0	6	0	-1.0
Annual median duration of low pulses (days)	0	0		0	0		0	0	
Annual number of high pulses	5	19	2.8	11	1	-0.9	4	0	-1.0
Annual median duration of high pulses (days)	5	2	-0.6	9	3	-0.7	6	15	1.5
Median rate of rising flows (cfs/day)	6	20	2.3	8	0	-1.0	6	0	-1.0
Median rate of falling flows (cfs/day)	6	0	-1.0	8	2	-0.8	6	18	2.0
Number of flow reversals	5	0	-1.0	9	0	-1.0	6	20	2.3

Table B-7. Percentile distribution of monthly median low flows in Sultan River at the downstream end of Reach 1 under pre- and post-Project conditions.

Month	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
July	23.0	50.3	168.3	325.1	422.1	202.4	218.9	310.3	358.1	646.0
August	15.6	17.9	21.9	25.9	140.9	183.8	200.7	216.5	287.1	326.4
September	16.1	17.0	22.9	72.7	95.1	201.9	237.3	304.7	380.8	414.4
October	18.8	33.6	100.5	236.4	360.4	241.3	285.3	360.6	404.1	490.4
November	101.3	202.4	307.2	559.8	702.0	262.1	283.8	438.0	917.2	979.8
December	185.9	238.8	330.5	406.2	488.5	235.9	433.3	624.0	732.8	841.0
January	174.5	231.1	341.0	450.5	515.4	287.5	420.2	522.3	766.2	878.8
February	162.2	234.3	355.5	423.4	517.9	367.0	409.1	555.2	803.4	836.5
March	222.6	329.6	402.7	494.4	613.5	345.5	412.6	489.0	588.4	667.0
April	293.4	406.4	610.3	763.6	858.1	303.7	435.0	593.4	703.5	826.7
May	396.4	463.4	640.4	751.2	803.5	340.3	403.6	609.3	759.0	858.1
June	265.2	320.4	485.4	615.1	792.5	281.0	319.6	407.8	747.2	905.9

Table B-8. Percentile distribution of extreme low flow characteristics and high flow pulse parameters in Sultan River at the downstream end of Reach 1 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Extreme low magnitude (cfs)	10.0	10.5	13.0	13.9	14.2					
Extreme low duration (days)	1.0	1.4	3.5	18.1	26.8					
Date of extreme low	Aug 28	Sep 4	Sep 13	Sep 21	Oct 20					
Extreme low frequency	0.1	2.0	2.0	3.8	5.0	0	0	0	0	0
High flow pulse magnitude (cfs)	1,147	1,240	1,538	1,735	2,041	803	909	1,194	1,477	1,781
High flow pulse duration (days)	3.6	4.0	4.5	6.0	6.5	2.1	4.0	6.3	9.0	15.4
Date of high flow pulse	Dec 25	Jan 14	Feb 23	Mar 22	Apr 2	Jan 16	Feb 6	Feb 23	Apr 3	May 4
High flow pulse frequency	13.3	17.0	19.0	22.8	25.0	8.0	9.0	10.0	14.0	18.0
High flow pulse rise rate (cfs/day)	322	363	434	550	739	158	185	221	241	281
High flow pulse fall rate (cfs/day)	-428	-318	-280	-193	-166	-157	-135	-112	-88	-65

Table B-9. Percentile distribution of small flood and large flood characteristics in Sultan River at the downstream end of Reach 1 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Small flood magnitude (cfs)	11,450	12,310	12,970	13,360	14,040			12,340		
Small flood duration (days)	4.6	11.9	14.0	18.6	22.6			111.0		
Date of small flood	Oct 19	Nov 22	Dec 22	Jan 11	Mar 14			Nov 29		
Small flood frequency	0.0	0.0	0.5	1.0	2.0	0.0	0.0	0.0	0.0	0.0
Small flood rise rate (cfs/day)	747	1,658	2,039	4,080	6,068			261		
Small flood fall rate (cfs/day)	-5,595	-2,021	-1,589	-1,145	-917			-172		
Large flood magnitude (cfs)	18,080	18,080	19,150	20,230	20,230			21,560		
Large flood duration (days)	11.0	11.0	11.0	11.0	11.0			82.0		
Date of large flood	Oct 21	Oct 21	Nov 7	Nov 24	Nov 24			Nov 24		
Large flood frequency	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0
Large flood rise rate (cfs/day)	2,852	2,852	3,856	4,861	4,861			516		
Large flood fall rate (cfs/day)	-2,950	-2,950	-2,685	-2,420	-2,420			-502		

Appendix C

Results of IHA/RVA Analyses of

Sultan River,

Upstream End of Reach 2

Table C-1. Percentile distribution of average monthly flows in Sultan River at the upstream end of Reach 2 under pre- and post-Project conditions.

Month	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
July	3.0	20.2	140.7	280.5	468.6	101.3	107.8	114.0	126.3	146.7
August	3.0	3.0	3.0	3.0	135.8	98.2	108.0	117.0	119.8	148.8
September	3.0	3.0	3.0	9.2	73.4	146.6	154.8	166.0	173.8	176.0
October	3.0	3.0	200.3	578.0	881.9	159.3	166.5	178.0	187.0	200.5
November	140.0	460.7	696.5	1,082.0	1,218.0	104.1	119.8	142.0	165.8	225.9
December	223.5	359.7	423.7	586.1	874.6	103.1	113.0	122.0	151.3	169.6
January	150.1	285.0	580.0	845.7	898.5	148.5	158.0	172.0	180.5	206.8
February	138.3	282.7	390.8	493.9	769.7	154.1	162.8	175.8	188.5	203.1
March	168.2	386.7	585.5	789.6	868.8	180.3	187.8	197.5	214.5	245.7
April	403.8	472.4	708.6	890.1	1,385.0	179.6	182.3	196.8	207.9	226.4
May	446.3	576.9	789.2	990.4	1,134.0	177.3	182.0	196.0	207.5	215.7
June	222.7	298.8	494.8	936.0	1,030.0	140.1	153.8	170.8	184.1	196.4

Table C-2. Results of range of variability analyses of average monthly flows in Sultan River at the upstream end of Reach 2.

Month	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
July	6	0	-1.0	8	20	1.5	6	0	-1.0
August	0	0	0.0	16	0	-1.0	4	20	4.0
September	0	0	0.0	15	0	-1.0	5	20	3.0
October	6	0	-1.0	8	20	1.5	6	0	-1.0
November	6	19	2.2	8	1	-0.9	6	0	-1.0
December	6	20	2.3	8	0	-1.0	6	0	-1.0
January	6	20	2.3	8	0	-1.0	6	0	-1.0
February	6	20	2.3	8	0	-1.0	6	0	-1.0
March	6	20	2.3	8	0	-1.0	6	0	-1.0
April	6	20	2.3	8	0	-1.0	6	0	-1.0
May	6	20	2.3	8	0	-1.0	6	0	-1.0
June	6	20	2.3	8	0	-1.0	6	0	-1.0

Table C-3. Percentile distribution of magnitude and duration of annual extreme water conditions in Sultan River at the upstream end of Reach 2 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
1-day minimum	3.0	3.0	3.0	3.0	3.0	71.2	96.3	101.0	108.5	111.9
3-day minimum	3.0	3.0	3.0	3.0	3.0	72.6	98.2	103.0	111.0	112.7
7-day minimum	3.0	3.0	3.0	3.0	3.0	79.3	98.6	106.0	112.9	114.5
30-day minimum	3.0	3.0	3.0	5.7	12.5	96.6	105.6	112.4	118.1	123.5
90-day minimum	12.0	39.0	67.5	112.3	201.4	111.4	118.2	129.1	138.3	146.8
1-day maximum	4,090	5,331	9,011	10,840	15,300	384	478	924	3,178	11,150
3-day maximum	2,249	3,658	6,037	7,674	9,057	290	365	607	1,853	6,726
7-day maximum	1,916	2,521	3,710	4,576	5,350	227	276	387	978	3,793
30-day maximum	1,125	1,467	1,820	2,159	3,066	201	221	253	439	1,615
90-day maximum	824	1,101	1,233	1,394	1,853	190	196	227	279	687
Number of zero-flow days	0	0	0	0	0	0	0	0	0	0
Base flow index	0.003	0.004	0.004	0.006	0.006	0.360	0.538	0.589	0.638	0.669

Table C-4. Results of range of variability analyses of magnitude and duration of annual extreme water conditions in Sultan River at the upstream end of Reach 2.

Parameter	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
1-day minimum	0	0		20	0	-1.0	0	20	
3-day minimum	0	0		20	0	-1.0	0	20	
7-day minimum	0	0		20	0	-1.0	0	20	
30-day minimum	0	0		14	0	-1.0	6	20	2.3
90-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
1-day maximum	6	18	2.0	8	0	-1.0	6	2	-0.7
3-day maximum	6	17	1.8	8	2	-0.8	6	1	-0.8
7-day maximum	6	17	1.8	8	2	-0.8	6	1	-0.8
30-day maximum	6	18	2.0	8	2	-0.8	6	0	-1.0
90-day maximum	6	20	2.3	8	0	-1.0	6	0	-1.0
Number of zero-flow days	0	0		20	20	0.0	0	0	
Base flow index	6	0	-1.0	8	0	-1.0	6	20	2.3

Table C-5. Percentile distribution of timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes in Sultan River at the upstream end of Reach 2 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Date of annual 1-day minimum	Jul 4	Jul 16	Jul 27	Aug 9	Aug 17	Jun 19	Jun 22	Jul 12	Aug 21	Nov 28
Date of annual 1-day maximum	Sep 30	Oct 25	Dec 13	Feb 17	Mar 2	Oct 1	Nov 4	Nov 30	Feb 13	Mar 25
Annual number of low pulses	3.1	4.0	6.0	8.0	11.8	0.0	0.0	0.0	1.8	6.8
Annual median duration of low pulses (days)	3.1	4.6	7.0	11.5	23.4					
Annual number of high pulses	12.0	14.0	16.5	22.5	25.9	0.0	0.0	1.0	1.8	4.0
Annual median duration of high pulses (days)	2.1	2.6	3.0	4.0	5.9	1.0	1.0	1.3	3.4	4.7
Median rate of rising flows (cfs/day)	59	80	102	144	207	2	2	5	6	13
Median rate of falling flows (cfs/day)	-119	-90	-67	-53	-48	-12	-6	-5	-3	-2
Number of flow reversals	80	88	99	115	121	98	137	153	172	182

Table C-6. Results of range of variability analyses of timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes in Sultan River at the upstream end of Reach 2.

Parameter	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
Date of annual 1-day minimum	6	11	0.8	9	3	-0.7	5	6	0.2
Date of annual 1-day maximum	6	5	-0.2	8	8	0.0	6	7	0.2
Annual number of low pulses	6	17	1.8	8	2	-0.8	6	1	-0.8
Annual median duration of low pulses (days)	5	3	-0.4	11	4	-0.6	4	0	-1.0
Annual number of high pulses	6	20	2.3	9	0	-1.0	5	0	-1.0
Annual median duration of high pulses (days)	5	7	0.4	9	3	-0.7	6	2	-0.7
Median rate of rising flows (cfs/day)	6	20	2.3	8	0	-1.0	6	0	-1.0
Median rate of falling flows (cfs/day)	6	0	-1.0	8	0	-1.0	6	20	2.3
Number of flow reversals	5	1	-0.8	9	2	-0.8	6	17	1.8

Table C-7. Percentile distribution of monthly median low flows in Sultan River at the upstream end of Reach 2 under pre- and post-Project conditions.

Month	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
July	42.6	92.1	176.7	269.0	355.5	101.3	107.8	114.0	126.3	146.7
August	17.7	21.7	71.2	106.7	176.5	98.2	108.0	117.0	119.8	148.8
September	25.6	59.4	95.1	137.7	222.4	146.6	154.8	166.0	173.8	176.0
October	59.6	99.1	154.7	235.3	301.6	159.3	166.1	178.0	187.0	200.1
November	85.9	175.6	232.7	462.1	573.6	103.1	119.3	136.5	148.9	163.8
December	122.4	182.4	252.2	320.3	388.1	103.1	113.0	121.0	141.6	156.0
January	136.3	198.7	262.9	351.1	369.4	148.3	155.8	171.8	180.3	202.0
February	108.1	170.3	275.5	340.9	401.0	154.1	162.8	173.5	183.6	202.4
March	162.6	266.8	326.0	400.7	468.2	180.2	187.8	197.5	214.5	244.8
April	222.7	317.0	486.3	618.6	709.2	179.6	182.3	196.8	207.9	226.4
May	330.0	385.6	521.6	640.8	685.0	177.3	182.0	196.0	207.5	215.7
June	217.6	259.5	412.6	436.7	597.4	130.5	153.8	170.8	184.1	196.4

Table C-8. Percentile distribution of extreme low flow characteristics and high flow pulse parameters in Sultan River at the upstream end of Reach 2 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Extreme low magnitude (cfs)	3.0	3.0	3.0	3.0	3.0					
Extreme low duration (days)	3.1	4.3	9.0	18.6	38.3					
Date of extreme low	Aug 4	Aug 14	Sep 2	Sep 16	Oct 17					
Extreme low frequency	2.0	3.0	4.0	5.0	7.0	0	0	0	0	0
High flow pulse magnitude (cfs)	894	1,071	1,218	1,572	1,743	445	485	530	683	1,056
High flow pulse duration (days)	3.1	4.0	4.5	5.8	7.0	1.0	1.0	1.3	2.0	3.0
Date of high flow pulse	Dec 19	Jan 14	Feb 25	Mar 25	Apr 4	Sep 15	Nov 21	Dec 17	Jan 19	Feb 28
High flow pulse frequency	14.2	17.0	18.0	22.0	25.9	0.1	2.0	4.0	5.0	5.9
High flow pulse rise rate (cfs/day)	290	318	385	512	589	192	256	315	367	642
High flow pulse fall rate (cfs/day)	-338	-272	-222	-186	-134	-357	-294	-238	-205	-166

Table C-9. Percentile distribution of small flood and large flood characteristics in Sultan River at the upstream end of Reach 2 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Small flood magnitude (cfs)	9,343	9,844	10,320	11,420	11,560			11,600		
Small flood duration (days)	4.6	11.5	14.3	19.5	22.8			9.0		
Date of small flood	Oct 19	Nov 21	Dec 22	Jan 11	Mar 14			Nov 29		
Small flood frequency	0.0	0.0	0.5	1.0	2.0	0.0	0.0	0.0	0.0	0.0
Small flood rise rate (cfs/day)	617	1,387	1,638	3,316	3,802			1890		
Small flood fall rate (cfs/day)	-4,668	-1,611	-1,384	-991	-618			-2805		
Large flood magnitude (cfs)	15,710	15,710	16,130	16,550	16,550			16,600		
Large flood duration (days)	11.0	11.0	13.0	15.0	15.0			6.0		
Date of large flood	Oct 21	Oct 21	Nov 7	Nov 24	Nov 24			Nov 24		
Large flood frequency	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0
Large flood rise rate (cfs/day)	1,552	1,552	2,766	3,980	3,980			5455		
Large flood fall rate (cfs/day)	-2,569	-2,569	-2,275	-1,981	-1,981			-4105		

Appendix D

Results of IHA/RVA Analyses of

Sultan River,

Downstream End of Reach 2

Table D-1. Percentile distribution of average monthly flows in Sultan River at the downstream end of Reach 2 under pre- and post-Project conditions.

Month	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
July	14.3	33.9	162.6	313.4	511.9	120.4	130.2	139.4	154.5	170.0
August	8.0	10.2	13.3	16.0	164.6	112.6	123.1	129.8	135.2	157.2
September	8.0	9.0	11.0	24.3	92.2	157.7	162.8	177.0	185.8	194.1
October	7.8	15.7	231.0	639.5	970.3	170.6	195.9	205.0	247.1	285.5
November	175.3	530.7	784.2	1,213.0	1,361.0	143.8	192.6	243.3	288.8	420.1
December	271.6	412.7	484.5	664.0	992.8	155.5	169.8	185.8	232.9	269.6
January	185.5	337.3	665.1	965.3	1,029.0	180.6	221.9	251.8	312.2	341.9
February	171.7	335.7	458.0	574.7	886.4	201.7	219.2	246.3	270.4	338.1
March	202.2	447.2	669.9	899.1	987.7	225.5	258.2	288.8	316.2	359.7
April	464.5	537.9	799.1	1,002.0	1,556.0	253.7	261.7	291.4	322.1	373.1
May	496.2	636.0	867.5	1,093.0	1,238.0	236.3	256.1	275.3	299.3	315.9
June	249.0	330.9	541.6	1,015.0	1,118.0	171.1	197.2	227.1	247.5	262.7

Table D-2. Results of range of variability analyses of average monthly flows in Sultan River at the downstream end of Reach 2.

Month	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
July	6	0	-1.0	8	20	1.5	6	0	-1.0
August	6	0	-1.0	9	0	-1.0	5	20	3.0
September	6	0	-1.0	8	0	-1.0	6	20	2.3
October	6	0	-1.0	8	20	1.5	6	0	-1.0
November	6	19	2.2	8	0	-1.0	6	1	-0.8
December	6	20	2.3	8	0	-1.0	6	0	-1.0
January	6	20	2.3	8	0	-1.0	6	0	-1.0
February	6	20	2.3	8	0	-1.0	6	0	-1.0
March	6	20	2.3	8	0	-1.0	6	0	-1.0
April	6	20	2.3	8	0	-1.0	6	0	-1.0
May	6	20	2.3	8	0	-1.0	6	0	-1.0
June	6	20	2.3	8	0	-1.0	6	0	-1.0

Table D-3. Percentile distribution of magnitude and duration of annual extreme water conditions in Sultan River at the downstream end of Reach 2 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
1-day minimum	4.8	6.5	7.6	8.7	11.0	93.4	107.0	115.2	119.7	125.8
3-day minimum	4.9	6.5	7.8	9.0	11.4	94.1	107.8	116.4	120.7	127.0
7-day minimum	5.0	7.1	8.2	9.4	12.3	97.3	109.1	118.6	126.2	133.3
30-day minimum	6.3	8.2	9.9	14.7	23.7	108.4	119.3	126.1	134.9	140.8
90-day minimum	20.2	50.0	83.9	132.5	228.3	129.6	141.4	147.6	157.8	173.5
1-day maximum	4,544	5,895	10,320	12,390	16,610	773	1,462	1,945	3,534	11,490
3-day maximum	2,454	4,163	6,790	8,691	9,893	564	809	1,383	2,259	7,491
7-day maximum	2,181	2,838	4,231	5,041	5,988	481	592	843	1,353	4,358
30-day maximum	1,276	1,628	2,033	2,413	3,426	357	411	472	688	2,039
90-day maximum	941	1,239	1,402	1,581	2,081	310	329	347	455	925
Number of zero-flow days	0	0	0	0	0	0	0	0	0	0
Base flow index	0.007	0.009	0.010	0.013	0.021	0.281	0.411	0.444	0.489	0.533

Table D-4. Results of range of variability analyses of magnitude and duration of annual extreme water conditions in Sultan River at the downstream end of Reach 2.

Parameter	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
1-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
3-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
7-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
30-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
90-day minimum	6	0	-1.0	8	0	-1.0	6	20	2.3
1-day maximum	6	18	2.0	8	1	-0.9	6	1	-0.8
3-day maximum	6	17	1.8	8	2	-0.8	6	1	-0.8
7-day maximum	6	17	1.8	8	2	-0.8	6	1	-0.8
30-day maximum	6	18	2.0	8	2	-0.8	6	0	-1.0
90-day maximum	6	20	2.3	8	0	-1.0	6	0	-1.0
Number of zero-flow days	0	0		20	20	0.0	0	0	
Base flow index	6	0	-1.0	8	0	-1.0	6	20	2.3

Table D-5. Percentile distribution of timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes in Sultan River at the downstream end of Reach 2 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Date of annual 1-day minimum	Aug 29	Sep 5	Sep 14	Sep 30	Oct 8	Jun 17	Jul 28	Aug 29	Sep 11	Sep 14
Date of annual 1-day maximum	Sep 30	Oct 25	Dec 13	Feb 17	Mar 2	Oct 1	Oct 24	Dec 7	Feb 13	Mar 17
Annual number of low pulses	3.1	4.0	6.0	8.0	11.8	0.0	1.0	2.0	4.8	6.8
Annual median duration of low pulses (days)	2.7	4.6	7.0	11.5	23.4					
Annual number of high pulses	12.0	14.0	16.0	22.0	27.7	0.0	1.3	3.5	5.0	6.0
Annual median duration of high pulses (days)	2.1	2.5	3.0	3.9	4.5	1.0	1.0	1.5	2.0	3.3
Median rate of rising flows (cfs/day)	46	60	76	107	131	6	7	10	14	19
Median rate of falling flows (cfs/day)	-90	-79	-48	-36	-29	-14	-11	-8	-6	-5
Number of flow reversals	92	100	107	122	126	125	133	140	147	155

Table D-6. Results of range of variability analyses of timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes in Sultan River at the downstream end of Reach 2.

Parameter	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
Date of annual 1-day minimum	5	12	1.4	9	7	-0.2	6	1	-0.8
Date of annual 1-day maximum	6	5	-0.2	8	9	0.1	6	6	0.0
Annual number of low pulses	6	15	1.5	8	4	-0.5	6	1	-0.8
Annual median duration of low pulses (days)	5	9	0.8	11	6	-0.5	4	2	-0.5
Annual number of high pulses	6	20	2.3	10	0	-1.0	4	0	-1.0
Annual median duration of high pulses (days)	6	14	1.3	9	1	-0.9	5	1	-0.8
Median rate of rising flows (cfs/day)	6	20	2.3	8	0	-1.0	6	0	-1.0
Median rate of falling flows (cfs/day)	6	0	-1.0	8	0	-1.0	6	20	2.3
Number of flow reversals	5	0	-1.0	9	1	-0.9	6	19	2.2

Table D-7. Percentile distribution of monthly median low flows in Sultan River at the downstream end of Reach 2 under pre- and post-Project conditions.

Month	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
July	14.2	39.2	151.6	300.8	392.9	120.4	130.2	139.4	153.6	169.8
August	10.1	11.4	13.6	15.9	123.1	112.6	123.1	129.8	135.2	157.2
September	10.3	10.9	14.2	58.9	80.6	157.7	162.8	177.0	185.8	190.6
October	11.9	22.1	87.0	209.3	332.7	170.6	192.5	204.9	236.8	268.1
November	80.2	178.4	277.4	509.3	643.9	143.7	171.6	208.2	251.5	262.0
December	158.0	214.7	297.0	367.7	444.5	154.5	168.5	176.6	191.4	220.3
January	148.2	206.4	303.7	403.6	445.2	175.3	213.1	243.3	260.0	303.5
February	138.4	204.9	322.9	379.6	465.0	201.7	219.2	245.0	258.7	301.5
March	196.3	295.1	368.6	463.3	553.1	225.4	258.1	285.7	300.0	338.0
April	262.4	367.2	555.3	703.4	792.8	253.7	259.9	290.4	321.2	358.4
May	367.2	428.9	580.9	702.8	750.0	236.3	256.1	275.3	299.1	315.9
June	244.8	297.2	454.2	570.8	742.4	171.1	195.7	225.5	236.0	261.9

Table D-8. Percentile distribution of extreme low flow characteristics and high flow pulse parameters in Sultan River at the downstream end of Reach 2 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Extreme low magnitude (cfs)	7.0	7.2	8.6	9.1	9.3					
Extreme low duration (days)	1.0	1.4	3.5	18.1	26.8					
Date of extreme low	Aug 28	Sep 4	Sep 13	Sep 21	Oct 20					
Extreme low frequency	0.1	2.0	2.0	3.8	5.0	0	0	0	0	0
High flow pulse magnitude (cfs)	1,048	1,185	1,483	1,726	1,915	509	571	726	929	1,227
High flow pulse duration (days)	3.6	4.0	4.0	5.8	7.0	1.0	1.0	2.0	2.0	3.0
Date of high flow pulse	Dec 23	Jan 18	Feb 22	Mar 22	Apr 2	Nov 25	Dec 14	Jan 13	Feb 21	Mar 23
High flow pulse frequency	14.1	16.3	19.0	22.8	25.0	5.1	6.3	9.5	11.0	15.7
High flow pulse rise rate (cfs/day)	317	363	432	571	683	187	233	309	380	421
High flow pulse fall rate (cfs/day)	-395	-302	-258	-179	-153	-384	-298	-217	-190	-151

Table D-9. Percentile distribution of small flood and large flood characteristics in Sultan River at the downstream end of Reach 2 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Small flood magnitude (cfs)	10,600	11,390	11,960	12,560	12,970			11,910		
Small flood duration (days)	4.6	11.5	13.5	18.6	22.6			11.0		
Date of small flood	Oct 19	Nov 22	Dec 22	Jan 11	Mar 14			Nov 29		
Small flood frequency	0.0	0.0	0.5	1.0	2.0	0.0	0.0	0.0	0.0	0.0
Small flood rise rate (cfs/day)	692	1,538	1,878	3,805	5,637			1666		
Small flood fall rate (cfs/day)	-5,190	-1,857	-1,576	-1,078	-904			-2309		
Large flood magnitude (cfs)	17,040	17,040	17,900	18,770	18,770			18,810		
Large flood duration (days)	11.0	11.0	11.0	11.0	11.0			7.0		
Date of large flood	Oct 21	Oct 21	Nov 7	Nov 24	Nov 24			Nov 24		
Large flood frequency	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0
Large flood rise rate (cfs/day)	2,689	2,689	3,601	4,512	4,512			4640		
Large flood fall rate (cfs/day)	-2,783	-2,783	-2,515	-2,246	-2,246			-4630		

Appendix E

Results of IHA/RVA Analyses of

Sultan River,

Upstream End of Reach 3

Table E-1. Percentile distribution of average monthly flows in Sultan River at the upstream end of Reach 3 under pre- and post-Project conditions.

Month	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
July	145.8	178.8	281.9	422.0	569.4	20.0	20.0	20.0	20.0	36.6
August	52.9	76.5	109.9	140.5	298.0	20.0	20.0	20.0	20.0	48.6
September	59.7	73.7	96.0	187.4	247.5	20.0	20.0	20.0	26.2	48.7
October	58.5	149.5	335.5	716.8	1,014.0	20.0	20.0	20.0	20.0	30.0
November	298.4	562.1	784.2	1,106.0	1,264.0	20.0	20.0	20.0	20.0	24.3
December	329.5	430.6	488.6	630.0	885.9	20.0	20.0	20.0	20.0	24.4
January	243.8	357.0	619.0	854.4	899.0	20.0	20.0	20.0	20.0	20.0
February	223.6	351.1	446.2	535.8	780.2	20.0	20.0	20.0	20.0	20.0
March	254.5	448.5	623.5	803.5	878.9	20.0	20.0	20.0	20.0	20.0
April	466.5	539.5	741.8	909.9	1,350.0	20.0	20.0	20.0	20.0	28.0
May	530.2	655.8	845.5	1,030.0	1,167.0	20.0	20.0	20.0	20.0	20.0
June	339.3	412.4	596.8	1,004.0	1,080.0	20.0	20.0	20.0	20.0	21.4

Table E-2. Results of range of variability analyses of average monthly flows in Sultan River at the upstream end of Reach 3.

Month	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
July	6	20	2.3	8	0	-1.0	6	0	-1.0
August	6	20	2.3	8	0	-1.0	6	0	-1.0
September	6	20	2.3	8	0	-1.0	6	0	-1.0
October	6	20	2.3	8	0	-1.0	6	0	-1.0
November	6	20	2.3	8	0	-1.0	6	0	-1.0
December	6	20	2.3	8	0	-1.0	6	0	-1.0
January	6	20	2.3	8	0	-1.0	6	0	-1.0
February	6	20	2.3	8	0	-1.0	6	0	-1.0
March	6	20	2.3	8	0	-1.0	6	0	-1.0
April	6	20	2.3	8	0	-1.0	6	0	-1.0
May	6	20	2.3	8	0	-1.0	6	0	-1.0
June	6	20	2.3	8	0	-1.0	6	0	-1.0

Table E-3. Percentile distribution of magnitude and duration of annual extreme water conditions in Sultan River at the upstream end of Reach 3 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
1-day minimum	22.4	40.3	57.6	66.3	94.8	20.0	20.0	20.0	20.0	20.0
3-day minimum	23.1	43.0	58.3	69.7	98.4	20.0	20.0	20.0	20.0	20.0
7-day minimum	25.8	47.0	61.9	71.2	105.4	20.0	20.0	20.0	20.0	20.0
30-day minimum	37.9	59.5	78.7	107.4	122.2	20.0	20.0	20.0	20.0	20.0
90-day minimum	99.8	130.3	182.2	244.8	320.6	20.0	20.0	20.2	21.5	22.0
1-day maximum	3,835	5,140	8,539	9,920	14,660	111	188	300	2,808	10,240
3-day maximum	2,288	3,355	5,736	7,097	8,701	57	103	175	1,466	6,065
7-day maximum	1,797	2,396	3,437	4,442	5,041	40	71	107	670	3,360
30-day maximum	1,106	1,453	1,735	2,116	2,898	30	34	46	213	1,285
90-day maximum	848	1,097	1,238	1,378	1,784	24	27	35	94	469
Number of zero-flow days	0	0	0	0	0	0	0	0	0	0
Base flow index	0.045	0.062	0.083	0.091	0.168	0.151	0.497	0.759	0.862	0.954

Table E-4. Results of range of variability analyses of magnitude and duration of annual extreme water conditions in Sultan River at the upstream end of Reach 3.

Parameter	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
1-day minimum	6	20	2.3	9	0	-1.0	5	0	-1.0
3-day minimum	6	20	2.3	8	0	-1.0	6	0	-1.0
7-day minimum	6	20	2.3	8	0	-1.0	6	0	-1.0
30-day minimum	6	20	2.3	8	0	-1.0	6	0	-1.0
90-day minimum	6	20	2.3	8	0	-1.0	6	0	-1.0
1-day maximum	6	18	2.0	8	0	-1.0	6	2	-0.7
3-day maximum	6	17	1.8	8	2	-0.8	6	1	-0.8
7-day maximum	6	18	2.0	8	1	-0.9	6	1	-0.8
30-day maximum	6	20	2.3	8	0	-1.0	6	0	-1.0
90-day maximum	6	20	2.3	8	0	-1.0	6	0	-1.0
Number of zero-flow days	0	0		20	20	0.0	0	0	
Base flow index	6	0	-1.0	8	0	-1.0	6	20	2.3

Table E-5. Percentile distribution of timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes in Sultan River at the upstream end of Reach 3 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Date of annual 1-day minimum	Feb 23	Aug 29	Sep 10	Oct 3	Oct 26	Jul 1	Jul 1	Jul 1	Jul 1	Jul 2
Date of annual 1-day maximum	Sep 30	Oct 25	Dec 13	Feb 17	Mar 2	Jul 26	Oct 24	Nov 24	Dec 10	Jan 23
Annual number of low pulses	4.0	4.3	7.0	10.0	11.0	0.0	0.0	1.0	2.0	3.9
Annual median duration of low pulses (days)	2.1	4.0	7.0	10.4	15.0	12.3	93.0	253.0	515.0	866.8
Annual number of high pulses	13.0	13.5	16.5	21.5	24.0	0.0	0.0	0.0	1.0	3.0
Annual median duration of high pulses (days)	2.0	2.3	3.0	3.8	5.0	2.0	2.0	2.5	4.0	4.0
Median rate of rising flows (cfs/day)	41	53	65	89	108	1	4	9	19	36
Median rate of falling flows (cfs/day)	-76	-67	-41	-31	-27	-34	-19	-11	-7	-3
Number of flow reversals	93	101	106	121	126	10	23	42	76	87

Table E-6. Results of range of variability analyses of timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes in Sultan River at the upstream end of Reach 3.

Parameter	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
Date of annual 1-day minimum	6	20	2.3	8	0	-1.0	6	0	-1.0
Date of annual 1-day maximum	6	2	-0.7	8	8	0.0	6	10	0.7
Annual number of low pulses	5	19	2.8	9	1	-0.9	6	0	-1.0
Annual median duration of low pulses (days)	3	0	-1.0	11	1	-0.9	6	12	1.0
Annual number of high pulses	5	20	3.0	10	0	-1.0	5	0	-1.0
Annual median duration of high pulses (days)	5	3	-0.4	10	1	-0.9	5	2	-0.6
Median rate of rising flows (cfs/day)	6	20	2.3	8	0	-1.0	6	0	-1.0
Median rate of falling flows (cfs/day)	6	0	-1.0	8	2	-0.8	6	18	2.0
Number of flow reversals	4	20	4.0	10	0	-1.0	6	0	-1.0

Table E-7. Percentile distribution of monthly median low flows in Sultan River at the upstream end of Reach 3 under pre- and post-Project conditions.

Month	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
July	144.1	172.4	272.4	385.2	470.4	89.1	97.3	115.5	134.9	135.7
August	85.0	95.5	114.0	138.0	244.0	77.8	84.0	90.1	104.0	119.9
September	87.7	92.2	134.0	194.2	224.8	81.1	82.1	89.3	101.2	103.7
October	88.7	164.1	218.0	290.0	387.8	83.6	90.6	126.9	166.8	173.5
November	227.2	256.4	350.5	561.5	682.3	93.6	105.3	163.9	238.3	337.9
December	249.7	280.5	333.5	392.3	464.5	96.3	116.2	134.2	165.3	259.3
January	223.1	282.9	354.1	429.8	451.7	83.5	120.0	144.2	204.0	289.4
February	199.4	253.8	381.2	408.5	469.4	119.5	121.2	244.3	336.1	427.2
March	248.9	337.4	426.0	478.4	518.8	76.8	80.3	116.2	183.6	289.9
April	339.0	398.8	544.0	659.5	754.3	80.3	80.3	85.1	208.4	208.4
May	422.0	463.5	596.0	724.5	760.0	96.7	98.3	128.0	154.1	154.4
June	331.0	380.8	520.9	567.0	734.5	80.9	80.9	91.7	125.3	125.3

Table E-8. Percentile distribution of extreme low flow characteristics and high flow pulse parameters in Sultan River at the upstream end of Reach 3 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Extreme low magnitude (cfs)	38.8	50.9	58.9	69.3	73.9	20.0	20.0	20.0	20.0	20.0
Extreme low duration (days)	1.0	2.3	5.3	16.6	21.0	10.0	17.0	40.0	59.0	162.0
Date of extreme low	Aug 19	Aug 31	Sep 14	Sep 30	Nov 1	Sep 27	Oct 31	Dec 9	Dec 27	Jan 10
Extreme low frequency	0.1	1.3	2.5	4.0	4.0	1.1	4.3	6.0	8.0	9.0
High flow pulse magnitude (cfs)	996	1,076	1,314	1,543	1,661	720	1,365	2,723	4,535	5,194
High flow pulse duration (days)	4.0	4.0	4.5	5.0	7.0	2.0	2.8	3.5	5.1	5.5
Date of high flow pulse	Dec 13	Jan 11	Feb 22	Mar 16	Apr 14	Oct 5	Oct 23	Nov 25	Nov 30	Dec 6
High flow pulse frequency	15.1	17.0	18.0	21.8	25.7	0.0	0.0	0.0	1.0	2.0
High flow pulse rise rate (cfs/day)	248	274	388	426	541	484	625	1271	2445	3335
High flow pulse fall rate (cfs/day)	-303	-244	-202	-170	-141	-2051	-1650	-671	-372	-309

Table E-9. Percentile distribution of small flood and large flood characteristics in Sultan River at the upstream end of Reach 3 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Small flood magnitude (cfs)	8,637	9,191	9,593	10,580	11,110			10,650		
Small flood duration (days)	5.5	10.8	14.0	19.4	22.8			8.0		
Date of small flood	Oct 19	Nov 21	Dec 22	Jan 11	Mar 14			Nov 29		
Small flood frequency	0.0	0.0	0.5	1.0	2.0	0.0	0.0	0.0	0.0	0.0
Small flood rise rate (cfs/day)	564	1,265	1,558	3,060	3,614			2059		
Small flood fall rate (cfs/day)	-2,929	-1,553	-1,313	-939	-578			-2613		
Large flood magnitude (cfs)	15,050	15,050	15,200	15,360	15,360			15,310		
Large flood duration (days)	11.0	11.0	13.0	15.0	15.0			5.0		
Date of large flood	Oct 21	Oct 21	Nov 7	Nov 24	Nov 24			Nov 24		
Large flood frequency	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0
Large flood rise rate (cfs/day)	1,469	1,469	2,569	3,669	3,669			5095		
Large flood fall rate (cfs/day)	-2,432	-2,432	-2,129	-1,827	-1,827			-4949		

Appendix F

Results of IHA/RVA Analyses of

Sultan River,

Downstream End of Reach 3

Table F-1. Percentile distribution of average monthly flows in Sultan River at the downstream end of Reach 3 under pre- and post-Project conditions.

Month	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
July	153.0	187.6	295.8	443.2	597.2	28.0	31.1	37.4	46.6	57.6
August	56.1	81.0	116.5	148.9	316.1	24.0	26.3	29.2	35.0	54.4
September	62.8	77.5	101.0	197.1	260.2	23.4	25.8	30.2	36.7	53.7
October	61.5	157.6	353.9	752.2	1,070.0	23.1	34.1	39.4	61.8	81.4
November	321.2	604.7	840.8	1,191.0	1,356.0	43.3	62.2	87.4	106.5	186.1
December	357.5	464.8	528.0	680.2	961.9	48.3	56.9	59.6	74.8	103.4
January	266.5	390.6	675.0	933.8	982.8	43.2	55.0	76.2	104.8	109.2
February	245.0	385.2	489.4	587.7	855.2	41.5	54.2	63.7	71.9	101.7
March	276.3	487.8	677.8	873.4	955.5	41.9	61.2	74.3	92.3	96.6
April	505.1	579.0	800.0	981.9	1,460.0	60.2	67.7	78.6	92.5	125.0
May	559.9	693.7	895.9	1,089.0	1,241.0	52.1	58.6	70.9	82.2	100.0
June	356.3	433.1	626.9	1,056.0	1,136.0	37.1	44.1	52.6	70.1	77.2

Table F-2. Results of range of variability analyses of average monthly flows in Sultan River at the downstream end of Reach 3.

Month	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
July	6	20	2.3	8	0	-1.0	6	0	-1.0
August	6	20	2.3	8	0	-1.0	6	0	-1.0
September	6	20	2.3	8	0	-1.0	6	0	-1.0
October	6	20	2.3	8	0	-1.0	6	0	-1.0
November	6	19	2.2	8	1	-0.9	6	0	-1.0
December	6	20	2.3	8	0	-1.0	6	0	-1.0
January	6	20	2.3	8	0	-1.0	6	0	-1.0
February	6	20	2.3	8	0	-1.0	6	0	-1.0
March	6	20	2.3	8	0	-1.0	6	0	-1.0
April	6	20	2.3	8	0	-1.0	6	0	-1.0
May	6	20	2.3	8	0	-1.0	6	0	-1.0
June	6	20	2.3	8	0	-1.0	6	0	-1.0

Table F-3. Percentile distribution of magnitude and duration of annual extreme water conditions in Sultan River at the downstream end of Reach 3 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
1-day minimum	23.5	43.5	60.8	70.1	99.9	21.2	22.5	23.5	24.3	26.9
3-day minimum	24.3	45.7	61.6	73.9	103.9	21.2	22.7	23.8	25.3	27.0
7-day minimum	27.1	49.4	65.4	75.3	111.3	21.4	23.1	24.1	26.6	29.2
30-day minimum	39.8	62.9	82.9	113.1	129.5	22.1	24.6	26.2	32.4	34.4
90-day minimum	105.0	137.6	192.0	258.3	337.8	27.3	28.8	34.4	39.6	56.0
1-day maximum	4,182	5,473	9,094	10,840	15,490	362	528	827	3,038	10,460
3-day maximum	2,405	3,670	6,132	7,678	9,227	271	339	582	1,726	6,511
7-day maximum	1,967	2,587	3,743	4,724	5,431	192	235	343	857	3,698
30-day maximum	1,204	1,567	1,894	2,262	3,118	115	149	184	363	1,543
90-day maximum	912	1,186	1,339	1,482	1,925	94	113	140	185	612
Number of zero-flow days	0	0	0	0	0	0	0	0	0	0
Base flow index	0.043	0.060	0.082	0.090	0.166	0.121	0.256	0.300	0.347	0.381

Table F-4. Results of range of variability analyses of magnitude and duration of annual extreme water conditions in Sultan River at the downstream end of Reach 3.

Parameter	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
1-day minimum	6	20	2.3	8	0	-1.0	6	0	-1.0
3-day minimum	6	20	2.3	8	0	-1.0	6	0	-1.0
7-day minimum	6	20	2.3	8	0	-1.0	6	0	-1.0
30-day minimum	6	20	2.3	8	0	-1.0	6	0	-1.0
90-day minimum	6	20	2.3	8	0	-1.0	6	0	-1.0
1-day maximum	6	18	2.0	8	0	-1.0	6	2	-0.7
3-day maximum	6	17	1.8	8	2	-0.8	6	1	-0.8
7-day maximum	6	18	2.0	8	1	-0.9	6	1	-0.8
30-day maximum	6	20	2.3	8	0	-1.0	6	0	-1.0
90-day maximum	6	20	2.3	8	0	-1.0	6	0	-1.0
Number of zero-flow days	0	0		20	20	0.0	0	0	
Base flow index	6	0	-1.0	8	0	-1.0	6	20	2.3

Table F-5. Percentile distribution of timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes in Sultan River at the downstream end of Reach 3 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Date of annual 1-day minimum	Feb 23	Aug 29	Sep 10	Oct 3	Oct 26	Jul 30	Sep 1	Sep 14	Sep 27	Oct 3
Date of annual 1-day maximum	Sep 30	Oct 25	Dec 13	Feb 17	Mar 2	Oct 6	Nov 4	Dec 5	Feb 14	Mar 17
Annual number of low pulses	3.1	4.3	7.5	10.0	11.0	3.0	4.0	6.5	7.8	10.0
Annual median duration of low pulses (days)	2.1	4.0	6.3	10.9	17.8	9.0	10.5	21.3	49.3	133.9
Annual number of high pulses	12.0	14.3	17.0	21.0	24.9	0.0	0.0	0.0	1.0	3.9
Annual median duration of high pulses (days)	2.0	2.5	3.0	3.9	5.0	1.0	1.1	2.5	3.0	4.0
Median rate of rising flows (cfs/day)	41	53	70	94	115	4	4	7	9	13
Median rate of falling flows (cfs/day)	-80	-70	-42	-34	-27	-7	-6	-4	-3	-3
Number of flow reversals	95	102	106	122	126	107	109	117	125	135

Table F-6. Results of range of variability analyses of timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes in Sultan River at the downstream end of Reach 3.

Parameter	Low RVA Category			Middle RVA Category			High RVA Category		
	Expected	Observed	Alteration	Expected	Observed	Alteration	Expected	Observed	Alteration
Date of annual 1-day minimum	6	4	-0.3	8	14	0.8	6	2	-0.7
Date of annual 1-day maximum	6	4	-0.3	8	8	0.0	6	8	0.3
Annual number of low pulses	5	6	0.2	9	11	0.2	6	3	-0.5
Annual median duration of low pulses (days)	6	0	-1.0	8	3	-0.6	6	17	1.8
Annual number of high pulses	5	20	3.0	11	0	-1.0	4	0	-1.0
Annual median duration of high pulses (days)	6	4	-0.3	8	3	-0.6	6	1	-0.8
Median rate of rising flows (cfs/day)	6	20	2.3	8	0	-1.0	6	0	-1.0
Median rate of falling flows (cfs/day)	6	0	-1.0	8	0	-1.0	6	20	2.3
Number of flow reversals	5	0	-1.0	9	10	0.1	6	10	0.7

Table F-7. Percentile distribution of monthly median low flows in Sultan River at the downstream end of Reach 3 under pre- and post-Project conditions.

Month	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
July	151.4	180.9	286.1	404.7	494.1	110.9	112.8	123.3	172.9	203.2
August	89.0	101.0	121.0	146.2	258.6	84.5	90.0	99.0	125.0	128.9
September	92.4	96.9	139.9	204.4	236.0	86.0	90.7	101.0	128.1	178.1
October	92.5	172.6	229.3	306.7	412.6	81.9	100.6	120.2	140.3	162.3
November	243.3	274.4	371.1	603.3	730.0	102.5	117.5	128.6	160.2	184.0
December	270.7	303.9	360.5	424.7	501.8	90.9	122.9	147.1	163.5	204.0
January	244.4	309.7	382.6	462.5	493.4	101.5	116.8	129.9	151.6	189.5
February	218.8	277.4	414.7	441.0	514.0	88.9	97.5	108.6	124.9	157.6
March	270.6	366.9	464.2	521.0	565.8	94.9	100.8	116.2	125.4	150.7
April	366.6	431.2	586.9	711.9	808.0	87.1	96.3	107.2	125.8	133.5
May	449.0	505.6	645.1	760.7	803.6	86.4	91.3	103.2	110.5	125.9
June	347.6	399.7	547.8	594.7	770.5	87.5	91.0	96.7	110.9	129.7

Table F-8. Percentile distribution of extreme low flow characteristics and high flow pulse parameters in Sultan River at the downstream end of Reach 3 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Extreme low magnitude (cfs)	40.9	53.8	62.1	71.9	74.7	41.8	49.1	54.2	56.4	59.0
Extreme low duration (days)	1.0	2.9	6.0	16.1	21.0	3.0	4.3	5.5	8.3	9.9
Date of extreme low	Aug 19	Aug 31	Sep 14	Oct 4	Nov 1	Dec 2	Dec 28	Jan 28	Feb 21	Apr 16
Extreme low frequency	0.1	1.3	2.0	3.8	4.0	13.0	15.0	21.0	24.0	27.7
High flow pulse magnitude (cfs)	1,053	1,163	1,376	1,663	1,881	577	644	713	1,105	3,993
High flow pulse duration (days)	4.0	4.0	4.8	5.0	6.5	1.0	1.0	1.0	2.5	3.4
Date of high flow pulse	Dec 13	Jan 12	Feb 23	Mar 16	Apr 15	Oct 12	Nov 24	Dec 11	Dec 29	Jan 28
High flow pulse frequency	14.2	17.0	18.5	21.8	25.7	0.0	0.3	2.5	3.8	4.0
High flow pulse rise rate (cfs/day)	286	303	400	521	583	323	429	482	801	1904
High flow pulse fall rate (cfs/day)	-329	-274	-228	-174	-154	-1856	-513	-422	-346	-327

Table F-9. Percentile distribution of small flood and large flood characteristics in Sultan River at the downstream end of Reach 3 under pre- and post-Project conditions.

Parameter	Pre-Project Conditions					Post-Project Conditions				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Small flood magnitude (cfs)	9,343	9,915	10,410	11,420	11,730			10,850		
Small flood duration (days)	5.5	10.8	14.0	19.4	22.8			9.0		
Date of small flood	Oct 19	Nov 21	Dec 22	Jan 11	Mar 14			Nov 29		
Small flood frequency	0.0	0.0	0.5	1.0	2.0	0.0	0.0	0.0	0.0	0.0
Small flood rise rate (cfs/day)	610	1,365	1,697	3,297	3,814			1755		
Small flood fall rate (cfs/day)	-3,155	-1,697	-1,426	-994	-622			-2641		
Large flood magnitude (cfs)	15,900	15,900	16,230	16,550	16,550			16,510		
Large flood duration (days)	11.0	11.0	13.0	15.0	15.0			7.0		
Date of large flood	Oct 21	Oct 21	Nov 7	Nov 24	Nov 24			Nov 24		
Large flood frequency	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0
Large flood rise rate (cfs/day)	1,552	1,552	2,754	3,955	3,955			4107		
Large flood fall rate (cfs/day)	-2,569	-2,569	-2,269	-1,969	-1,969			-4104		

Appendix G

Responses to Draft Report Comments

STAKEHOLDER COMMENT	LICENSEE RESPONSE
Y. Robert Iwamoto (US Forest Service) – Excerpt of ISR Comments Filed December 11, 2007	
Page 4, RSP 23 - IHA/RVA Downstream of Culmback Dam, Paragraph 1 The methods used to synthesize pre-project flows are not well explained. In an attempt to provide a perspective, the explanation of the 20-year period of flow to use (1984-2004) only discusses average annual flows of those 20 years versus the longer period of record at the nearby Gold Bar flow gauge. It also critical to understand how those years compare regarding peak and base flows. The Forest Service recommends that the PUD include such a discussion.	Flow records from the nearby Skykomish River near Gold Bar (USGS Gage 12134500) were examined to determine how the selected 20-year period (July 1, 1984 through June 30, 2004) compares with a longer period with regard to high flows and low flows. Annual peak flows and seven-day low flows were determined for each year during the entire period of record to characterize the high flow and low flow regimes, respectively. A flood-frequency analysis was performed on the annual peak flows for two periods: the 79-year period from 1928 through 2006; and the 20-year period from 1985 through 2004. A Log-Pearson Type III distribution was developed for the peak flows from both periods, and the 1.5-year flood was determined for each period. The 1.5-year flood is often used to characterize bankfull flow, a condition particularly meaningful with regard to fluvial morphology. The 1.5-year floods were found to be 32,500 and 35,700 cfs for the 79-year and 20-year periods, respectively. Therefore, the 1.5-year flood for the selected 20-year period is 10% greater than the 1.5-year flood for the longer period. The annual seven-day low flow was determined for each of the 79-years of the period of record. The median seven-day low flow was determined for two periods: the 79-year period from 1928 through 2006; and the 20-year period from 1985 through 2004. The median seven-day low flow was used to characterize the low flow regime of both periods. The median seven-day low flows were found to be 594 and 458 cfs for the 79-year and 20-year periods, respectively. Therefore, the median seven-day low flow for the selected 20-year period is 23% less than the median seven-day low flow for the longer period. This information will also be included in the technical reports.
Page 5, RSP 23 - IHA/RVA Downstream of Culmback Dam, Paragraph 2 Sections 3.2 and 3.3 of the ISR state that pre-project synthesized flows are based on estimates of total inflow into Spada Lake. The only gauge station cited for these tributary streams is the one located on the South Fork Sultan River (12137290). The Forest Service requests the PUD to provide the specific data and methods that were used to estimate the inputs from the other tributaries above and below Culmback Dam. It appears that possibly regional regression curves, or other data was used to estimate inputs for each sub-watershed, but it is not stated. Also, it would be helpful to elaborate on what data	Total daily inflow to Spada Lake from all upstream sources (gaged and ungaged) was determined by adding the total daily change in storage in Spada Lake with the daily release from Culmback Dam to the Sultan River and the daily flow used for power generation. A regional regression approach was used by Bechtel Incorporated (1980) to estimate daily flows to the Sultan River from tributary sources downstream from Culmback Dam. Monthly ratios between the daily inflow from downstream tributaries and the total inflow to Spada Lake were derived from basin characteristics such as drainage area, main channel slope, lake area, mean basin

STAKEHOLDER COMMENT	LICENSEE RESPONSE
and equations are being used to synthesize flows in the downstream sub-basins through application of monthly flow ratios to the daily inflows into Spada Lake.	elevation, forest cover, mean annual precipitation, and mean minimum January temperature. Bechtel Incorporated (1980) relied on regression equations published by the U.S. Geological Survey to develop these monthly ratios. **References:** Bechtel Incorporated, 1980. Sultan River Project Phase II Engineering Feasibility Report, prepared for Public Utility District No. 1 of Snohomish County, March.
Tulalip Tribes – Excerpt of ISR Comments Filed 11/15/07 (comments and responses below correspond to pagination of the 11/06/07 comments sent to the co-licensees and attached to the 11/15/07 cover letter)	
Page 11, RSP 23–IHA/RVA Downstream of Culmback Dam, Paragraph 2 Our primary concerns are that the appropriate data be used to run the model, and that the operational causes and ecological consequences of the observed hydrological changes (i.e., differences in pre- and post-project flow conditions, as indexed by IHA metrics) be fully elaborated and discussed in the final report.	Indicators of Hydrologic Alteration/Range of Variability (IHA/RVA) are components of an analytical software package typically used to characterize and compare complex river reach or river basin-scale hydrologic regimes from two or more periods of time, such as pre-dam and post-dam. The program assesses and presents a summary of 67 hydrology statistics derived from daily hydrologic data (e.g., magnitude of monthly flows, timing of annual extreme water conditions, frequency and duration of high and low pulses, etc.). The results of an IHA/RVA analysis can then be used to illustrate the effects of Project operations on the pre-Project flow regime. Impacts of Project operations on the pre-Project flow regime are discussed in RSP 23 in terms of changes to the hydrologic regime as measured by the 67 hydrological statistics. The ecological response to Project operations will depend not only on changes to the hydrologic regime, but also other factors such as changes to the thermal regime and sediment supply to the Sultan River. Ecological consequences of Project operations will be discussed in several other ongoing studies such as: RSP 3 (Sultan River Instream Flow Study) and RSP 22 (Sultan River Physical Processes Study). These other studies will interpret the results of RSP 23 within a larger context of other environmental factors to determine the ecological response to Project operations.