February 6, 2023 (revised)

via e-filing

Ms. Kimberly D. Bose, Secretary Federal Energy Regulatory Commission
888 First Street NE
Washington, D.C. 20426

Re: Draft License Application: SCL Skagit River Hydroelectric Project FERC No. 553-235

Dear Secretary Bose,

The Skagit County Dike and Drainage Districts Flood Control Partnership ("**Partnership**") and Skagit County government ("**County**") jointly submit this comment letter with respect to Seattle City Light's ("**SCL**") Draft License Application ("**DLA**") for the Skagit River Hydroelectric Project, P-553 ("**Project**").

This comment letter addresses only flood risks and flood protection issues. Comments related to fisheries mitigation for the Project were addressed in the Joint Skagit County/Drainage Consortium letter filed separately with FERC on January 11, 2023.[1]

The Partnership represents five diking special purpose districts that protect the major population centers and critical infrastructure in Skagit County. [2] These districts are responsible for operations and maintenance of approximately 36 miles of Skagit River levees that protect the cities of Burlington, Mount Vernon, and La Conner, Interstate 5, a major Burlington Northern Sante-Fe railway, major oil and gas pipelines, and the City of Anacortes water treatment plant, which serves the City of Oak Harbor, Naval Air Station Whidbey, the Swinomish Indian Tribal Community, and two major west coast refineries, in addition to the City of Anacortes itself.

Skagit County is the government of general jurisdiction in the Skagit Valley and plays a significant role in flood readiness, flood protection, emergency response services, and land use regulation.

In addition, this filing is made on behalf of the cities of Mount Vernon, Burlington, Sedro-Woolley, and Anacortes, as well as the Skagit County Drainage and Irrigation District Consortium, LLC, each of which has significant populations, businesses, critical infrastructure, and other interests impacted by the Project and the flood risk reduction it provides. Copies of their letters of support are included as **Attachment 1**.

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[1] Comments of Skagit County and Skagit County Drainage and Irrigation District Consortium, LLC dated January 9, 2023, filed January 11, 2023 (FERC Accession No. 20230110-5074).

[2] Skagit County Dike District No. 1, Skagit County Dike District No. 3, Skagit County Dike, Drainage and Irrigation Improvement District No. 12, Skagit County Dike District No. 17, and Skagit County Consolidated Diking Improvement District No. 22.

As SCL has unequivocally stated in prior filings, flood control is the Project's first operational priority.[3] Ross Dam and its associated reservoir – the uppermost of the three Skagit Project reservoirs – is the only portion of the Project operated for flood storage.

For the reasons set forth in the enclosed Memorandum, we request that the Commission increase the flood storage requirement at Ross Lake from 120,000 ac-ft to 200,000 ac-ft, and move the date of full flood storage draw down from December 1 to November 1. This change is necessary to further the flood control priority of the Project.

The specific purpose of our request is to reduce risk to existing critical infrastructure and development, in order to protect the lives and property of our citizens. We acknowledge that past development practices in the Skagit Valley are partially responsible for the flood risk we face, and we also recognize that climate change is likely to exacerbate these risks. As a community, our objective is to reduce these risks to the fullest extent possible. We have no intention of utilizing increased flood storage at Ross as a mechanism to re-evaluate existing 100-year flood maps.

Our request is founded on sound science, is supported by the U.S. Army Corps of Engineers' recommendations, and accommodates a broad range of interests, including tribal interest in downstream flow augmentation for the benefit of anadromous species. We request SCL incorporate our joint proposal into its Final License Application, which the Commission should incorporate as a new license condition.

Sincerely,

BOARD OF COUNTY COMMISSIONERS
SKAGIT COUNTY, WASHINGTON

Ron Wesen, Chair

Lisa Janicki, Commissioner

Peter Browning, Commissioner

SKAGIT COUNTY DIKE AND DRAINAGE FLOOD CONTROL PARTNERSHIP

By:
Daryl Hamburg, Chair

[3] *See, e.g.,* Notice of Intent and Pre-Application Document, ES-2, filed April 24, 2020 (FERC Accession No. 20200427-5341).

cc:

U.S. Senator Patty Murray
U.S. Senator Maria Cantwell
U.S. Representative Rick Larsen
U.S. Representative Suzan DelBene
COL Alexander Bullock, Seattle District, U.S. Army Corps of Engineers
Steve Edwards, Chair, Swinomish Indian Tribal Community
Nino Maltos, Chair, Sauk-Suiattle Indian Tribe
Marilyn Scott, Chair, Upper Skagit Indian Tribe
Tom Wooten, Chair, Samish Indian Nation
Senator Ron Muzzall, Washington State 10th Legislative District
Representative Dave Paul, Washington State 10th Legislative District
Representative Clyde Shavers, Washington State 10th Legislative District
Senator Keith Wagoner, Washington State 39th Legislative District
Representative Carolyn Eslick, Washington State 39th Legislative District
Representative Sam Low, Washington State 39th Legislative District
Senator Liz Lovelett, Washington State 40th Legislative District
Representative Debra Lekanoff, Washington State 40th Legislative District
Representative Alex Ramel, Washington State 40th Legislative District
Roger Millar, Secretary, Washington State Department of Transportation
Bruce Harrell, Mayor, City of Seattle
Sara Nelson, Chair, City Light Committee, Seattle City Council
Deborah Juarez, Vice Chair, City Light Committee, Seattle City Council
Jill Boudreau, Mayor, City of Mount Vernon
Julia Johnson, Mayor, City of Sedro-Woolley
Matt Miller, Mayor, City of Anacortes
Steve Sexton, Mayor, City of Burlington
Mandi Bates, Mayor, Town of Hamilton
Ramon Hayes, Mayor, Town of La Conner
Ed Hills, Mayor, Town of Lyman
Marla Reed, Mayor, Town of Concrete
Joe Lindquist, President, Skagit Public Utility District
Debra Smith, General Manager, Seattle City Light
Matt Cutlip, FERC, Office of Energy Projects, Division of Hydropower Licensing Skagit Project Relicensing Coordinator

1. Summary.

Throughout the SCL FERC relicensing process, the Partnership and the County have made clear our primary interest in evaluating Project operations to provide more and earlier flood storage at the Ross Reservoir, which is necessary to reduce flood risks to downstream communities.

On March 28, 2022, the Partnership and County filed a formal request to operate Ross with 200,000 acre/feet of flood storage no later than November 1 of each year.[4] Despite our early and continuous effort at coordination, SCL's Draft License Application does not address our concerns in any way. Specifically, the DLA states: "At this time, City Light proposes to operate the Project in a manner consistent with the current license."[5]

The DLA reflects unwillingness to modify project operations as necessary to increase regulatory flood storage and shift storage availability one month earlier per our March 28, 2022 request.

The Partnership and County request that SCL incorporate our Proposed Flood Risk License Requirement ("**Flood Proposal**") in the Final License Application (**Table 1**).

Table 1. Summary of Flood Risk Reduction Ross Operational Change Request

License Element	Current License Requirement	Proposed License Requirement
Ross Flood Storage Capacity (ac-ft)	120,000	200,000
Date of Full Flood Storage Availability	Dec. 1	Nov. 1

In support of our Flood Proposal, the following sections provide detailed information regarding:

- Known flood risks in downstream communities;
- The original project purpose and licensing conditions related to Ross flood storage;
- Current operations and baseline conditions;
- Results of operational modeling of proposed flood risk reduction scenario;
- Concerns about recently published SCL flood risk reduction studies; and
- Concerns about the lack of transparency and process to date.

[4] Joint Skagit County and Skagit Dike Partnership Operations Model Flood Storage Proposal, filed March 28, 2022 (FERC Accession No.20220328-5031).
[5] SCL DLA. Exhibit B, Project Operations and Resource Utilization Section 5.0 Future Resource Utilization and SCL Draft License Application; Exhibit H ECPA Factor Sections 2.2.1, 2.3.2, 3.1.2, filed November 30, 2022 (FERC Accession No. 20221130-5335).

We request that SCL and the Commission consider this information in reviewing the DLA and preparing the Final License Application ("**FLA**"), and we ask that the Commission include our Flood Proposal in the Project's NEPA analysis.

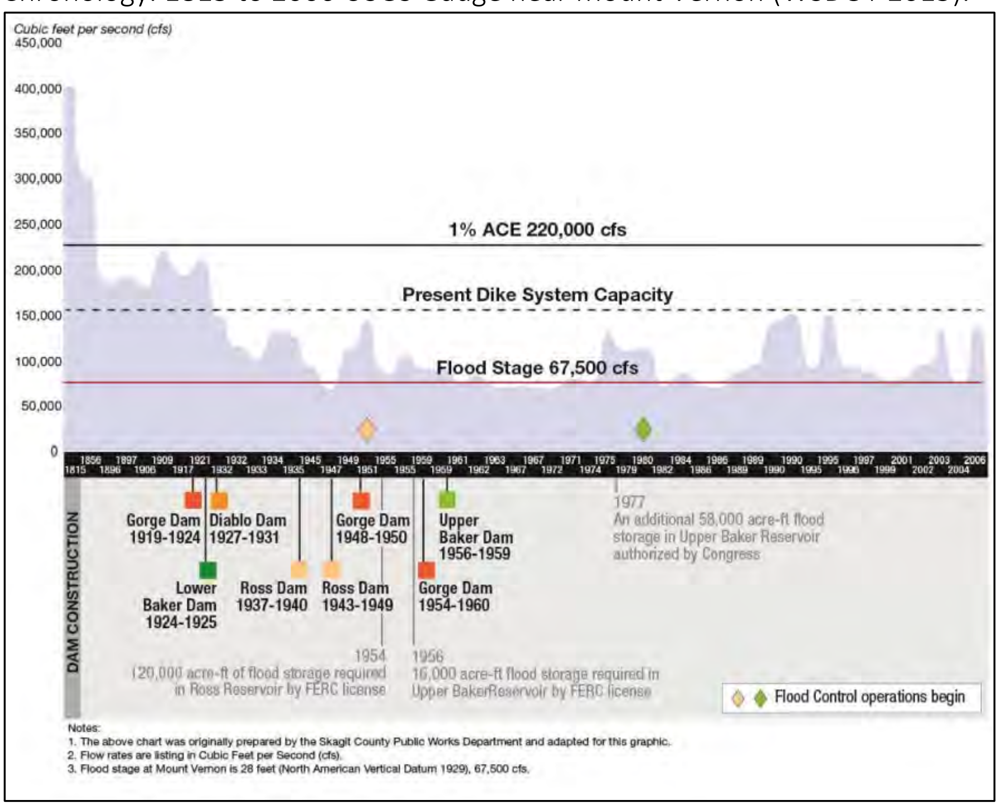
2. <u>Known Flood Risks</u>.

Assessing the jeopardy that flooding creates for our community involves a complex relationship between (1) flood hazards (defined as the magnitude, timing, and probability that a flood will occur); and (2) flood risks (defined as human life, property, and critical infrastructure located in the floodplain). Both flood hazards and flood risks have changed dramatically in the Skagit Valley since the early 1900's.

A. *<u>Flood Hazards</u>*.

The magnitude and probability that a catastrophic flood will occur have decreased over the past 100-years with the construction of dams and their associated flood storage requirements. As illustrated in **Figure 1**, the four largest documented floods on the Skagit River (1897, 1909, 1917, and 1921) all occurred before the dams were constructed.

Figure 1. Skagit River Recorded Discharges Exceeding Flood Stage and Dam Construction Chronology. 1815 to 2006 USGS Gauge near Mount Vernon (WSDOT 2015):[6]



[6] ACE = Annual Chance of Exceedance

The seasonality of floods has also likely changed over the past 100-years, and is predicted to continue to change, as discussed below in the section on climate change. U.S. Geological Survey ("**USGS**") and National Weather Service ("**NWS**") data at the Concrete gage make clear that major Skagit River flood events frequently occur well before December 1, the date when full flood storage at Ross is required under the current license, and often occur well before November 15 (**Table 2**).

Table 2. Summary of recent Skagit River Major Flood Events

Flood Date	Flood Category[N1]	Stage at Concrete (ft)	Discharge Rate at Concrete (cfs)
Nov. 11, 1990	Major	Unverified	127,000
Nov. 25, 1990	Major	40.20	146,000
Nov. 8, 1995	Major	39.37	143,000
Oct. 17, 2003	Major	33.12	94,000
Oct. 21, 2003[N2]	Major	42.21	166,000
Nov. 6, 2006	Major	39.37	145,000
Nov. 23, 2017	Major	34.69	106,000
Nov. 15, 2021	Major	38.93	134,000

N1. NWS defines a major flood event as a river stage at Concrete greater than 32.5 ft.
N2. Flood of record

Each of these major flood events resulted in damage to levees that required costly repairs. Each of these flood events also resulted in damage to several small communities downstream of the Skagit Project. Between 1990 and 2003, Skagit County Department of Emergency Management reported over $78 million in flood related repairs.

B. *Flood Risk*.

In 1954, when flood storage was authorized at Ross, Skagit County had a population of 43,000, with limited infrastructure located in the floodplain. Today, Skagit County has a population of more than 131,000 people, with real and personal property assessed in excess of $24 billion, much of which is located within the approximately 90,000 acres situated in the 100-yr floodplain of the Skagit River. *See*, Federal Emergency Management Agency (FEMA) Floodplain Maps for Skagit River, included as **Attachment 2**.

The cities of Burlington, LaConner, Mount Vernon, and Sedro Woolley are located in within the 100-year floodplain of the Skagit River, in whole or in part. In addition, numerous small towns are also located at least partially in the floodplain, including Bow, Concrete, Conway, Edison, Hamilton, Lyman.

Critical infrastructure located in the Skagit River floodplain includes the City of Anacortes water intake and treatment system that serves the cities of Anacortes, LaConner and Oak Harbor, Naval Air Station Whidbey, the Swinomish Indian Tribal Community, and two major West Coast refineries. Other critical infrastructure situated in the floodplain includes the wastewater treatment plants for the cities of Sedro Woolley, Burlington, Mount Vernon, and LaConner.

In addition, several major highways and local roads including Interstate 5, State Route (SR) 9, SR 11, SR 20, and SR 532 are located in the floodplain. Finally, numerous hospitals, fire stations, senior centers, and schools are also located in the Skagit River floodplain. A catastrophic flood would create significant property damage, potential loss of life, and severe impact to our regional economy and daily activity.

Between 1993 and 2015, Skagit County worked closely with the U.S. Army Corps of Engineers ("**USACE**") to evaluate flood hazards in the Skagit Watershed. This study, the Skagit River Flood Risk Management General Investigation ("**GI Study**"), included detailed hydrologic and hydraulic analyses to characterize flood hazards, and an evaluation of alternatives to reduce flood risks. The GI Study did *not* evaluate potential benefits of operational changes at Ross, because SCL's Federal Power Act re-licensing was considered to be outside the GI Study's scope.

In 2015, Washington State Department of Transportation ("**WSDOT**") completed a Resilient Transportation Network study, seeking to improve the resiliency of transportation facilities to climate change and extreme weather events such as floods (WSDOT 2015).[7] Similar to the work performed under the auspices of the GI Study, the 2015 WSDOT Resilient Transportation Network study concluded that increased flood storage at upstream reservoirs was a key strategy that would improve transportation resiliency.[8]

In another study, WSDOT estimated that a closure of I-5 alone during a 100-year flood event would be comparable to that of a closure in Lewis County due to flooding, costing between $11.9 million and up to $20.6 million for an anticipated 5-day closure alone.[9] Additional closures of SR 9, SR 11, SR20, and SR 532 would further cripple economic activities and access

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[7] A copy of the WSDOT 2015 Resilient Transportation Network Study is attached as **Exhibit A**.
[8] *Id*. at 28-30
[9] A copy of relevant portions of the WSDOT's "Chehalis River Basin I-5 Flood Protection Near Centralia and Chehalis" study, dated November 26, 2014, is attached hereto as **Exhibit B**. The stated range is based on the share of through traffic that takes a detour rather than delays a trip, with the higher figure assuming a full closure.

to essential services, as evidenced by the 2021 flood when SR 9, SR 11, and SR 20 and many local roads were closed.

3. History of Skagit Project Flood Storage.

The Project is managed to provide flood storage at Ross Dam, the Project's uppermost impoundment. By contrast, Gorge Dam and Diablo Dam provide no flood storage capacity, and, from a flood control perspective, are managed solely as pass-through facilities.[10] Despite the fact that the Ross Dam's original license required 200,000 acre/feet of storage by November 1, the current license contains an unsatisfactory and inadequate drawdown requirement of 120,000 acre/feet by December 1. A historical analysis reveals that SCL's argument for reduced flood storage has been overcome by events, and is no longer relevant.

The Project was originally licensed by the Federal Power Commission on October 29, 1927. The first phase of Ross was authorized by License Amendment No. 1 on July 23, 1937, to pool elevation 1,500 feet.

In the early 1940s, as SCL was considering raising Ross Dam to an elevation of 1,620 feet, U.S. Representative Henry "Scoop" Jackson wrote to USACE, urging careful consideration of the Skagit County Board of Commissioners' request that SCL be allowed to raise Ross Dam only on condition the top 15 feet of the reservoir be set aside for flood storage.[11]

Consistent with this request, USACE recommended and the Federal Power Commission required 200,000 acre/feet of storage at Ross, no later than November 1 of each year:

> Upon installation of the spillway gates it is provided that during the period November 1 to April 1 200,000 acre-feet of storage space in Ross Reservoir shall be reserved by the licensee for flood control and utilized as prescribed herein. [12]

The Order was based on an explicit recommendation by USACE regarding the necessity of 200,000 ac/ft by November 1:

> The Chief of Engineers and the Secretary of War have approved plans insofar as they affect navigation, and have recommended that during the period November 1 to April 1, 200,000 acre-feet of storage be reserved in Ross Reservoir for the purpose of flood

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[10] U.S. Army Corps of Engineers Water Control Manual for Skagit Project, 2002.
[11] Letter from Rep. "Scoop" Jackson to Army Corps dated July 15, 1946, last visited December 20, 2022, copy attached as **Exhibit C**.
[12] Skagit Project License Amendment No. 4, Order, Paragraph 18(d) dated April 29, 1947, at PDF 3 (copy attached as **Exhibit D**.

> control and that methods of operating the reservoir in the interests of flood control be required as hereinafter provided.[13]

On December 27, 1948, SCL wrote to the Federal Power Commission claiming that there wasn't enough data around Ross flood storage, insisting that more study was required.[14] On January 26, 1950, USACE suggested that SCL conduct a study of Ross utilization.[15] In response, on July 17, 1950, SCL furnished an analysis of the effects of Ross drawdown on power production and economics. SCL argued that drawdown for flood storage conflicted with SCL's preference to retain water into the winter months to support peak winter month power production, "when power is at a premium."[16] SCL claimed that the estimated lost power production (as between *no* flood control storage and 200,000 ac-ft by November 1) would result in a loss of only $91,462 per year.[17]

On September 17, 1954 – without any apparent notice or opportunity to be heard for Skagit County and its citizens – the Federal Power Commission amended License Article 36, downgrading flood storage capacity at Ross Reservoir from 200,000 ac-ft by November 1 to 120,000 ac-ft by December 1.[18] This remains in place today.[19]

In other words, SCL successfully negotiated a reduced and inadequate level of flood storage (120,000 ac-ft) on the basis of economic rationale to benefit the utility, by arguing that providing any flood storage at all would mean $91,462 in reduced winter power production.

Since 1954, the seasonal value of power produced has changed substantially, as average daily load has tipped toward summertime peak.[20] As a result, the justification for reducing flood storage offered in the 1950's - that winter peak power prices demanded reduction of flood storage - is no longer the case.

As part of the 1995 Project License, SCL entered into a Fisheries Settlement Agreement ("**FSA**") with Skagit Treaty Tribes requiring SCL to spill water in late summer and early fall for the purposes of augmenting flows downstream of the Project to benefit anadromous species.[21]

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[13] *Id*., Paragraph 7 and PDF 2.
[14] See, Letter from SCL to Federal Power Commission, dated December 27, 1948, copy attached as **Exhibit E**.
[15] Letter from Army Corps Seattle District to SCL dated January 26, 1950, copy attached as **Exhibit F**.
[16] Letter from SCL to Army Corps Seattle District dated July 17, 1950, see in particular PDF 2, copy attached as **Exhibit G**.
[17] *Id*.
[18] Original Skagit Project License with Amendments, Amendment No. 9 (revising Article 36), dated September 17, 1954, at PDF 134, copy attached as **Exhibit H**.
[19] 1995 Project License, Article 301, PDF 33.
[20] *See, e.g.,* U.S. Energy Information Administration, "Today in Energy" website.
[21] 1991 Fisheries Settlement Agreement (as Revised 2011)(FERC Accession No. 20110825-5015).

As USGS data furnished in this comment letter reflect, water spillage for fish flows has, for the past two decades, resulted in draw down of Ross Reservoir well below that required by the Project license for flood storage. The net effect of the FSA has been additional flood storage, which has been utilized during flood events, albeit unpredictably and irregularly.

In summary, the historical record of the Project suggests that our proposal for earlier fall drawdown for the purposes of flood risk reduction has positive environmental benefits for fisheries, with little apparent economic impact to SCL.

4. Proposed Flood Risk Reduction Request.

The Partnership and the County jointly submitted an alternative operational scenario to SCL on March 28, 2022, which was filed in the Project record.[22] As previously stated, our Flood Proposal has two key components: (1) it shifts the timing of flood storage to earlier in the season and (2) increases the total volume of flood storage provided at Ross (**Table 3**).

Table 3. Summary of Flood Risk Reduction Operational Change Request.

License Element	Current License Requirement[N1]	Proposed License Requirement
Ross Lake Stage (ft, NAVD88)	1,595.85	1,589.04
Flood Storage Capacity (ac-ft)	120,000	200,000
Date of Full Flood Storage Availability	Dec. 1	Nov. 1

N1. Public Article 301

Since our March 2022 request was filed, SCL has used HDR's Computer Hydro-Electric Operations and Planning Software ("**CHEOPS**") model to evaluate a variety of operational scenarios, for the stated purpose of developing a single operational proposal that meets the needs of License Participants. Our review of the CHEOPS model demonstrates that it does not adequately represent flood operations, and should not be used for evaluating how changes in flood operations reduce flood risk in downstream communities. A technical memorandum prepared by Anchor QEA reviews the CHEOPS model and provides the basis for the foregoing opinion, included as **Attachment 3**.

To address the limitations of the CHEOPS model and the fact that SCL did not successfully develop an integrated alternative Operational Model prior to filing the DLA, we have developed an alternative method for characterizing the importance of our Flood Proposal, based on:

1) Known information on recent Skagit River major floods;
2) Data from current operations and the November 2021 flood event; and

[22] Joint County-Partnership Flood Risk Reduction Proposal Letter dated March 28, 2022 (FERC Accession No. 0220328-5031).

3) Climate change literature review.

In addition, we have included a high-level evaluation of our modeling scenario as compared to the baseline operations, FSA requirements, and baseline power production. We integrated our scenario with alternative operations that also (1) drawdown Ross earlier in the season, which has been supported by the National Park Service; and (2) diverts flows into the Gorge bypass reach as proposed by the Upper Skagit Indian Tribe.

A. *Skagit River Major Flood Events*.

Most major floods on the Skagit River occur in the fall, the result of large atmospheric rivers. As shown on Table 2, the eight major flood events over the last 32 years have all occurred before December 1. The most recent major flood occurred on November 15, 2021. As such, it is clear that major Skagit River flood events frequently occur well before December 1 when full flood storage required at Ross under the existing license is available, and often occur well before November 15.

The seasonality of floods has also likely changed over the past 100 years, and is predicted to continue to change, as discussed in the section on climate change of this comment letter, and in the Anchor QEA technical memo provided in Attachment 3.

B. *Current Operations and the November 2021 Major Flood Event*.

The importance of earlier and additional flood storage at Ross is vividly demonstrated by an analysis of the November 2021 flood event. The November 2021 flood is comparable to other major floods in terms of seasonality, stage, and flow below the Skagit Project (see Table 2). The flow measured at the Concrete gage was 134,000 cfs, and, at the Mount Vernon gage, 125,000 cfs (USGS 2023). Those flows have a return frequency of between 10 and 25 years (**Table 4**), even though the November 2021 flood was a record inflow to the Ross reservoir, estimated at 67,000 cfs (see Figure 1).

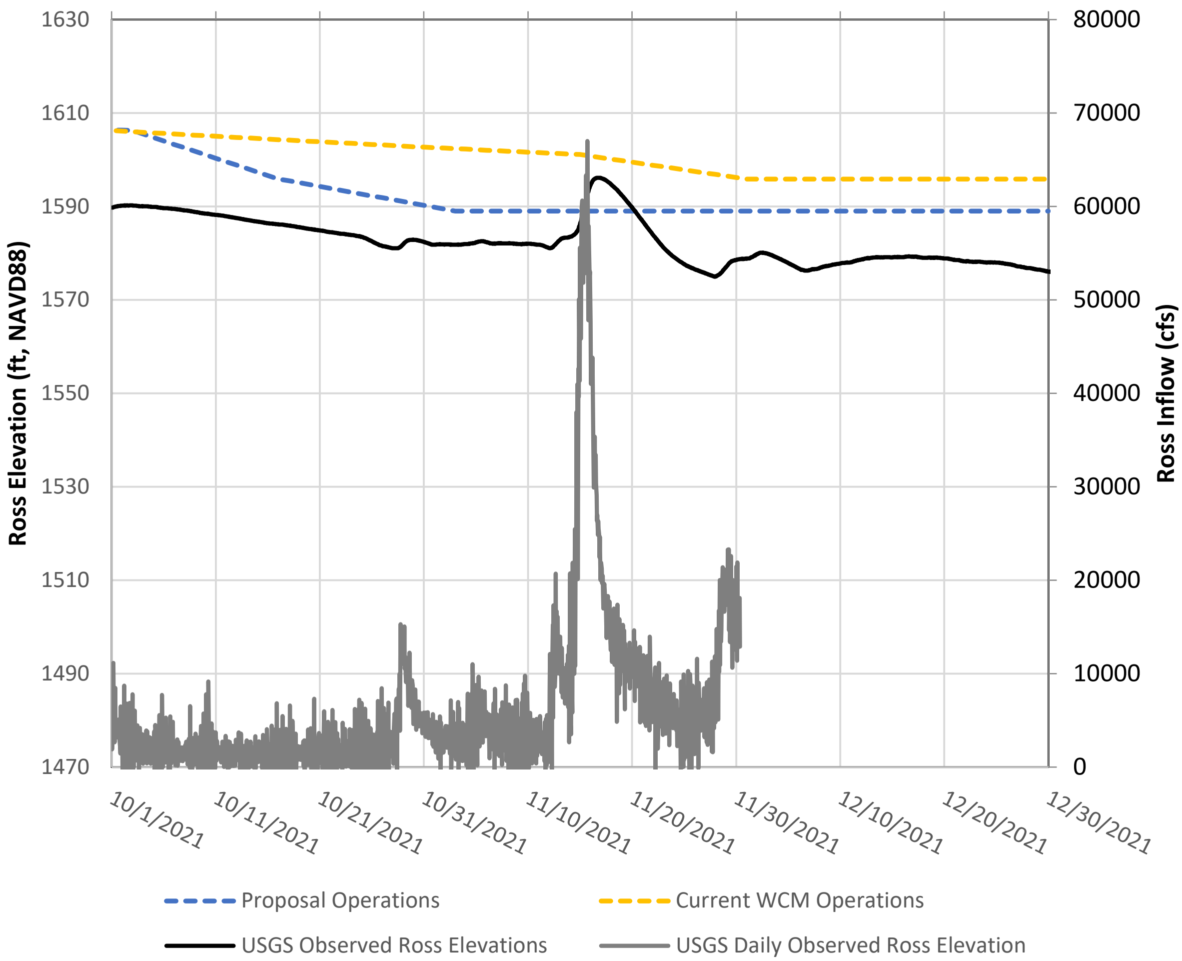
Table 4. Recurrence Intervals of Floods on Skagit River.

Recurrence Interval	Regulated Flow Concrete (cfs)	Regulated Flow Sedro-Woolley (cfs)	Regulated Flow Mount Vernon (cfs)
2-year	77,300	80,500	76,900
5-year	101,100	105,200	92,900
10-year	127,700	133,000	119,000
25-year	165,300	169,800	149,800
50-year	189,100	197,400	167,600
100-year	225,900	235,700	206,500

Source: U.S. Army Corps of Engineers 2014

Figure 2 provides a comparison of Ross water levels with USACE Water Control Manual ("**WCM**") requirements for the period of October 1 to December 31, 2021, which encompasses the November 2021 flood, and includes our Flood Proposal for comparison.

Figure 2. November 2021 Flood Operations.



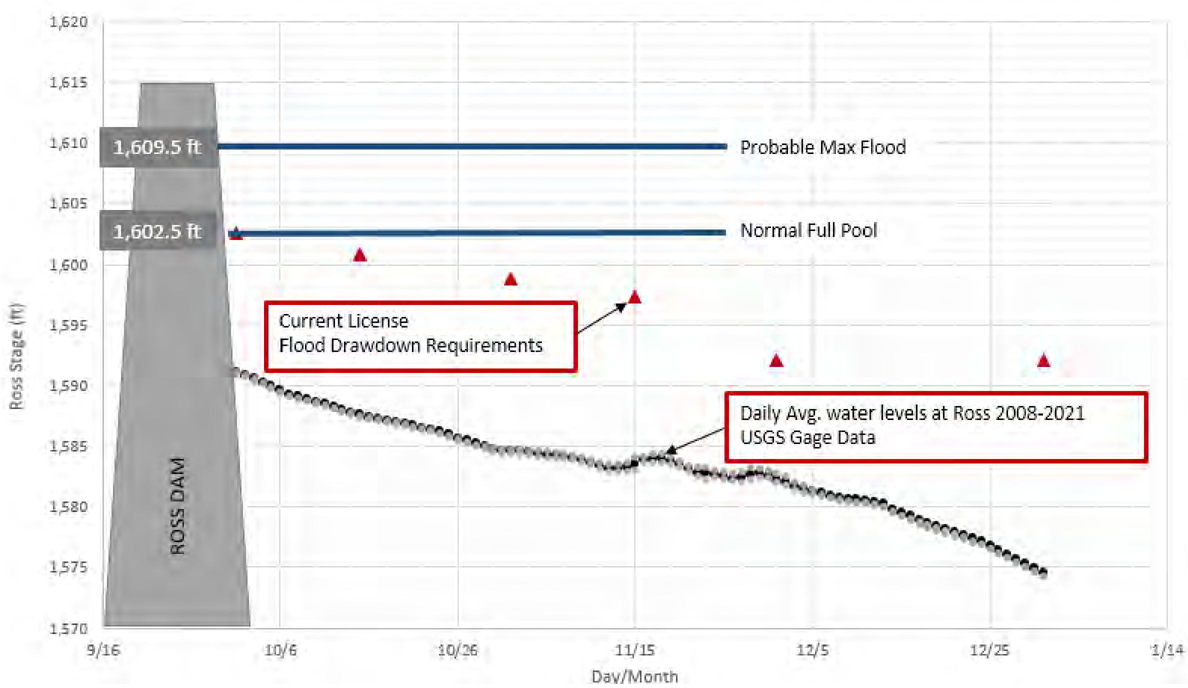
Prior to the November 15, 2021 flood, and despite an unusually wet fall, there was approximately 178,000 ac-ft of storage in the Ross reservoir. By comparison, the current WCM would have only required 60,000 ac-ft of storage by November 15. Thus, had it not been for the extra storage at Ross (coupled with the much smaller amount of storage available in the Baker system), USACE estimates that the flood in Mount Vernon would have been 8 feet higher, which would have had devastating effects on our community.[23]

[23] U.S. Army Corps of Engineers, Seattle District, "Army Corps of Engineers dam operations significantly reduced downstream flood risk," November 19, 2021, copy attached as **Exhibit I**.

Based on our analysis of USGS records, standard operations at Ross since 2008 include significant fall drawdown in excess of the requirements for flood control in the current license and the WCM.

In addition, USGS records document that Ross reservoir continues to be drawn down well below the flood storage requirements during the winter months, as depicted by **Figure 3**:

Figure 3. USGS Water Surface Elevation Data: Ross Reservoir 2008-2021.



For the purposes of the CHEOPS Operations Model, SCL's OM-01 Operations Model Revised Study Plan ("**OM-01 RSP**") defines the Base Case as operations under the current license:

> For purposes of developing the Operations Model, the Base Case represents the Project's operations under the current FERC license. The objective of this study is to develop an Operations Model that represents existing Project operations with reasonable accuracy for purposes of relicensing, and which can be used to simulate potential future operations under a variety of operating scenarios.
> …
> The Base Case has specific relevance in FERC relicensing proceedings as it represents the baseline conditions to which other scenarios of potential future operations are compared.[24]

[24] SCL OM-01 Revised Study Plan, p.2-1, PDF 8, April 7, 2021 (FERC Accession No. 20210407-5163).

After SCL filed the OM-1 RSP with the Commission, SCL developed an alternative Base Case referred to as the R3 Baseline. The R3 Baseline was developed by modifying the Base Case *to include a 10-ft operational buffer in addition to current license and FSA requirements*.

We are concerned that SCL is utilizing the R3 Baseline instead of the Base Case to draw conclusions regarding Project Operations and an evaluation of our Flood Proposal. The DLA states that the

> [e]ffects of large drawdowns in Ross Lake….are due overwhelmingly to flood-control measures required by the license rather than the operation of City Light's hydroelectric facilities."[25]

This statement is in direct conflict with statements made by SCL facility operations staff, who have told us that early fall drawdown in excess of that required by the current license is principally due to license requirements requiring water release to augment instream flows for fish, not flood control. It is also in conflict with SCL statements reported in USACE's GI Study:

> Ross Reservoir often provides significantly greater storage early in the flood control season than is required under the terms of its operating license. According to a representative from SCL, Ross reservoir elevations in the early fall are driven by a combination of factors including summer/fall weather conditions, energy demand, fisheries compliance requirements, and conditions in the energy market in general.[26]

In an effort to better understand the differences between the Base Case and the R3 Baseline and understand how the current license and FSA requirements effect fall operations of Ross we conducted a comparative analysis. *See*, Attachment 3.

Our comparative analysis indicates that that there is little difference in predicted operations between the Base Case and the R3 Baseline. This means that the current license and FSA requirements dictate fall operations, and *not* the additive 10-ft operational buffer reflected in the R3 Baseline.

These findings support our conclusion that current operational drawdown of Ross in the fall is not a function of the 10-ft operational buffer as implied in the R3 Baseline, but rather current license and FSA requirements.

Furthermore, because the fall drawdown greatly exceeds the current license requirements for flood drawdown, our understanding is that SCL draws Ross down in the fall to meet flow

[25] DLA Exhibit E, p.4-265 (PDF 395).

[26] USACE, Skagit River Basin General Investigation Flood Risk Reduction Hydraulic Analysis Final Study Report, August 2013, Section 3.1.2 (Ross), p. 16, copy attached as **Exhibit K**.

obligations under the FSA and to produce power and is not related to license conditions pertaining to flood control (FERC 2011).

Based on our analysis of USGS data and the Operations Model, our request for earlier and larger drawdown of Ross for the purposes of flood risk reduction is aligned with FSA obligations for fall spawning and incubation flows. We request that our Flood Proposal be evaluated compared to the Base Case, and not the modified R3 Baseline developed by SCL.

5. **Climate Change Literature Review**.

Our Flood Proposal is even more critical in light of changing climate, and the increasing magnitude of atmospheric river events.

Key studies, referenced regularly by SCL throughout the licensing process, include Lee *et al* (2016)[27] and Banderagoda *et al* (2020).[28] In addition, SCL has performed a climate change analysis involving the Project, documented in the 2022 Integrated Resource Plan (SCL 2022).[29]

The Partnership and County provide the following comments and concerns regarding these three documents to the extent they will be used to inform decisions about flood risk reduction, project operations, or as part of the relicensing process generally. Additional comments are provided in Anchor QEA's technical memo provided in Attachment 3.

Lee *et al* used only two global climate models (CanESM2 and CCSM4) in the review of climate change impacts. Best practices for climate change modeling include use of a larger ensemble of global climate models ("**GCMs**"), which are readily available for the Pacific Northwest and the Skagit Basin. Based on our review of modeling results, SCL climate models show an overall increase in the total inflow volume to Ross compared to historic conditions. In addition, climate models predict that peak inflows shift from spring to winter, with slight increase in the magnitude of peak daily inflows in the fall. However, the predicted future (2080s) fall and winter peak inflow of approximately 45,000 cfs is much less than the peak inflow to Ross of 67,000 cfs that occurred during the November 2021 flood event.

Accordingly, it does not appear the hydrologic modeling adequately represents future peak flows, due either to a limited selection of GCMs or a poorly calibrated model. SCL reports the highest peak flow under 2080s decadal conditions at approximately 70,000 cfs. However, the

[27] Lee, SY, A.F. Hamlet, AF, and E.E. Grossman (2016). Impacts of Climate Change on Regulated Streamflow, Hydrologic Extremes, Hydropower Production, and Sediment Discharge in the Skagit River Basin. Northwest Science.
[28] Bandaragoda, C., S. LEE, E. Istanbulluoglu, A. Hamlet (2020). Hydrology, Stream Temperature, and Sediment Impacts of Climate Change in the Sauk River Basin, *referenced in* SCL Revised Study Plan dated April 7, 2021, at p.6-53 and OM-o1 Operations Model Revised Study Plan, p.2-2 (FERC Accession No. 20210407-5163).
[29] Seattle City Light 2022 Integrated Resource Plan, PDF 90-91.

model output shows that peak occurring in July, which appears to be in error as all other large floods occur in fall and winter. SCL provides no explanation for the July flood outlier.

Lee *et al* further conclude that "alternative flood control operations are shown to be largely ineffective in mitigating the increased flood risk" from climate change. In their opinion, atmospheric rivers are "warm enough that there is little increase in contributing basin area with additional climate change warming," thus, Lee *et al* conclude these events are not likely to get significantly larger.[30]

However, more recent research (Espinoza *et al* 2018) states that atmospheric rivers will be "~25% longer, ~25% wider, and exhibit stronger integrated water vapor transports (IVTs) under RCP8.5."[31] This indicates that a larger portion of the Skagit Basin could be impacted by an atmospheric river for a longer period of time, which would increase peak flows and the volume of inflow that Ross receives during an atmospheric river event.

While Bandaragoda *et al* (2020) may not be entirely representative of inflows to the SCL Project, it also indicates shifting trends in hydrology under climate scenarios. Importantly, Bandaragoda *et al* highlights that historically, median monthly instream flows decline from October to March, predicting that future trends will involve an increase in monthly median flow rates in Thunder Creek, a tributary of Diablo, in the fall and winter. The change is due to a predicted shift to a more rain-dominated basin as snowpack declines.[32] This predicted trend will likely impact the operations of the SCL project, and is further justification for our Flood Proposal.

In summary, according to the most recent climate change research, large flood events will continue to occur in the fall, but will likely be exacerbated by larger atmospheric river events. This supports our request for additional and earlier storage at Ross.

6. Summary of Relicensing Process to date: Concerns about Technical Analysis, Schedule and Transparency.

The County, Partnership, and Consortium have been participating in the SCL FERC relicensing process since 2018. Since that time, we have been clear that our primary concern is related to flood risk reduction through change to the timing and volume of flood storage at

[30] Lee *et al*, at 36.
[31] Espinoza, V., D.E. Waliser, Bin-Guan, D.A. Lavers, F. M. Ralph (2018). Global Analysis of Climate Change Projection Effects on Atmospheric Rivers, page 4299, copy attached hereto as **Exhibit J**.
[32] Bandaragoda *et al*, at 39-49

Ross. We have repeatedly requested that SCL evaluate operational changes and downstream flood risk in meetings, correspondence, and numerous FERC filings.[33]

Throughout SCL's FERC process, we have found it difficult to work with SCL on technical issues. The technical tools available are not detailed enough to evaluate flood risks, there has been a lack of transparency, and there has been no comprehensive evaluation of an integrated Alternative Operational Scenario.

In the DLA, SCL states that

> [m]any of the PME measures have been developed with input from licensing participants (LPs). City Light continues to engage LPs regarding Protection, Mitigation and Enhancement ("PME") measures that will be included in the Proposed Action in the Final License Application (FLA).[34]

Nevertheless, the DLA includes no reference to our requested alternative operational scenario aimed at flood risk reduction, nor does the DLA include any acknowledgment of our multiple requests for analysis of an operational change at Ross.

Throughout this process, County, Partnership, and Consortium staff have raised concerns, both informally and formally, requesting that SCL use the updated operations model to evaluate our flood risk reduction proposal, as compared to (1) the existing FSA protocols; (2) recreational targets in the existing license; and (3) power production. To date, SCL has not developed an integrated alternative operational proposal.

[33] Skagit County Comment Letter dated September 15, 2020 (FERC Accession No. 20200916-5058); Study Plan Requests of Consortium and Skagit Dike District Partnership (the "Partnership"), dated September 21, 2020 (FERC Accession No. 20201021-5092); Comment Letter by Consortium requesting operations trend analysis, dated September 21, 2020 (FERC Accession No. 20200921-5070); Study Plan Requests of Skagit County dated October 23, 2020 (FERC Accession No. 20201023-5137); Comments of Skagit County on Initial Study Plan, dated March 4, 2021 (FERC Accession No. 20210304-5112); Comments of Consortium on Proposed Study Plan, dated March 4, 2021 (FERC Accession No. 0304-5124); Skagit County Comments on Revised Study Plan, dated May 5, 2021 (FERC Accession No. 20210506-5015); Comments of Consortium and Partnership on Revised Study Plan, dated May 5, 2021 (FERC Accession No. 0505-5067); Comments of Skagit County and Partnership re Operations Model dated March 25, 2022 (FERC Accession No. 20220328-5031); Comments of Skagit County on Interim Study Report, dated May 5, 2022 (FERC Accession No. 20220505-5112); Comments of Consortium and Partnership dated May 5, 2022 (FERC Accession No. 20220505-5135); Comments of Consortium on Interim Study Report dated May 5, 2022 (FERC Accession No. 20220505-5136); Comments of Consortium and Partnership dated September 26, 2022 (FERC Accession No. 20220926-5093).
[34] DLA Exhibit E, pp.1-2 (PDF 41).

To the contrary, the DLA clearly expresses SCL's intention to simply maintain the status quo at the Project with respect to flood storage. SCL's DLA goes on to state as follows:

> City Light anticipates including a proposal in the FLA to refine the flood risk management benefits of the Project. City Light is currently engaged in dialogue with the USACE and other LPs and will provide more information on these measures in the FLA.[35]

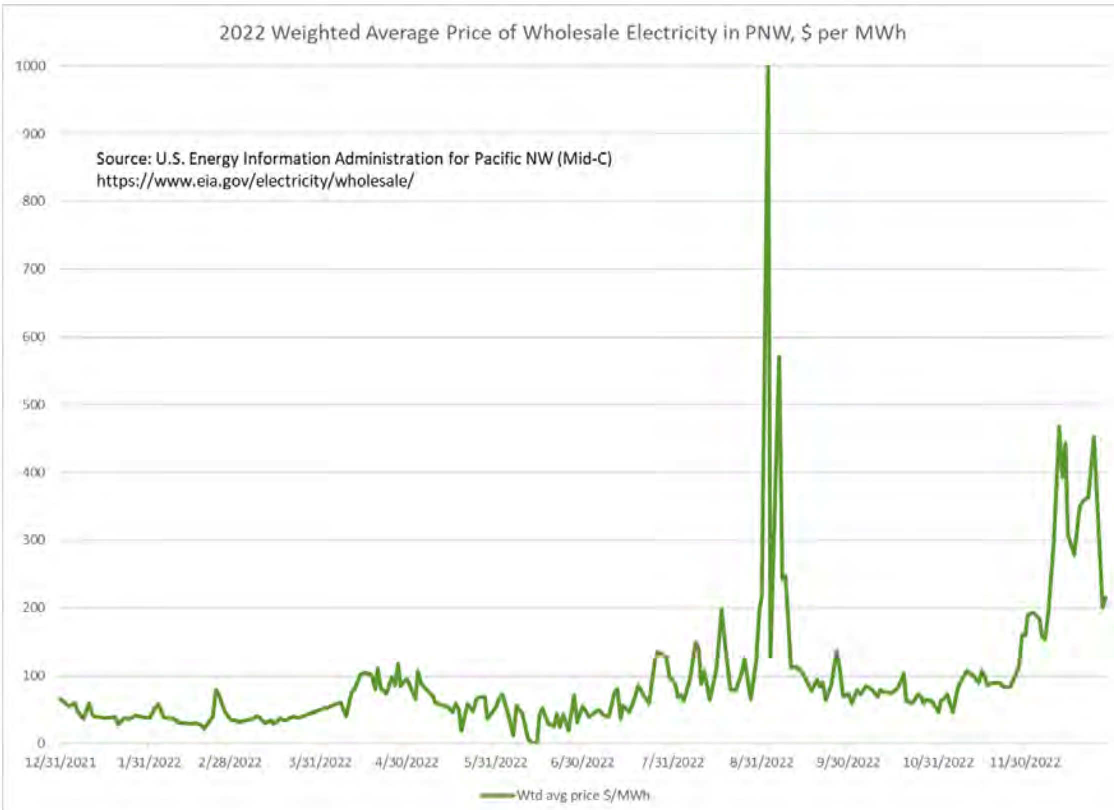
Notwithstanding SCL's statements in the DLA, and despite our diligent participation in SCL's process for the past four years, SCL has not engaged in any substantive dialogue with the Partnership, County, or Consortium as it pertains to our Flood Proposal.

7. Economics.

We have conducted a brief review of U.S. Energy Markets using data from the U.S. Energy Administration. This data spans over 20 years and indicates a peak in the price of wholesale energy in the Pacific Northwest in the late summer and early fall (**Figure 4**).

[35] DLA Appendix E, p.4-276 (PDF 406).

Figure 4. Summary of Weighted Average Price of Wholesale Electricity in the PNW. source U.S. Energy Administration. 2022.



This peak roughly coincides with the earlier drawdown of Ross that our Flood Proposal would require. The shift in time from late September/October to earlier in the year appears to be of financial benefit to SCL, given higher summertime electrical demand in recent years.

In addition, no water is lost from the power production system under our proposal, and total energy produced by SCL over the course of the year would be impacted little if at all by our Flood Proposal.

If anything, our Flood Proposal will reduce uncontrolled spill during flood events, which would result in more water in the system for the purposes of power production. Unfortunately, the CHEOPS model developed by SCL does not accurately simulate flood operations, and, therefore, this benefit cannot be numerically validated.

The trend of increased summertime and decreased wintertime electrical usage is only like to grow more pronounced as the climate warms. According to SCL's 2015 "Climate Change Vulnerability Assessment and Adaptation Plan," climate change will mean:

> An increase in electricity demand for cooling in summer, which could cause summer peaks to approach winter peaks in localized areas of the distribution system.
>
> A decrease in electricity demand for heating in winter, which could lower retail sales and have financial consequences for the utility.[36]

Accepting SCL's climate change assessment as true, it reflects that providing safe flood storage as well as flow augmentation for fish by releasing water in late summer and early fall is increasingly unlikely to have any material impact on SCL's economic interest in power production.

8. Conclusion.

Our Flood Proposal requests increase to the volume of storage in Ross Lake from 120,000 ac-ft to 200,000 ac-ft, and a change to the date of full flood storage drawdown from December 1 to November 1. The technical documentation provided in this document fully supports that our Flood Proposal:

1) Is based on reducing known existing flood risks in downstream communities;
2) Is consistent with original project purpose and licensing conditions;
3) Has a positive environmental impact, including support for tribal interest in streamflow augmentation; and
4) Appears to have little to no economic impact to SCL

As evidenced by the November 2021 flood event, additional hard storage behind Ross Dam will provide significant benefit by reducing the risk of flood damage and loss of life. The purpose of this request is to reduce risk to *existing* populations and critical infrastructure.

As the jurisdictions with responsibility for flood risk reduction and public safety in the Skagit Valley, we believe our request is fair and reasonable. Our Flood Proposal should be incorporated into the Final License Application, and the new license.

[36] Seattle City Light Climate Change Vulnerability Assessment and Adaptation Plan Summary, 2016, copy of relevant excerpts attached as **Exhibit L**.

References

Bandaragoda, C., S. LEE, E. Istanbulluoglu, A. Hamlet (2020). Hydrology, Stream Temperature, and Sediment Impacts of Climate Change in the Sauk River Basin, HydroShare, http://www.hydroshare.org/resource/e5ad2935979647d6af5f1a9f6bdecdea

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Espinoza, V., D.E. Waliser, Bin-Guan, D.A. Lavers, F. M. Ralph. 2018. Global Analysis of Climate Change Projection Effects on Atmospheric Rivers. First published: 19 April 2018. https://doi.org/10.1029/2017GL076968

FERC (Federal Energy Relicensing Commission) 2011. Skagit River Hydroelectric Project FERC NO. 553 Revised Fisheries Settlement Agreement Incorporating Anadromous Fish-Flow Plan (Flow Plan) and anadromous and resident fish non-flow (Non-Flow Plan). ORIGINAL: APRIL 1991 REVISED: JANUARY 2011

Lee, SY, A.F. Hamlet, AF, and E.E. Grossman. 2016. Impacts of Climate Change on Regulated Streamflow, Hydrologic Extremes, Hydropower Production, and Sediment Discharge in the Skagit River Basin. Northwest Science, 90(1) : 23-43. Published by: Northwest Scientific Association. URL: https://doi.org/10.3955/046.090.0104

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Seattle City Light (SCL) 2022. Integrated Resource Plan

U.S. Energy Administration. 2022. Wholesale Electricity and Natural Gas Market Data. release date: December 29, 2022. U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

Washington State Dept. of Transportation. 2015.

<u>LIST OF ATTACHMENTS</u>:

Attachment 1	Letters of Support
Attachment 2:	Skagit Floodplain FEMA Maps
Attachment 3:	Anchor QEA Technical Memorandum

<u>LIST OF EXHIBITS</u>:

Exhibit A	Washington State Department of Transportation, 2015 Resilient Transportation Network Study (2015)
Exhibit B	Washington State Department of Transportation, Chehalis River Basin I-5 Flood Protection Near Centralia and Chehalis study, dated November 26, 2014, relevant excerpts
Exhibit C	Letter from U.S. Rep. "Scoop" Jackson to U.S. Army Corps of Engineers, dated July 15, 1946
Exhibit D	Skagit Project License Amendment No. 4, Order, dated April 29, 1947
Exhibit E	Letter from SCL to Federal Power Commission, dated December 27, 1948
Exhibit F	Letter from Army Corps Seattle District to SCL, dated January 26, 1950
Exhibit G	Letter from SCL to Army Corps Seattle District, dated July 17, 1950
Exhibit H	Original Skagit Project License with Amendments, Amendment No. 9 (revising Article 36), dated September 17, 1954
Exhibit I	U.S. Army Corps of Engineers, Seattle District, "Army Corps of Engineers dam operations significantly reduced downstream flood risk," November 19, 2021
Exhibit J	Espinoza, V., D.E. Waliser, Bin-Guan, D.A. Lavers, F. M. Ralph (2018). Global Analysis of Climate Change Projection Effects on Atmospheric Rivers
Exhibit K	USACE, Skagit River Basin General Investigation Flood Risk Reduction Hydraulic Analysis Final Study Report, August 2013
Exhibit L	Seattle City Light Climate Change Vulnerability Assessment and Adaptation Plan Summary, 2016, relevant excerpts

Attachment 1 Letters of Support

January 24, 2023

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E., Room 1A
Washington, D.C. 20426

Re: Skagit Hydroelectric Project Relicensing, Seattle City Light, Project No. 553-235

Secretary Bose,

The City of Anacortes appreciates the opportunity to comment on the federal relicensing of the Skagit Hydroelectric Project, FERC Project No. 553-235 (the "Project"), owned and operated by Seattle City Light ("Seattle").

The City of Anacortes ("City") operates a water treatment plant on the Skagit River, located on Riverbend Road in Mount Vernon. The current plant was built in 2013 and has the expandable capacity to produce 55 million gallons of treated water per day. The plant serves approximately 56,000 residential, commercial, and industrial customers in the region, including the City of Oak Harbor which serves the Naval Air Station at Whidbey Island, the Town of La Conner, the HF Sinclair and Marathon Refineries, the Swinomish Indian Tribal Community, and Skagit Public Utility District #1. The City is the largest water supplier in the Skagit basin and its ability to operate is critical to the water supply of the entire region.

Seattle's Project was originally authorized with a primary priority of flood control, as the Project is built on public land. The original recommendation from the U.S. Army Corps of Engineers was that 200,000 acre/feet of flood storage be required at Ross reservoir. However, the Project licensing only required 120,000 acre/feet of storage by December, despite historic evidence that floods have occurred in October and November.

Seattle has managed the Project to provide additional flood storage capacity earlier and in excess of what the FERC license required. Had Seattle not provided that additional capacity voluntarily, the U.S. Army Corps of Engineers estimates that the November 2021 Skagit flood would have been approximately 8-10 feet higher at Mount Vernon, where the City's water treatment plant is located. Flooding at the City's water treatment plant would be catastrophic and could lead to interruption of regional water supply, contamination of water supply, and destruction of valuable public infrastructure.

The U.S. Army Corps of Engineers continues to recommend new license requirements that provide safe and appropriate drawdown level for the Ross reservoir at 200,000 acre/feet no later than November 1 of each year. The City now requests that FERC require Seattle to follow the U.S. Army Corps of Engineers recommendations for drawdown and timing as a requirement of its Project license.

We endorse the Flood Storage Proposal jointly filed in the FERC record by Skagit County, Skagit County Diking and Drainage Irrigation Consortium and Skagit Dike District Partnership, which supports 200,000 acre/feet by November 1 as the correct storage requirement. We respectfully request that Seattle be required to use 200,000 acre/feet of storage by November 1 as the baseline license requirement for flood storage in establishing proper environmental protection, mitigation, and enhancement (PM&E) measures with other licensing parties.

Thank you for your consideration and the opportunity to provide comment.

Matt Miller, Mayor

Jeremy Carter, Councilmember

Excused absence

Anthony Young, Councilmember

Ryan Walters, Councilmember

Christine Cleland-McGrath, Councilmember

Bruce McDougall, Councilmember

Excused absence

Amanda Hubik, Councilmember

Carolyn Moulton, Councilmember

CITY OF Burlington
SKAGIT COUNTY, WASHINGTON INCORPORATED 1902

February 2, 2023

Kimberly D. Bose, Secretary

Federal Energy Regulatory Commission

888 First Street, N.E., Room 1A

Washington D.C. 20426

RE: Skagit Hydroelectric Project Relicensing, Seattle City Light, Project No. 553-235

Secretary Bose:

As the elected leaders of the City of Burlington, we appreciate the opportunity to comment on the application for relicensing of the Skagit Hydroelectric Project, FERC Project No. 553-235 as proposed by Seattle City Light (SCL). This application, and the request to increase the flood storage level and timing of said increase is crucial to long term flood protection to our city's residents and businesses alike.

The City of Burlington is home to nearly 10,000 residents and is the economic hub of Skagit County. Additionally, the city incorporates the vital transportation arteries of Interstate 5 (north and south bound), Washington State Hwy 20 (east and west bound), and the north/south rail line of Burlington Northern Santa Fe. All of these would be drastically impacted by a major flood event with limited flood storage availability.

Over the past few years, the City of Burlington has partnered with our local Dike District (Dike District 12) to raise the levee by up to 4 feet in an effort to increase protection to our city. However, our most recent flood event of November 2021 demonstrated that even with this increased protection, absent SCL voluntarily providing additional flood storage (up to 178,000 ac.-ft.); the flood level in Burlington would have been up to 8 ft. higher resulting in catastrophic consequences to our city and the wider region.

In 1954 when the project was authorized by Congress with the goal of providing flood storage protection, the initial requirement was to provide 200,000 ac.-ft. of flood storage. The final approval required only 120,000 ac.-ft. of flood storage available on December 1. It would have been difficult at the time to predict the growth we would see in our region over the next 70 years or so, coupled with the changes we are seeing to our climate. Looking forward another 70 years, it is much easier to see the need for 200,000 ac.-ft. of flood storage earlier in the year is clear as we see flood events occurring earlier, and with more volume than previously recorded.

The City of Burlington agrees with the Army Corps of Engineers recommendation that SCL be required to provide 200,000 ac.-ft. of flood storage as of November 1 every year as part of the relicensing approval. We support the Flood Storage Proposal filed by the Skagit County Dike and Drainage Districts Flood Control Partnership and Skagit County.

Licensing a project such as this, that is located on land owned by us all should include protections for us all.

Thank you for considering our comments and concerns.

Steve Sexton

Mayor

Bill Aslett

City Councilmember

Keith Chaplin

City Councilmember

Anna Chotzen

City Councilmember

Joe DeGloria

City Councilmember

Scott Green

City Councilmember

James Stavig

City Councilmember

Jamie Weiss

City Councilmember

City of MOUNT VERNON

ORIGINAL

August 17, 2022

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E., Room 1A
Washington D.C. 20426

RE: Skagit Hydroelectric Project Relicensing, Seattle City Light, Project No. 553-235

Secretary Bose,

Thank you for this opportunity to comment on the ongoing federal relicensing of the Skagit Hydroelectric Project, FERC Project No. 553-235 (the "Project"), owned and operated by Seattle City Light ("Seattle").

The City of Mount Vernon ("City") is the largest city in Skagit County and its county seat, located on the Skagit River downstream of the Project.

While we've successfully directed more recent growth into upland areas, the City's historic center, major commercial zones, and key transportation routes are located within the Skagit River floodplain, and are at significant risk of catastrophic flooding.

The Project was authorized by Congress with flood control as its first priority, in part because the Project is built on public land. At the time, the U.S. Army Corps of Engineers recommended 200,000 acre/feet of flood storage drawdown at Ross reservoir. For reasons that are not entirely clear, the Project was required to provide only 120,000 acre/feet of storage by December 1, despite the fact that many historic Skagit floods have occurred in October and November.

Over the past several decades, Seattle has operated the Project in a manner that affords substantial flood storage capacity both earlier and well in excess of that required by Seattle's current FERC license. Had this additional drawdown capacity not been available, the U.S. Army Corps of Engineers estimates that the November 2021 Skagit flood would have been approximately 8-10 feet higher at Mount Vernon, which would have overtopped local levees, causing massive destruction, pollution discharge, and, potentially, billions of dollars in damage. A major flood such as our event last November also effects the Burlington Northern rail line, several Washington State highways and Interstate 5.

The U.S. Army Corps of Engineers continues to recommend new license requirements that provide safe and appropriate drawdown level for the Ross reservoir at 200,000 acre feet no later than November 1 of each year. The City requests that FERC require SCL to optimize flood storage consistent with U.S. Army Corps of Engineers recommendations for drawdown and timing, and ask that the U.S. Army Corps of Engineers' recommendation be included as a mandatory condition in the Project license.

We endorse the Flood Storage Proposal jointly filed in the FERC record by Skagit County, Skagit County Diking and Drainage Irrigation Consortium and Skagit Dike District Partnership, which supports 200,000 acre/feet by November 1 as the appropriate storage requirement.[1]

In the interest of efficiency, we respectfully request that Seattle be required to use 200,000 acre/feet of storage by November 1 as the baseline license requirement for flood storage in establishing appropriate environmental protection, mitigation and enhancement (PM&E) measures with other licensing parties.

Thank you for your consideration of the City's point of view on this matter.

Jill Boudreau
Mayor

Mary Hudson
City Councilmember

Melissa Beaton
City Councilmember

Mark Hulst
City Councilmember

Richard Brocksmith
City Councilmember

Gary Molenaar
City Councilmember

Iris Carlas
City Councilmember

Juan Morales
City Councilmember

[1] Letter from Skagit County, Skagit County Diking and Irrigation District Consortium and Skagit Dike District Partnership dated March 25, 2022 (FERC Accession No. 20220328-5031)

CITY OF SEDRO-WOOLLEY
Sedro-Woolley Municipal Building
325 Metcalf Street
Sedro-Woolley, WA 98284
Phone (360) 855-1661
Fax (360) 855-0707

December 14, 2022

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E., Room 1A
Washington D.C. 20426

RE: Skagit Hydroelectric Project Relicensing, Seattle City Light, Project

No. 553-235

Secretary Bose:

Thank you for this opportunity to comment on the ongoing federal relicensing of the Skagit Hydroelectric Project, FERC Project No. 553-235 (the "Project"), owned and operated by Seattle City Light ("Seattle").

The City of Sedro-Woolley ("City") is the third largest city in Skagit County, located on the Skagit River downstream of the Project.

Flood control is the project's first operational priority. At the time the Project was authorized, the U.S. Army Corps of Engineers recommended, and the federal government resultantly required, 200,000 acre/feet of flood storage drawdown at Ross reservoir. Based on a misleading analysis of historic floods, Seattle secured a change to Project operations in 1953 requiring only 120,000 acre/feet of storage by December 1, an inadequate level of protection given the fact that many historic Skagit floods occur in October and November, which climate change will only intensify.

Due to Skagit tribes' insistence that Seattle release water for fish flow augmentation, over the past several decades Seattle has operated the Project in a manner that affords substantial flood storage capacity both earlier and well in excess of that required by Seattle's current FERC license, a requirement with little financial impact on Seattle due to increased summertime electrical demand in recent decades. Had this additional drawdown capacity not been available, the U.S. Army Corps of Engineers estimates that the November 2021 Skagit flood would have been approximately 8-10 feet higher in Sedro-Woolley. This would have flooded a portion of our city and inundated our Wastewater Treatment Plan and other Public Works facilities, causing pollution discharge and damage requiring months to repair. It would also have flooded our hospital and an assisted care facility and cut off nearly every route in and out of our city. Such an event would have resulted in millions of dollars of damage to our community and local economy and displaced some of our residents.

While the Tribes' fish flows have fortuitously saved our community from damage, there is no actual requirement in the current license that Seattle continue to operate the Project safely. The Army Corps continues to recommend a new license requirement that would mandate safe and appropriate drawdown of the Ross reservoir at 200,000 acre feet no later than November 1 of each year. The City requests that FERC require Seattle to optimize flood storage consistent with U.S. Army Corps of Engineers recommendations for drawdown and timing, and we ask that the U.S. Army Corps of Engineers' recommendation be included as a mandatory condition in the Project license. Our community's representatives are proactively working with the Upper Skagit Indian Tribe to deconflict flood storage and fish passage, and we support the Tribe in their request that fish passage be included as a mandatory Project condition.

We endorse the Flood Storage Proposal jointly filed in the FERC record by Skagit County, Skagit County Diking and Drainage Irrigation Consortium and Skagit Dike District Partnership, which supports 200,000 acre/feet by November 1 as the appropriate storage requirement.[1]

In the interest of efficiency, we respectfully request that Seattle be required to use 200,000 acre/feet of storage by November 1 as the baseline license requirement for flood storage in establishing appropriate environmental protection, mitigation and enhancement (PM&E) measures with other licensing parties.

Thank you for your consideration of the City's point of view on this matter.

Sincerely,

Mayor, Julia Johnson ____________________

Councilmember, Brendan McGoffin ____________________

Councilmember, JoEllen Kesti ____________________

Councilmember Sarah Diamond ____________________

Councilmember, Glenn Allen ____________________

Councilmember, Chuck Owen ______________________

Councilmember, Joe Burns ______________________

Councilmember, Nick Lavacca ______________________

[1] **Letter from Skagit County, Skagit County Diking and Irrigation District Consortium and Skagit Dike District Partnership dated March 25, 2022 (FERC Accession No. 20220328-5031)**

CC: Mayor Bruce Harrell and the Seattle City Council
Chair Marilyn Scott and Council, Upper Skagit Indian Tribe
Chair Steve Edwards and Senate, Swinomish Indian Tribal Community
Chair Nino Maltos and Council, Sauk-Suiattle Indian Tribe

Skagit County Drainage and Irrigation Districts Consortium LLC
2017 Continental Pl. Suite 4
Mount Vernon, WA 98273
360.708.0344

February 2, 2023

via e-filing
Ms. Kimberly D. Bose, Secretary Federal Energy Regulatory Commission
888 First Street NE
Washington, D.C. 20426

Re: Draft License Application: SCL Skagit River Hydroelectric Project FERC No. 553-235

Dear Ms. Bose,

The Skagit County Drainage and Irrigation Districts Consortium LLC (Consortium) is a Watershed Management Partnership created under the authority of RCW 39.34.200. The twelve (12) dike, drainage, and irrigation special purpose districts represented by the Consortium encompass more than 58,000 acres of land in the Skagit and Samish river floodplains, constituting a majority of the prime farmland within Skagit County as well as residential and commercial development[1].

We are writing to support the Skagit County Dike and Drainage Districts Flood Control Partnership ("Partnership") and Skagit County government ("County"), which have jointly submitted a comment letter with respect to Seattle City Light's ("SCL") Draft License Application ("DLA") for the Skagit River Hydroelectric Project, P-553 ("Project").

For the reasons set forth in the Partnership and County comment letter, we support the request that the Commission increase the flood storage requirement at Ross Lake from 120,000 ac-ft to 200,000 ac-ft, as well as move up the date of full flood storage draw down from December 1 to November 1.

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[1] Member Districts include Skagit Dike District 3, Skagit Dike, Drainage and Irrigation District 5, Skagit Dike, Drainage and Irrigation District 12, Skagit Drainage and Irrigation District 14, Skagit Drainage and Irrigation District 15, Skagit Drainage and Irrigation District 16, Skagit Drainage and Irrigation District 17, Skagit Drainage and Irrigation District 18, Skagit Drainage and Irrigation District 19, Skagit Drainage and Irrigation District 22, Skagit Consolidated Dike, Drainage and Irrigation District 22, Skagit Dike, Drainage and Irrigation District 25

We support this request to reduce risk to existing farmland, critical infrastructure and development. We believe that the Partnership and County request is supported by sound science and accommodates a broad range of interests. We also believe that the Partnership and County request is consistent with the original (1947) intent of the US Army Corps of Engineers for flood storage at Ross. We request SCL incorporate the Partnership and County flood storage proposal into its Final License Application, which the Commission should then incorporate as a new license condition.

Sincerely,

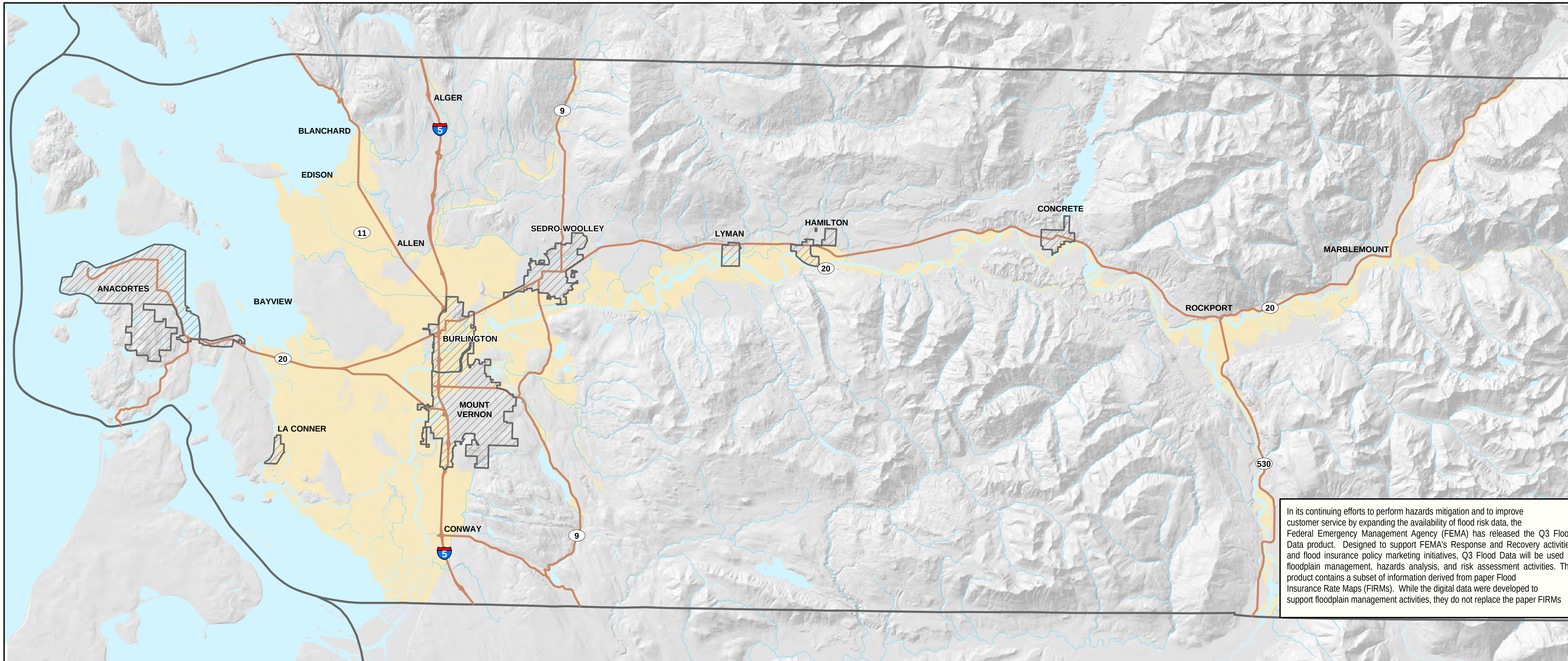
John Wolden, Chair

Norm Hoffman, Vice Chair

Attachment 2: Skagit Floodplain FEMA Maps

Skagit County

FEMA 100 YEAR FLOODPLAIN



N
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0 2.5 5 10
Miles

Seattle City Light FERC Draft License Application Comments.
Attachment B. Figure B-1

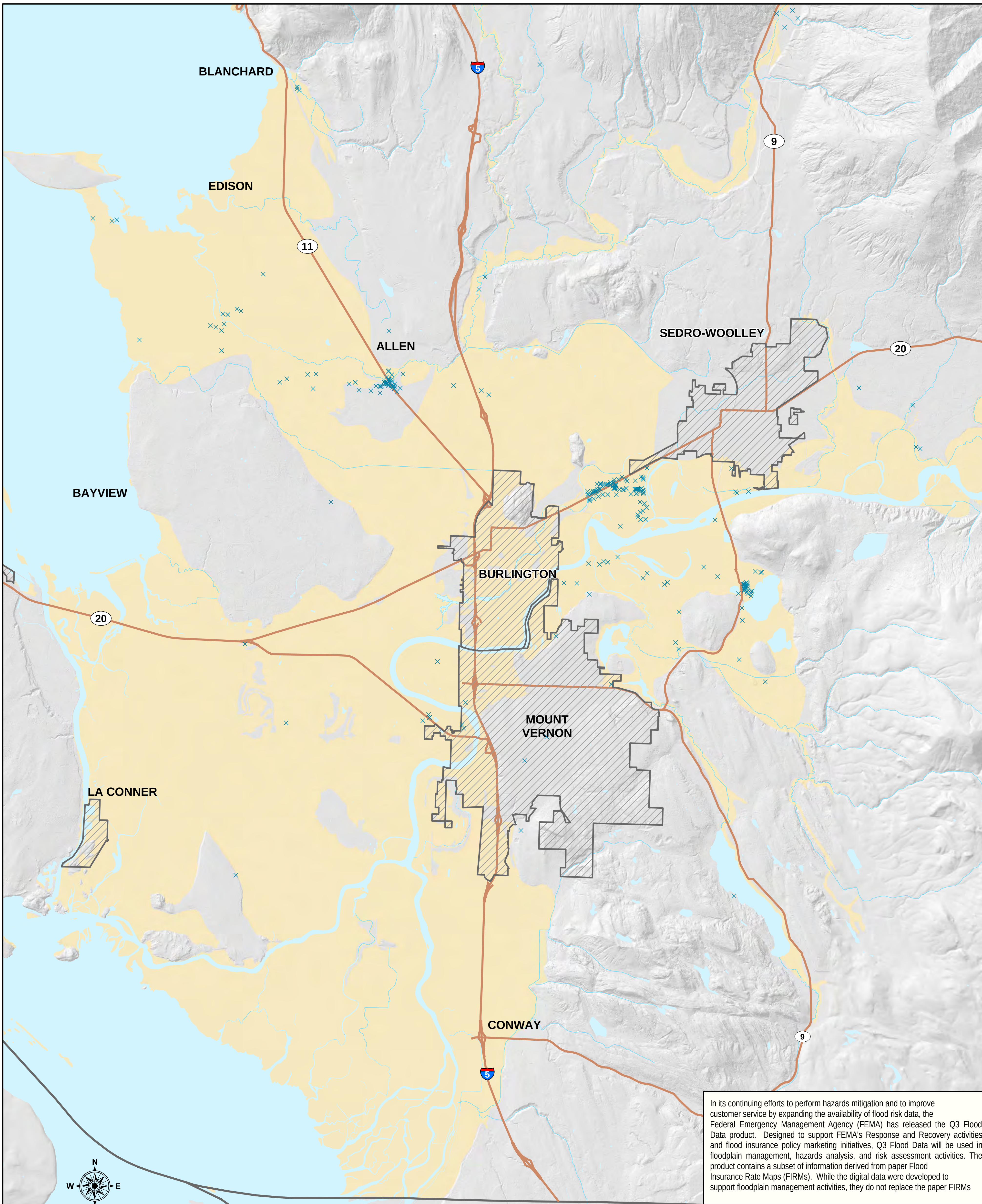
FEMA 100 Year Floodplain

Map Print Date: January 2023

Skagit County GIS

Skagit County

FEMA 100 YEAR FLOODPLAIN



In its continuing efforts to perform hazards mitigation and to improve customer service by expanding the availability of flood risk data, the Federal Emergency Management Agency (FEMA) has released the Q3 Flood Data product. Designed to support FEMA's Response and Recovery activities and flood insurance policy marketing initiatives, Q3 Flood Data will be used in floodplain management, hazards analysis, and risk assessment activities. The product contains a subset of information derived from paper Flood Insurance Rate Maps (FIRMs). While the digital data were developed to support floodplain management activities, they do not replace the paper FIRMs

Seattle City Light FERC Draft License Application Comments.
Attachment B. Figure B-2

0 0.5 1 2 3 4
Miles

× Reported Flood Damage Nov. 2021

FEMA 100 Year Floodplain

Map Print Date: January 2023

Skagit County GIS

Attachment 3: Anchor QEA Technical Memorandum

February 2023
Skagit River Project Federal Power Act Relicensing Support

Skagit River Project Operations Model Review

Prepared for Skagit County Dike and Drainage Flood Control Partnership

February 2023
Skagit River Project Federal Power Act Relicensing Support

Skagit River Project Operations Model Review

Prepared for
Skagit County Dike and Drainage Flood Control Partnership
P.O. Box 2926
Mt. Vernon, Washington 98273

Prepared by
Anchor QEA, LLC
1201 3rd Ave, Suite 2600
Seattle, Washington 98101

1201 3rd Avenue, Suite 2600
Seattle, Washington 98101
206.287.9130

ANCHOR QEA

February 2, 2023

Jenna Friebel
Executive Director
Skagit Drainage and Irrigation District Consortium
2017 Continental Place Suite 4
Mount Vernon, WA 98273

Re: Skagit River Project Relicensing

Dear Jenna,

Enclosed is our review of hydrologic and operations modeling performed by Seattle City Light in support of the Federal Power Act relicensing process for the Skagit River Hydroelectric Project and our analysis of the Skagit County Dike and Drainage Flood Control Partnership and Skagit County's request that SCL incorporate the Proposed Flood Risk License Requirement in the Final License Application.

The analysis and findings contained in this report were prepared under the supervision of the undersigned Professional Engineer in the State of Washington.

We appreciate the opportunity to perform this work to support efforts to reduce flood risks in Skagit County. Please contact us with questions and how we further support you through the relicensing process.

Sincerely,

Robert A. Montgomery

Robert A. Montgomery, P.E.
Principal Engineer

TABLE OF CONTENTS

TABLES

FIGURES

ABBREVIATIONS

% Bias	percent bias
AR	Atmospheric river
cfs	cubic feet per second
CHEOPS	Computer Hydroelectric Operations and Planning Software
CMIP5	Coupled Model Intercomparison Project Phase 5
County	Skagit County
DHSVM	Distributed Hydrologic Soil Vegetation Model
Flood Proposal	Partnership and Skagit County's Proposed Flood Risk License Requirement
FSA	Fisheries Settlement Agreement
ft	feet
GCM	global climate model
IRP	Integrated Resources Plan
IVT	integrated vapor transport
IWV	integrated water vapor
MWh	megawatt hours
NAVD88	North American Vertical Datum of 1988
NWRFC	Northwest River Forecast Center
OFCN	Official Flood Control Notification
Partnership	Skagit County Dike and Drainage Districts Flood Control Partnership
R^2	coefficient of determination
RCM	regional climate model
RCP	representative concentration pathway
RMSE	root mean squared error
RSR	RMSE-observations standard deviation ratio
SCL	Seattle City Light
Skagit River Project	Skagit River Hydroelectric Project
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WCM	Water Control Manual
WRF	Weather Research & Forecasting Model

1 Purpose of Report

Anchor QEA, LLC, was retained by the Skagit County Dike and Drainage Flood Control Partnership (Partnership) to review hydrologic and operations modeling performed by Seattle City Light (SCL) in support of the Federal Power Act relicensing process for the Skagit River Hydroelectric Project (Skagit River Project). We were also asked to review the effect of the Partnership and Skagit County's (County) request that SCL incorporate the Proposed Flood Risk License Requirement (Flood Proposal) in the Final License Application. The flood risk reduction request is to increase the flood storage capacity in November by providing 200,000 acre-feet of flood storage on November 1st of each year. That is in comparison to the current license requirement to provide 120,000 acre-feet of flood storage capacity on December 1st of each year.

Anchor QEA's scope included:

- Reviewing the operations model used by SCL and the model input
- Using the operations model to analyze the effect of the Partnership and the County's request to increase flood storage capacity on November 1st
- Reviewing SCL climate change modeling results and providing an opinion on the potential increase in peak flows expected in the future.

2 Operations Models

Skagit River Project operations were modeled in the Computer Hydroelectric Operations and Planning Software (CHEOPS) developed by HDR Engineering, Inc. CHEOPS is designed for long-term analysis of the effects of operational and physical changes made to the modeled hydro system (HDR 2022). The CHEOPS model developed by SCL for the Skagit River Project has a model domain between the inflow to the Ross Lake to the outflow from Gorge Dam. Below Gorge Dam, inflows were estimated to the U.S. Geological Survey (USGS) gage Skagit River at Marblemount (Marblemount gage, USGS 12181000; USGS 2023).

2.1 Model Hydrology Inputs

Hydrology inputs to the CHEOPS model were determined using a combination of proration and summation methods to translate USGS gage flow data to inflows to the Skagit River Project reservoirs and incremental flow differences between the Skagit River Project and the USGS gages. Proration is a method that scales historical flow records to another location based on the relative size of the contributing watersheds (Equation 1). Summation is a hydrologic water budget equation used to determine the inflow to a reservoir from the prorated outflow, change in storage, and losses, where losses are the average monthly historical evaporative losses (Equation 2). The CHEOPS model hydrology inputs were daily average flows and incremental flow differences that were developed for a period of record between January 1, 1988, and December 31, 2021. The model hydrology inputs for 2021 were added to the period of record in October 2022 after considerable model development had occurred.

Equation 1

$$Q_{target} = \left(\frac{A_{target}}{A_{reference}}\right) * Q_{reference}$$

where:

Q_{target}	=	the flow at the target location
A_{target}	=	the watershed area of the target location
$Q_{reference}$	=	the flow at the reference location
$A_{reference}$	=	the watershed area of the reference location

Equation 2

$$Q_i = Q_O - \Delta S - losses$$

where:

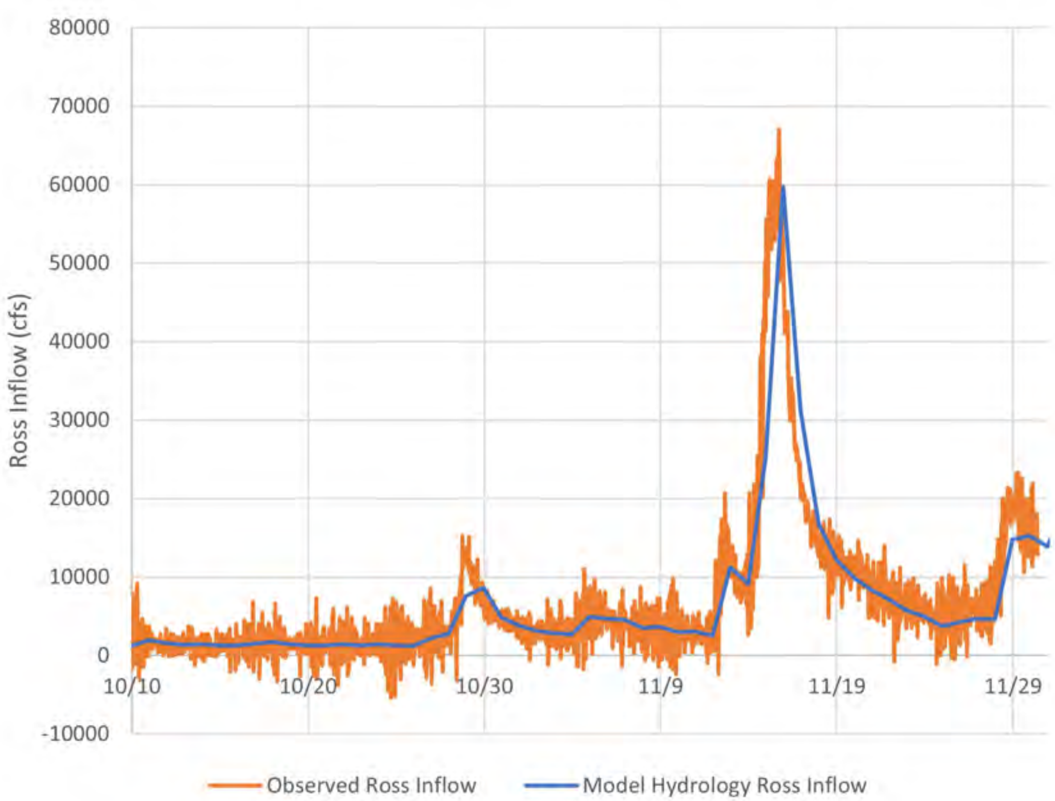
Q_i	=	the reservoir inflow
Q_O	=	the reservoir outflow
ΔS	=	the change in storage in the reservoir over the timestep
$losses$	=	the evaporative losses

Hydrology inputs include the inflows to Ross Lake, Diablo reservoir, and Gorge reservoir as well as the incremental flows between the Gorge Dam outflow and the USGS Skagit River at Newhalem gage (Newhalem gage, USGS 12178000) and the Marblemount gage (USGS 2023). The incremental flow between Gorge Dam and the two USGS gages was determined using the proration method (Equation 1). Incremental flows between the Gorge Dam outflow and the Diablo Dam outflow were determined using a monthly, linear-based proration between the Newhalem gage and the discontinued USGS Stetattle Creek near Newhalem gage (Stetattle gage) for the period of September 1, 1943, to November 23, 1983, to convert the Newhalem gage flows for the Skagit River Project model period of record to the Stetattle gage location. Flows at the Stetattle gage location were then prorated using Equation 1 to determine flows at the Diablo Dam outflow. Flows from the USGS Thunder Creek near Newhalem gage (Thunder Creek Gage, USGS 12175500) were prorated to determine the incremental flow between the Diablo Dam outflow and the Ross Dam outflow. Inflows to Ross Lake were determined using the summation method (Equation 2) using flows from the Newhalem gage and computed incremental flows between the Newhalem gage; Gorge, Diablo, and Ross dams; estimated Ross Lake evaporation; and change in storage for the three reservoirs (based on the Newhalem gage flow record.)

2.1.1 *Modeled Ross Lake Inflows Compared to Observed Ross Lake Inflows for the 2021 Flood*

Hourly Ross Lake inflow data for the November 2021 flood was provided to Anchor QEA by the Partnership. The Partnership obtained the data from SCL. It appears the hourly data was derived using the summation method with Ross Lake elevation data and discharge data from Ross Lake. The daily average Ross Lake inflows developed for the model input hydrology are compared to the hourly Ross Lake inflows during the November 15, 2021, flood in Figure 1. The peak hourly Ross Lake inflow for this flood event was estimated to be 67,014 cubic feet per second (cfs) on November 15, 2021, at 7:00 p.m. (PST) while the model input daily average flow on November 15, 2021, was 59,777 cfs, which is less than the hourly peak inflow by just over 7,000 cfs. Because the peak flow during the flood event happens on a sub-daily scale, an average over the 24-hour period underestimates the hourly peak flow. This most likely occurs for all daily average inflows compared to the peak hourly inflow during a flood event, which leads to underestimation of peak inflows to Ross Lake during flood events in the hydrology input files used for both historical and climate change simulations.

Figure 1
Observed Ross Lake Inflow and Model Hydrology Ross Lake Inflow for the November 2021 Flood



2.1.2 Climate Change Hydrology

Two regional change models (RCMs), Can-ESM2 and CCSM4, for the high relative concentration pathway (RCP) 8.5 developed by the University of Washington Climate Impacts Group were used to develop inputs for a Distributed Hydrology Soil Vegetation Model (DHSVM). DHSVM is a spatially distributed, physics-based hydrology model that can represent effects of local climate, topography, soil, and vegetation on snow accumulation and melt as well as overland and subsurface hydrologic processes (PNNL 2023). DHSVM was used to develop streamflows for the Skagit River Basin for a simulated historical period from January 1, 1988, to December 31, 2010, and a simulated future period from January 1, 2011, to December 31, 2099. The maximum daily average peak inflow to Ross Lake during the future period was predicted to be 69,894 cfs on July 10, 2021, and 47,542 cfs on January 6, 2088, for the Can-ESM2 and CCSM4 models, respectively. Further discussion of the methods used to develop climate change hydrology within the context of climate change literature for the Skagit River Basin are presented in Section 3.

2.2 Model Scenarios

Three CHEOPS model scenarios were evaluated. The SCL developed model is named "Baseline R3." Two additional model scenarios were developed by Anchor QEA, "Revised Baseline" and "Flood Proposal." A description of the model scenarios is contained in the following sections.

2.2.1 SCL Baseline R3

The iteration of the Baseline model for the Skagit River Project developed by SCL that was provided to Anchor QEA in September 2022 was titled "Baseline R3." SCL described updates made in the Baseline R3 model during the Operations Modeling Workshop meeting on October 4, 2022. In the Baseline R3 model the spill elevation was set to the flood control rule curve and the target elevation was set to be 10 feet below the flood control rule curve. To date, no definitive explanation for the basis of setting the target elevation to 10 feet below the flood control rule curve has been provided by SCL. It is assumed that the target elevation relative to the flood control rule curve was set based on calibration to observed flow data rather than a physical representation of Ross Lake, dam, or operations. The spill elevations and target elevations for the Baseline R3 scenario are shown in Table 1. The Baseline R3 scenario also incorporates the requirements of the Revised Fisheries Settlement Agreement (FSA), which is described in Section 2.4.

2.2.2 Revised Baseline Scenario

The Revised Baseline scenario was prepared by Anchor QEA by modifying the spill elevation and target elevation parameters of the Baseline R3 scenario to follow the elevations in the current license agreement described in the 2002 Skagit River Project Water Control Manual (WCM; USACE 2002). This scenario was developed for the purpose of representing the current operations, as written in the governing current license agreement rather than attempting to calibrate the operations to the observed data. The target elevation for Ross Lake was set to the flood control rule curve, and the spill elevation was set to a constant elevation at the normal maximum water surface elevation in Ross Lake of 1607.86 in the North American Vertical Datum of 1988 (NAVD88). The flood control rule curve in the current license agreement was set to reach the flood storage capacity of 120,000 cfs by December 1st. Representing the current operations as designated by the current license agreement provides insight into how real-time operations represented by the historical observations compare, assuming that model performance is reasonable. The spill elevation and target elevations are shown in Table 1. The Revised Baseline scenario does not modify the Revised FSA incorporated in the Baseline R3 scenario.

2.2.3 Flood Proposal Scenario

The Flood Proposal scenario was prepared by Anchor QEA by modifying the Revised Baseline scenario target elevation to represent the Partnership and the County's Flood Proposal presented in the March 24, 2022, letter to Kimberly Bose, Secretary of the Federal Energy Regulatory Commission (Partnership 2022). The modification to the flood control rule curve (represented by the target elevation) increases the flood storage capacity to 200,000 acre-feet by November 1st. The spill elevation was not modified from the Revised Baseline scenario. The spill elevation and target elevations are shown in Table 1. The Flood Proposal scenario does not modify the Revised FSA incorporated in the Baseline R3 scenario.

Table 1
Model Scenario Spill and Target Elevations.

	Baseline R3[1]		Revised Baseline[2]		Flood Proposal	
Date	Target Elevation (ft)	Spill Elevation (ft)	Target Elevation (ft)	Spill Elevation (ft)	Target Elevation (ft)	Spill Elevation (ft)
1-Jan	1581.67	1608.76	1595.89	1608.76	1589.04	1608.76
1-Feb	1568.18	--	1568.18	1608.76	1568.18	1608.76
1-Mar	1547.02	--	1547.02	1608.76	1547.02	1608.76
1-Apr	1534.83	--	1534.83	1608.76	1534.83	1608.76
1-May	1539.49	--	1539.49	1608.76	1539.49	1608.76
1-Jun	1580.65	--	1580.65	1608.76	1580.65	1608.76
1-Jul	1605.13	--	1605.13	1608.76	1605.13	1608.76
31-Jul	1607.76	--	1607.76	1608.76	1607.76	1608.76
8-Sep	1607.76	--	1607.76	1608.76	1607.76	1608.76
1-Oct	1598.76	1608.76	1606.24	1608.76	1606.24	1608.76
15-Oct	--	1607.06	1604.54	1608.76	1595.89	1608.76
1-Nov	1595.1	1605.10	1602.58	1608.76	1589.04	1608.76

Date	Baseline R3[1]		Revised Baseline[2]		Flood Proposal	
	Target Elevation (ft)	Spill Elevation (ft)	Target Elevation (ft)	Spill Elevation (ft)	Target Elevation (ft)	Spill Elevation (ft)
15-Nov	--	1603.63	1601.11	1608.76	1589.04	1608.76
1-Dec	1588.37	1598.37	1595.89	1608.76	1589.04	1608.76
31-Dec	1581.67	1598.37	1595.89	1608.76	1589.04	1608.76

Notes: All elevations are in feet, NAVD88

1. The Baseline R3 (SCL) scenario does not correspond to the current license agreement as it incorporates a 10-foot buffer for modeling purposes
2. The Revised Baseline scenario target elevations correspond to the flood control rule curve of the current license agreement

The changes made to the spill elevation and target elevations to develop the Revised Baseline scenario and Flood Proposal scenario were applied only to the Ross parameters; Diablo and Gorge parameters were not changed from the SCL Baseline R3 scenario. The spill elevation is described in the CHEOPS User's Guide as, "the reservoir elevation at which the plant begins to spill to avoid going above. The elevation can relate to a variety of physical situations…" (HDR 2022). The target elevation is described as, "the end of the day elevations which the model tries to return the reservoir to at the end of the day" (HDR 2022). All scenarios were run with the hydrology input file developed by SCL and described in Section 2.1. Climate change hydrology was used in runs of the Revised Baseline and Flood Proposal scenarios.

2.3 Model Results

2.3.1 Baseline Scenarios Performance During Floods

A review of the CHEOPS model performance during floods was completed by comparing model output to observed water surface elevations in Ross Lake and outflows from the Skagit River Project. The Newhalem gage is the nearest downstream USGS gage on the Skagit River located approximately 3 miles downstream of the Skagit River Project. Data from the Newhalem gage (USGS 2023) was used in the comparison. Normal operations of the Skagit River Project are the responsibility of SCL; the U.S. Army Corps of Engineers (USACE) Seattle District is responsible for flood control regulation. Flood control regulation is initiated when the National Weather Service Northwest River Forecast Center (NWRFC) forecasts that unregulated discharge at Concrete, Washington, will reach 90,000 cfs within 8 hours and issues an Official Flood Control Notice (OFCN), and it ends when NWRFC notifies SCL to cancel the OFCN when the flood control operation is ended. When an OFCN is issued, the WCM directs that the minimum discharge from Ross Lake (5,000 cfs) should be reached as soon as possible as the function of Ross Lake flood storage is to offset inputs to the Skagit River from unregulated watersheds.

The floods used in the comparison are listed in Table 2 along with the peak flow recorded at the Newhalem gage. Outputs from the CHEOPS model scenarios used for model performance evaluation during floods include 1) the gross outflow from Gorge, converted to flow at Newhalem by subtracting the daily evaporation losses and applying the incremental flow difference between Gorge and Newhalem determined by SCL as described in Section 2.1 and 2) the daily end elevation in Ross Lake. The CHEOPS model does not have an output for daily average elevation in Ross Lake; however, because the CHEOPS model inputs are daily average inflows and the model's hourly timestep is a uniform distribution of the daily average input, it is likely a reasonable comparison to daily average elevations measured at the USGS gage at Ross Reservoir (USGS 12175000). The modeled daily end elevation and observed daily average elevations are not the same measurement; therefore, they are not compared in Section 3.8 Model Performance Statistics.

Table 2
Flood Events on the Skagit River Reviewed in Model

Major Flood Events	Peak Daily Flow, Skagit River at Newhalem (cfs)
11/13/1990	26,700
11/28/1990	21,300
10/22/2003	32,700
11/08/2006	25,100
11/17/2021	28,500

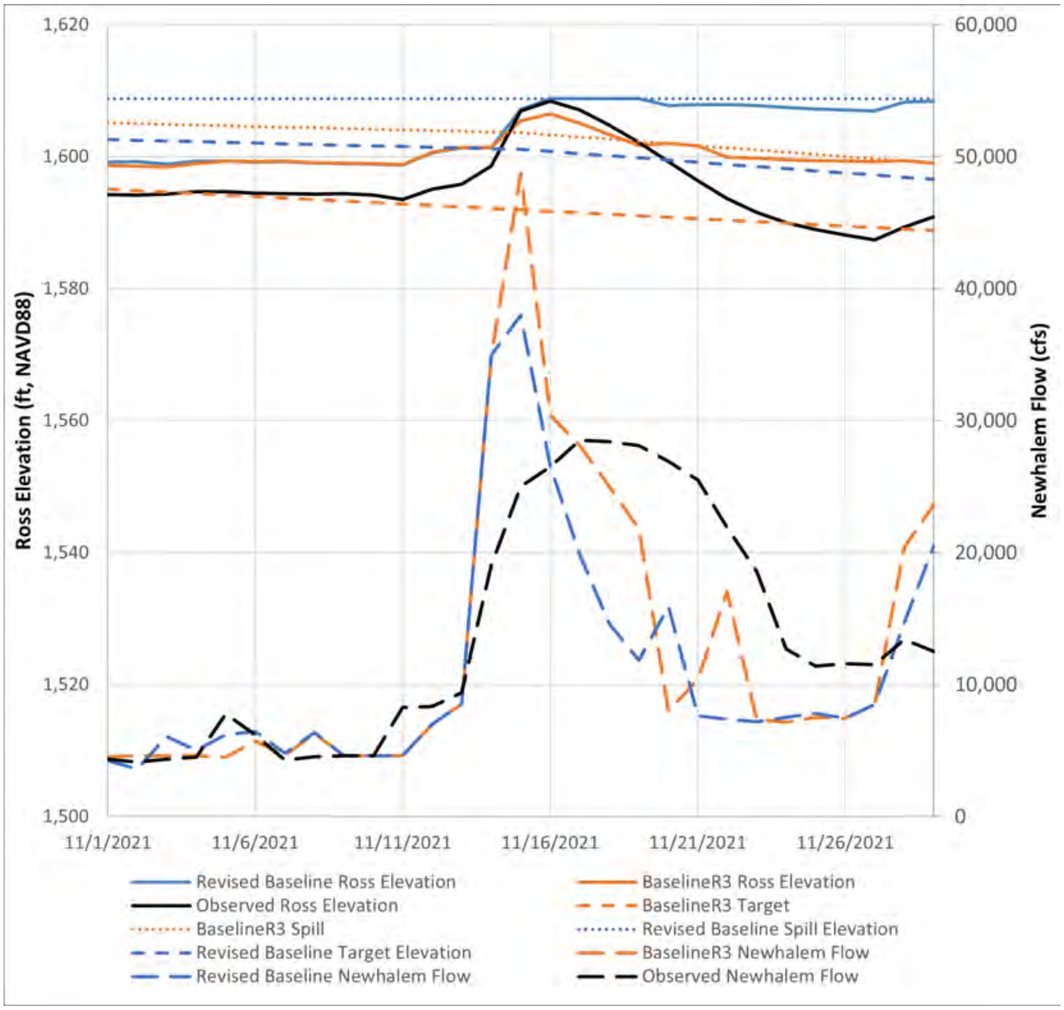
2.3.1.1 2021 Flood

A comparison of modeled to observed flows for the November 2021 event is shown in Figure 2. The modeled results show an overprediction of flood discharges by the Baseline R3 scenario of about 20,000 cfs or about 70% higher than observed. The flood peaks are also predicted to be 2 days earlier than observed. The Revised Baseline scenario performed slightly better, with peak flows estimated to be 10,000 cfs or 29% higher than observed. The 2021 flood has the highest estimated peak hourly inflow in the historic record to Ross Lake, 67,014 cfs, which corresponds to the daily average flow model input of 59,777 cfs (see Section 2.1). For the peak end of day elevation in Ross Lake, the Baseline R3 scenario underpredicted the observed daily average elevation by about 3 feet, while the Revised Baseline scenario underpredicted the observed daily average elevation by 1.3 feet. This indicates that the Revised Baseline scenario performed better at estimating the initial reservoir storage response to the peak daily inflow. The CHEOPS model attempted to have the daily end elevation meet the target elevation but did not force spill due to the target elevation during a flood event. Because the flood control rule curve is set to the target elevation in the Revised Baseline scenario the Ross Lake elevation remained elevated for a longer period following the peak inflow compared to both the Baseline R3 scenario and observed daily average Ross Lake levels.

The observed daily average Ross Lake elevation before the November 2021 event occurred was constant from the beginning of November, 1,594.2 feet to 1594.7 feet, which is nearly 8 feet below the flood control elevation shown in the current license agreement for November 1st. The additional storage available during the event reduced peak outflows from Ross Lake and reduced downstream flows and flooding more than predicted by the Baseline R3 and Revised Baseline models.

This benefit is seen by comparing the return frequency of the observed peak hourly Ross Lake inflow to the return frequency of the flow measured at the USGS Skagit River near Concrete, Washington, gage (Concrete gage, USGS 12194000) and USGS Skagit River near Mount Vernon, Washington gage (Mount Vernon gage, USGS 12200500). The flow measured at the Concrete gage was 132,000 cfs and the flow measured at the Mount Vernon gage was 125,000 cfs (USGS 2023). Those flows have a return frequency between 10 and 25 years based on a USACE flow frequency study (USACE 2013). The peak hourly inflow to Ross Lake was the highest event of record, estimated at 67,014 cfs. The quantity of storage at Ross Lake contributed to the ability of the Skagit River Project to attenuate the peak inflows and prevent peak flows at Concrete and Mount Vernon from exceeding the estimated Skagit Valley primary levee capacity of 150,000 cfs, which could cause excessive damage to the region.

Figure 2
Observed and Modeled Skagit River at Newhalem Flows and Ross Lake Elevations November 2021 Flood

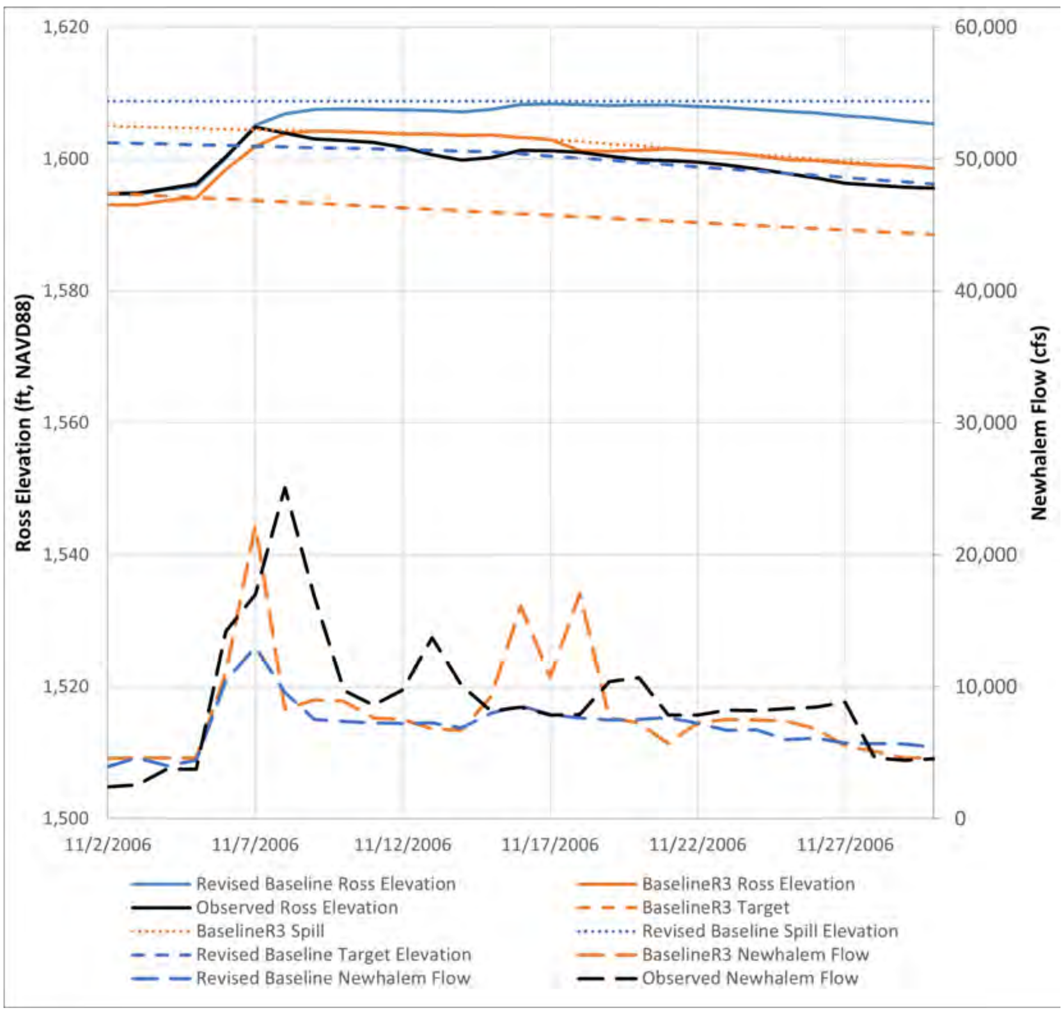


Notes:
Revised Baseline and Baseline R3 Ross Elevations are daily end elevations
Observed Ross Elevation is a daily average elevation

2.3.1.2 2006 Flood

A comparison of modeled to observed flows for the November 2006 event is shown in Figure 3. The Baseline R3 scenario underpredicted daily average peak flows by about 3,000 cfs or about 9% lower than observed. The Revised Baseline scenario underpredicted daily average peak flows by about 12,000 cfs or 50% lower than observed. Both modeled daily average flood peaks occurred 1 day earlier than observed. During the rising limb of the flood event, the Revised Baseline scenario matched the observed reservoir elevations closely, while the Baseline R3 scenario underpredicted the observed Ross Lake elevations by about 3 feet. However, after the observed peak daily average elevation occurred on November 7, 2006, the elevations modeled in the Baseline R3 and Revised Baseline scenarios did not follow the evacuation of the reservoir that was observed. The Baseline R3 scenario end of day elevations continued to rise to a peak elevation of about 1,604 feet, which held for 4 days, and the Revised Baseline scenario end of day elevations continued to rise to a peak elevation of about 1,608 feet that occurred 9 days later on November 16, 2006. As in 2021, this indicates that the Revised Baseline scenario performed well when predicting the observed data during the rising limb of the flood event but performed poorly when modeling evacuation of the reservoir following a peak flow event.

Figure 3
Observed and Modeled Skagit River at Newhalem Flows and Ross Lake Elevations November 2006 Flood

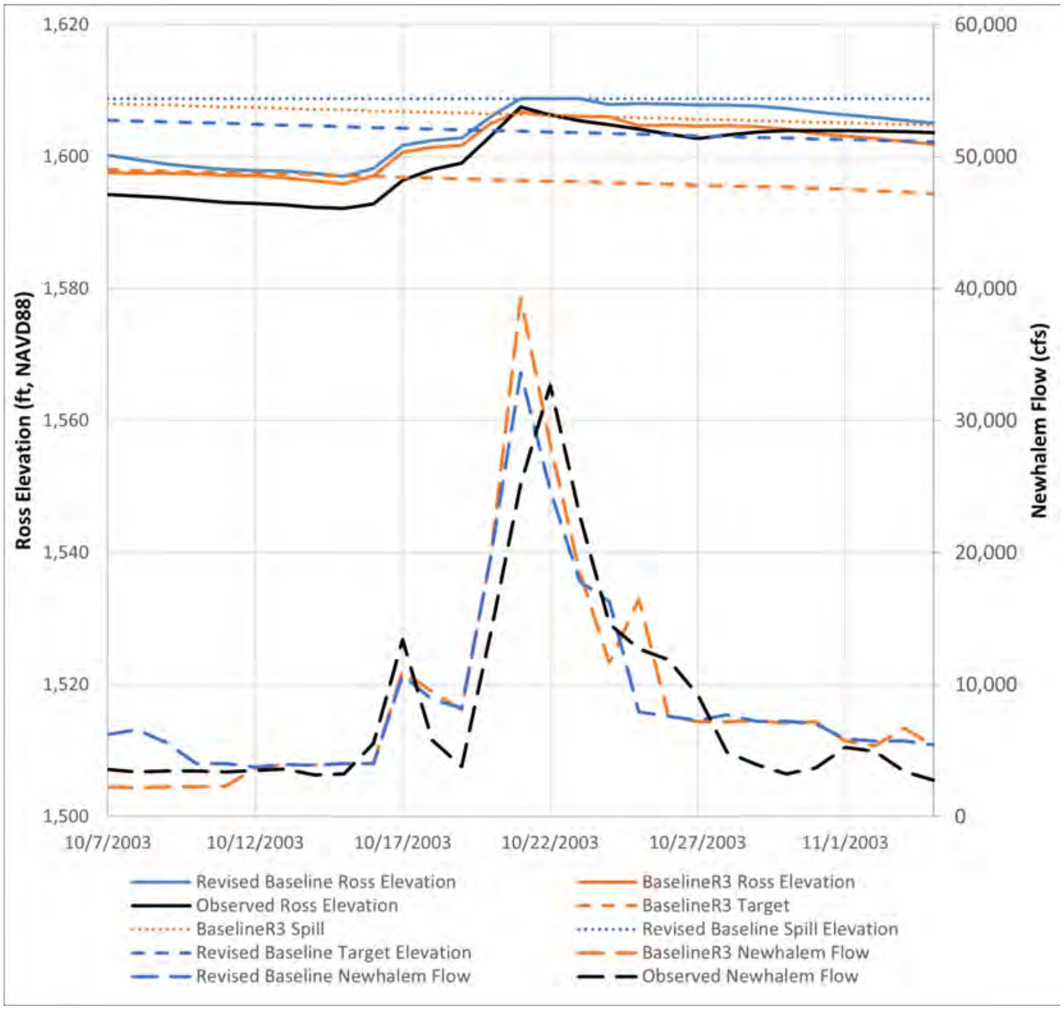


Notes:
Revised Baseline and Baseline R3 Ross Elevations are daily end elevations
Observed Ross Elevations are daily average elevations

2.3.1.3 2003 Flood

A comparison of modeled to observed flows for the October 2003 event is shown in Figure 4. The Baseline R3 scenario results showed an overprediction of daily average peak flows of about 6,500 cfs or about 20% higher than observed. The Revised Baseline scenario performed slightly better, overpredicting peak daily average flows by less than 1,000 cfs or less than 3%. However, the peak daily flows in both scenarios were predicted to be a day earlier than observed. During the 2003 flood, the Revised Baseline daily end elevations were higher than the observed daily average Ross Lake elevations before and during the duration of the flood event, while the Baseline R3 daily end elevations were a reasonable representation of the observed daily average Ross Lake elevations during the reservoir evacuation following the flood peak. The October 2003 event is an example of a flood event where a smaller storm occurred only a few days prior (on November 17, 2003) to the second larger flood event on November 21, 2003. The daily average peak flow for the first event reached 13,400 cfs at the Newhalem gage. The first event caused the available Ross Lake storage to be partially filled, and Ross Lake was not able to be evacuated before the larger event occurred 4 days later. Because of this, higher peak flows occurred at Newhalem during the second larger event. The models overestimate the peak flows from the second event because they also underestimate the storage available in Ross Lake at the beginning of both the first and second event.

Figure 4
Observed and Modeled Skagit River at Newhalem Flows and Ross Lake Elevations October 2003 Flood



Notes:
Revised Baseline and Baseline R3 Ross Elevations are daily end elevations
Observed Ross Elevations are daily average elevations

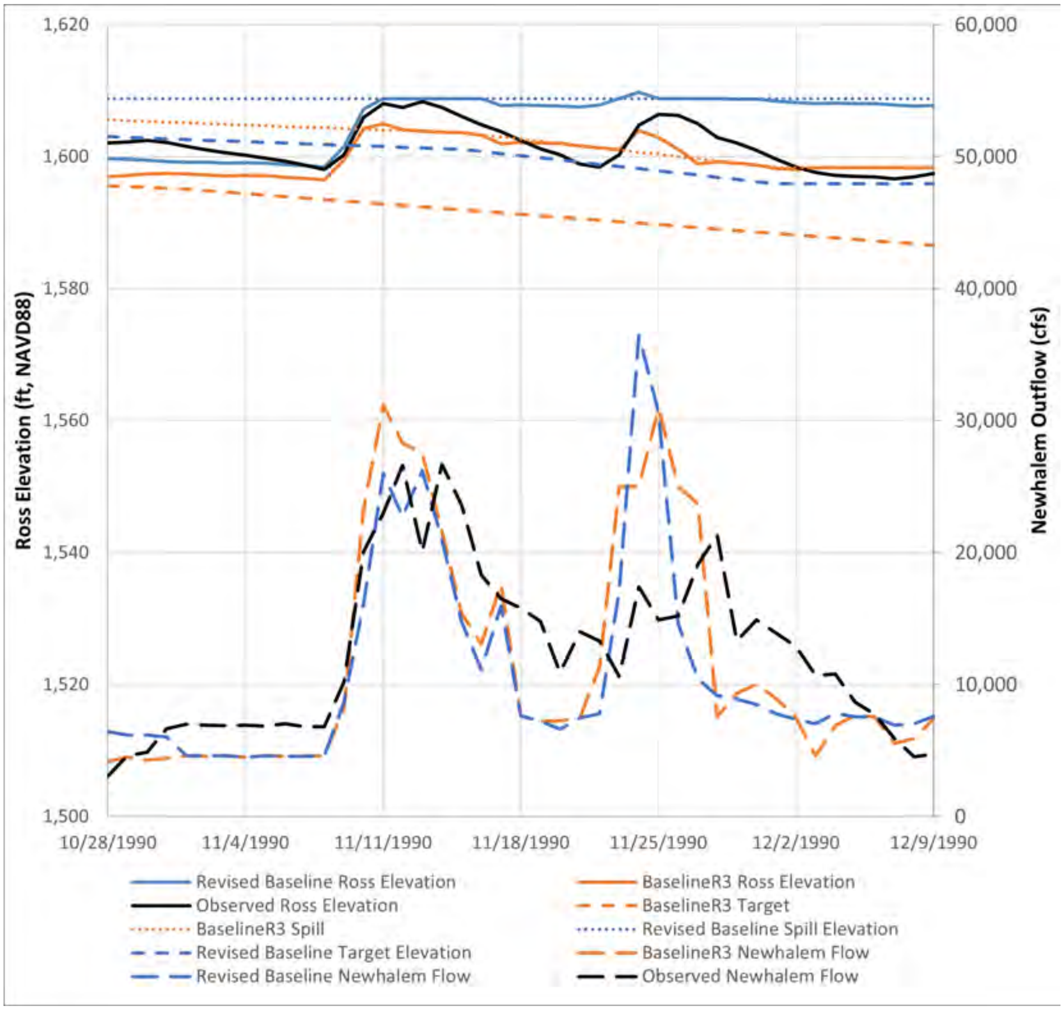
2.3.1.4 1990 Floods

Two peak flow events occurred in November 1990 on November 11, 1990, and November 25, 1990. Both events had observed peak daily average flows over 20,000 cfs. A comparison of modeled to observed flows for the November 1990 events is shown in Figure 5. For the earlier event, the Baseline R3 scenario results showed an overprediction of flood discharges of about 5,000 cfs or about 20% higher than observed. The flood peaks were also predicted to be a day earlier than observed. The Revised Baseline scenario performed slightly better, with peak flows matching closely (within 2%), but the peak daily flow was predicted to be one day later than observed. Both the Baseline R3 and

Revised Baseline scenarios did not perform well when predicting the rate of evacuation observed from Ross Lake because both maintained relatively level end of day Ross Lake elevations following the peak flow while the observed daily average elevation decreased sharply following the peak flow.

Because the end of day Ross Lake elevations were higher in the Baseline R3 and Revised Baseline scenarios compared to the observed daily average Ross Lake elevation, both scenarios largely overpredicted the peak flows at Newhalem for the second event that occurred 14 days later, on November 25, 1990. The Baseline R3 scenario overpredicted the observed daily average flow by about 10,000 cfs or 45% higher than observed, and the observed peak occurred 3 days earlier than predicted. The Revised Baseline scenario overpredicted the observed daily average flow by about 15,000 cfs or 70% higher than observed, and the observed peak occurred 4 days earlier than predicted. During the November 25, 1990, event the Baseline R3 scenario end of day elevation underpredicted the observed daily average elevation. The Revised Baseline scenario did not perform well at predicting the reservoir evacuation, and the end of day elevations remained at or just below the spill elevation for the duration of the storm events.

Figure 5
Observed and Modeled Skagit River at Newhalem Flows and Ross Lake Elevations November 1990 Floods



Notes:
Revised Baseline and Baseline R3 Ross Elevations are daily end elevations
Observed Ross Elevations are daily average elevations

2.3.2 Peak Flow and Evacuation

Table 3 shows modeled peak flows for the Baseline R3 and Revised Baseline scenarios. Based on the difference between modeled and observed peak flows, the Baseline R3 scenario tends to overpredict observed peak daily flows more than the Revised Baseline. Because the Baseline R3 scenario uses the spill elevation parameter to represent the flood control rule curve, the CHEOPS models larger amounts of outflow from the system, compared to the Revised Baseline scenario where the reservoir is allowed to fill to the spill elevation set to the normal maximum water surface elevation during a storm event. The flood control rule curve is intended to manage reservoir levels so that flood storage is available when a large storm event occurs, typically in the fall. However, the flood control rule curve is not a spillway or forcing elevation as is modeled in the Baseline R3 scenario.

Neither Baseline scenario performs well at simulating the evacuation of Ross Lake after a flood event compared to observed operations. The WCM describes reservoir evacuation procedures. Once the flood crest reaches the Concrete gage, Ross Dam begins releasing flows equal to the inflows. When flows at the Concrete gage decrease to 90,000 cfs, Ross Dam begins flood pool evacuation, which is performed as quickly as possible without exceeding maximum flows or rate-of-rise criteria (USACE 2002). The Baseline R3 tends to model the Ross Lake elevations after a flood event more accurately because the spill elevation parameter set to the flood control rule curve forces evacuation more aggressively than the target elevation parameter but still tends to overestimate daily elevations in Ross Lake during evacuation. In the Revised Baseline scenario, the target elevations set to the flood control rule curve do not force evacuation to represent operations described in the WCM.

Table 3 shows examples of how the CHEOPS model with a daily average timestep is not an adequate tool to represent flood operations. The operations during a flood event happen on an hourly timescale. For example, the OFCN is issued only 8 hours before an unregulated peak flow of 90,000 cfs is predicted to reach the Concrete gage. The physical parameters of the target elevation or spill elevation, which are varied on a monthly or sub-monthly scale, are not capable of adjusting the model to represent hourly or sub-hourly operations during a flood.

Table 3
Comparison of Modeled Daily Average Peak Flows

Flood Event	Observed Daily Average Peak Flow (cfs)	Baseline R3 Daily Average Peak Flow (cfs)	Revised Baseline Daily Average Peak Flow (cfs)	Baseline R3 - Observed	Revised Baseline - Observed
11/13/1990	26,700	31,209	26,001	4,509	-699
11/28/1990	21,300	30,925	30,613	9,625	9,313
10/22/2003	32,700	39,293	33,119	6,593	419
11/8/2006	25,100	22,260	12,429	-2,840	-12,671
11/15/2021	28,500	48,725	36,886	20,225	8,386

2.3.3 Model Performance Statistics

Comparative statistics were calculated to assess model performance when predicting flows at Newhalem, compared to observed daily averages, for the Baseline R3 scenario and Revised Baseline scenario (Table 4). Performance statistics for Ross Lake elevations are not included as the CHEOPS model output for Ross Lake elevations were end of day elevations while the USGS observed data were daily average elevations; while related, these datasets are not comparable for performance statistics.

R^2 is the coefficient of determination. The ideal value of R^2 is 1.0, but model performance is considered acceptable for R^2 greater than 0.5. R^2 tends to be oversensitive to extreme values (outliers) and insensitive to additive or proportional differences between the observed and modeled data (Moriasi et al. 2007). Root mean squared error (RMSE) provides a measure of fit that is scaled based on the squared units of the data, which can be helpful in evaluating scaled performance. The ideal RMSE value is 0, and lower RMSE values indicate a better model performance. The RMSE-observations standard deviation ratio (RSR) standardizes the RMSE based on the standard deviation of the observed data, with acceptable model performance being an RSR of 0.5 or less, indicating that the RMSE of the modeled data is at most one-half of the observed standard deviation. Percent bias (% bias) determines the average tendency of modeled data to be larger or smaller than observed data; a negative % bias indicates model overestimation bias, and a positive % bias indicates model underestimation bias. An ideal % bias is 0.0%, but acceptable model performance is a % bias of less than 15%.

For the Skagit River at Newhalem flow, the Revised Baseline model has acceptable model performance indicated by R^2 for five out of six flood events, while the Baseline R3 model has acceptable model performance for only four flood events. Both scenarios had acceptable model performance for RSR for all flood events, likely due to the large magnitude of standard deviation in the modeled flows rather than acceptable error. The model performance indicated by % bias shows that the Baseline R3 and Revised Baseline models have overestimation or underestimation bias for the same flood events; however, Baseline R3 tends to have a smaller magnitude of % bias in either direction. Because the R^2 tends to be sensitive to extreme events and the % bias indicates average tendencies of a model to overpredict or underpredict flows, the model performance indicates that the Revised Baseline tends to predict flows from the Skagit River Project for the peak flow better while the Baseline R3 scenario is a better prediction of the overall flow.

Table 4
Model Performance Statistics

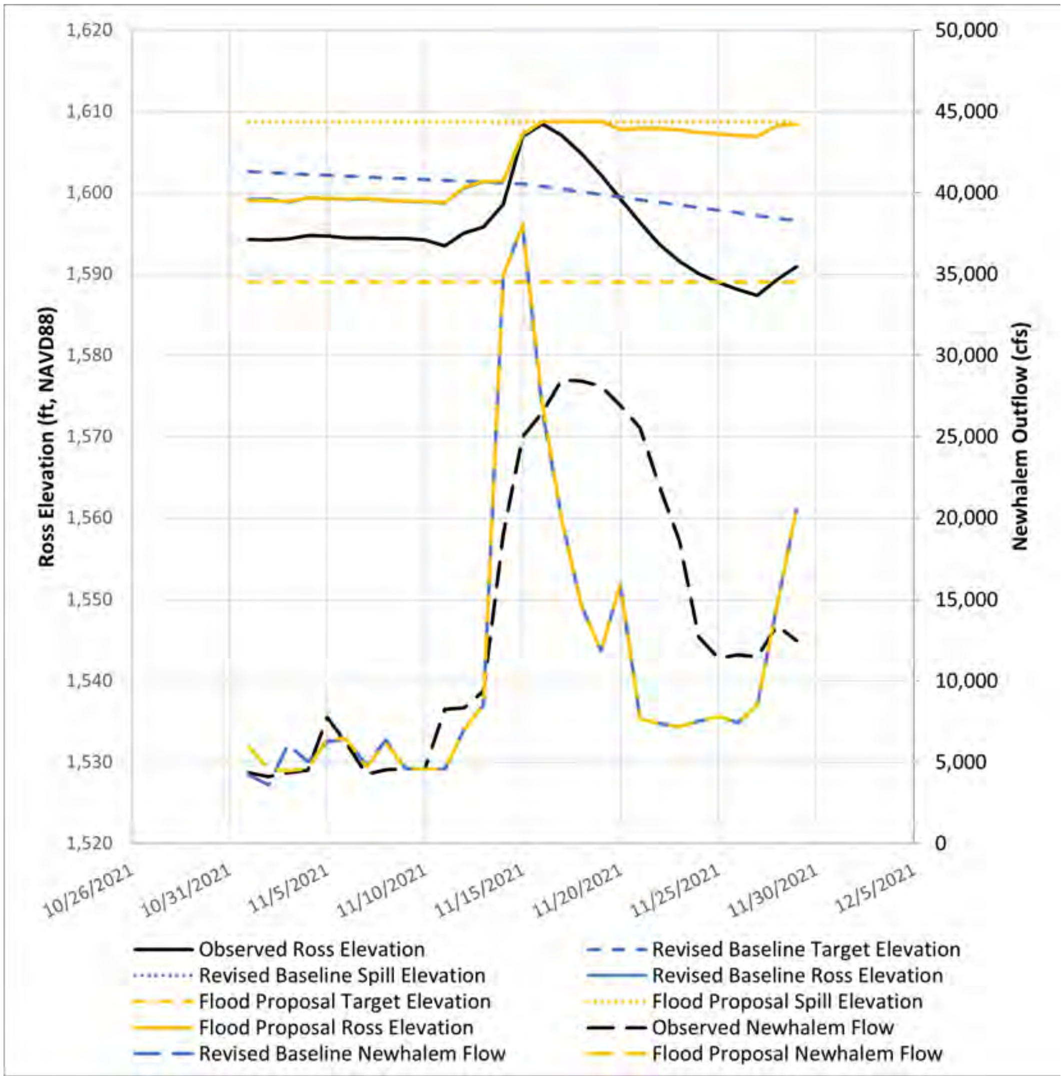
Scenario	Date	R^2	RMSE (cfs)	Standard Deviation (cfs)	RSR	% Bias
Baseline R3 Newhalem Flow	11/13/1990	0.7840	31,900	231,800	0.1376	2.4516
	11/28/1990	0.6099	37,600	263,700	0.1426	3.7162
	10/22/2003	0.8923	20,600	169,200	0.1220	-10.8090
	11/8/2006	0.4453	25,500	151,900	0.1676	9.6839
	11/15/2021	0.7033	43,500	241,700	0.1798	5.4933
Revised Baseline Newhalem Flow	11/13/1990	0.7554	30,000	185,600	0.1616	22.7568
	11/28/1990	0.5651	36,700	245,900	0.1492	10.3536
	10/22/2003	0.6890	30,800	169,800	0.1816	-11.1674
	11/8/2006	0.5713	24,400	128,400	0.1901	24.3999
	11/15/2021	0.7788	35,500	197,700	0.1795	23.7716

Note: Blue highlighted cells indicate statistics that represent acceptable model performance as described above.

2.3.4 Flood Proposal Scenario Results

The Flood Proposal scenario modified the Revised Baseline scenario target elevations to represent the Partnership and County's flood operations proposal to modify the flood control rule curve of the current license agreement described in the 2002 WCM. The results of the Flood Proposal scenario are shown in Figure 6. The change to the target elevation representing the flood control rule curve resulted in very little difference between the modeled Ross Lake end of day elevations or the daily average flow at Newhalem. However, this result is not indicative of whether the Flood Proposal is effective, but rather indicates that the CHEOPS model is not adequate for modeling alternative proposed scenarios. The spill elevation and target elevation, which are physical parameters, are not well suited to represent changes to operations during peak flood events, especially given that the CHEOPS model results have a daily timestep. The Revised FSA, described in Section 2.4, prescribes required maximum and minimum flows and is the main driver of Ross Lake operations in the fall rather than flood control operations.

Figure 6
Flood Proposal Scenario Results Compared to Revised Baseline and Observed for the 2021 Flood



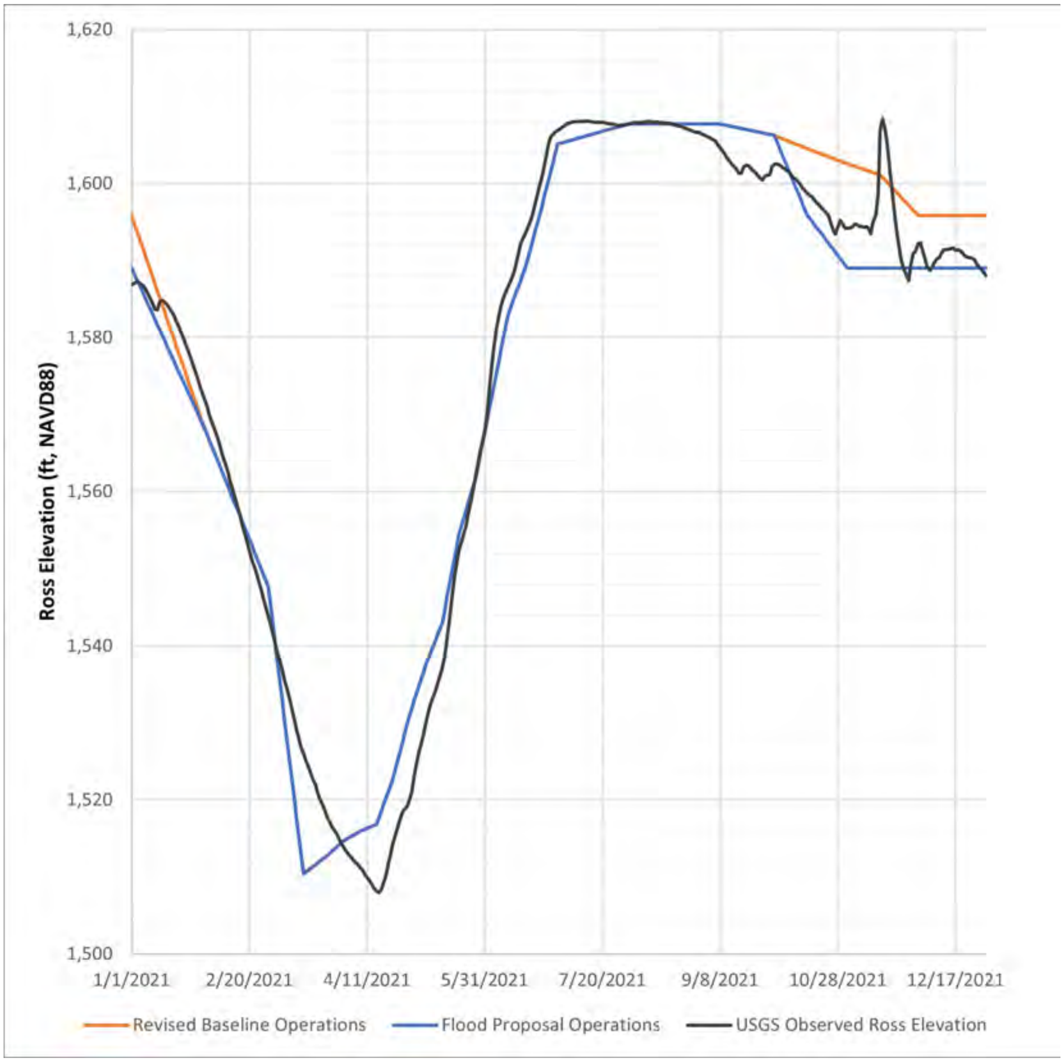
2.3.5 Discussion of Model Performance for Floods

The intended use of the CHEOPS model is stated to be "designed for long-term analysis" (HDR 2022). Peak flood events such as those examined above are not long-term events and occur on an hourly or sub-daily scale, which has a finer timestep than that modeled by CHEOPS. Additionally, as discussed in Section 2.1.1, the inflow data to the model is likely systematically biased as daily peak flows underestimate observed peak hourly flows. As such, the model results cannot be expected to perform accurately to predict the observed response or the response to the proposed flood control operations during a peak flood event.

Although the statistics presented in Table 4 overall indicate reasonable model performance for the Baseline R3 and Revised Baseline scenario, the model performance statistics were not acceptable for all floods during either scenario, and the magnitude of values for RMSE and standard deviations indicate large modeling errors for both scenarios. Large flood events that occur at a sub-daily scale are best represented by hourly or even sub-hourly timesteps. CHEOPS, modeled at a daily average timestep, is not well suited to examine the operations of the Skagit River Project during large flood events.

The best representation of the Partnership and County's Flood Proposal is the observed data of the 2021 flood event. Figure 7 shows the observed Ross Lake elevations for the 2021 calendar year. Revised Baseline target elevations represent the flood control rule curve of the current license operations as written in the 2002 WCM; Flood Proposal target elevations represent the proposed changes to the flood control rule curve. It can be seen that in the months leading up to the November 15, 2021, flood event, the observed operations of Ross Lake followed or were below the proposed flood control rule curve between August and November and following the November 15 flood event. Operations in 2021 adhered more closely to the proposed flood control rule curve than to the current license agreement flood control rule curve. As discussed in Section 2.3.1.1, the observed operations of the Skagit River Project in 2021 resulted in improved flood control operations, indicated by the reduced peak, compared to either Baseline scenario.

Figure 7
Observed Ross Lake Elevations for 2021 Compared to Flood Proposal and Revised Baseline Target Elevations



Note: The Revised Baseline Operations are representative of the current license agreement operations.

2.4 Flood Proposal Effect on Other Operations

2.4.1 Flow Releases

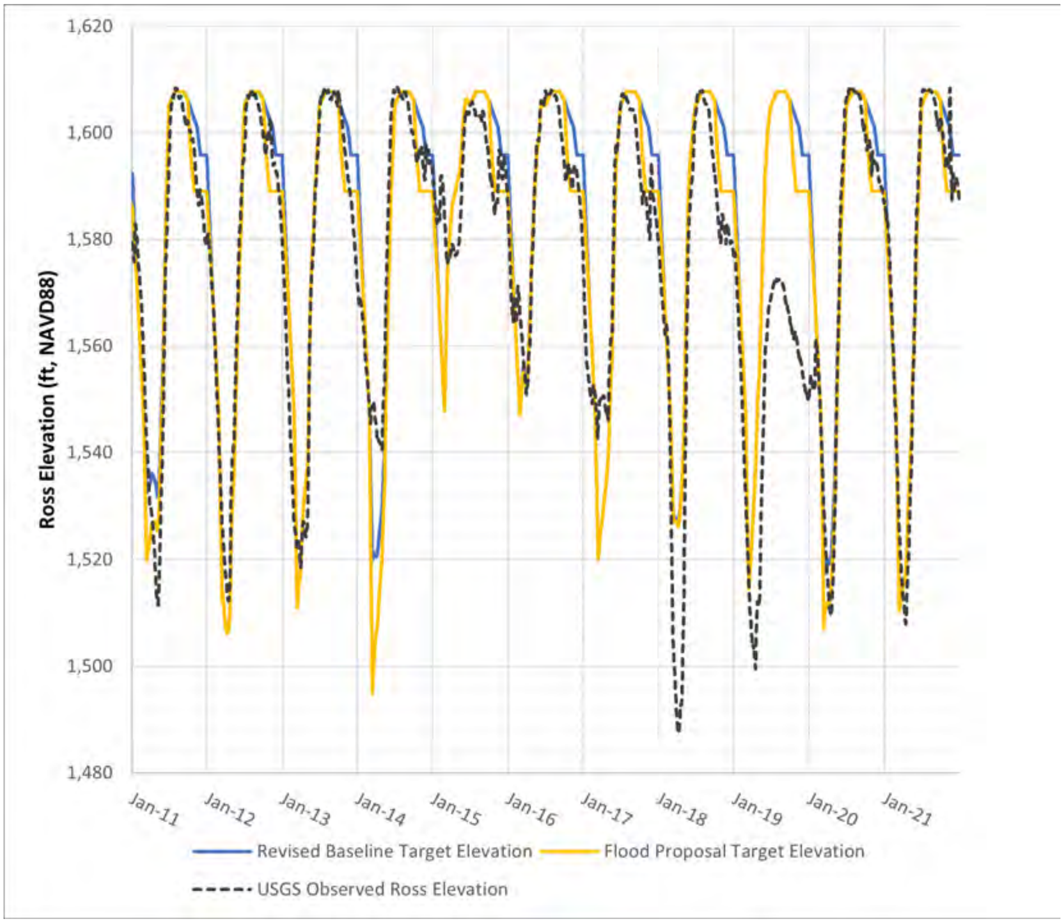
The Skagit River Project FSA was originally issued in April 1991 and revised in 2011 (FERC 2011). The FSA establishes SCL's obligations to Skagit River fishery resources including related spawning grounds and habitat affected by the Skagit River Project. The 2011 Revised FSA describes required Ross Lake operations related to lake levels.

- Fill Ross Lake as early and as full as possible after April 15 each year, subject to adequate runoff, anadromous fisheries protection flows, flood protection, minimized spill, and firm power generation needs.
- Hold Ross Lake as close to full as possible through Labor Day weekend, subject to adequate runoff, anadromous fisheries protection flows, flood protection, minimized spill, and firm power generation needs.
- In any overdraft year (i.e., in those years in which Ross Lake is drafted below the energy content curve), bring Ross Lake's level up to the Variable Energy Content Curve no later than March 31.

The Revised FSA also describes the Anadromous Fish Flow Plan, which describes the minimum and maximum flow requirements to protect and improve anadromous fish habitat and fish production in the Skagit River. Flows are regulated for spawning periods, incubation periods and for salmon fry protection, with each specifies of salmon in the Skagit River (chinook, pink, and chum salmon) having different flow requirements.

It is assumed that in 2021, as well as the other years of operation since 2011, the flows from the Skagit River Project were regulated according to the requirements of the Revised FSA. The average observed monthly Ross Lake elevation, Revised Baseline scenario operations, and Flood Proposal operations are shown in Figure 8. Operations according to the flood control rule curve are represented by the target elevation in the Revised Baseline and Flood Proposal scenarios. In 2020 and 2021 the monthly average observed elevations showed the observed operations were very close to the proposed flood control rule curve operations and maintained lower elevations during the fall and winter months than the current license agreement. In 2017 and 2018 the observed operations during the fall and winter months were below both the Revised Baseline and Flood Proposal operations and resulted in lower monthly average summer elevations than modeled in the Flood Proposal scenario. The operations of Ross Lake since the 2011 Revised FSA was issued have been close to or lower than the Flood Proposal operations and in all years, lower than the Revised Baseline operations during the fall and winter months. This indicates that it will be possible to continue to maintain the 2011 Revised FSA under the Flood Proposal.

Figure 8
Monthly Average Observed Ross Lake Elevations Compared to Revised Baseline and Flood Proposal Operations for 2011 to 2021



2.4.2 Ross Lake Levels

Haze charts for Ross Lake water surface elevations are provided in Figure 9 for the Revised Baseline scenario and Figure 10 for the Flood Proposal scenario. The haze charts show Ross Lake levels for the entire year over the 1988 to 2021 period of record used in the CHEOPS models. A visual examination of the charts shows little difference in Ross Lake's levels beyond the winter flood season following the implementation of the Flood Proposal. Figure 11 shows the monthly average Ross Lake elevation for the Revised Baseline and Flood Proposal scenarios. Like the haze charts, the scatter points are the average monthly Ross Lake elevations for each year, and the line represents the average of all years. Statistics on changes to monthly average water levels are provided in Table 5. The difference from monthly average observed Ross Lake elevations is greater for the Revised Baseline scenario than the Flood Proposal scenario for all months except July. This indicates that current Ross Lake operations have maintained monthly average elevations closer to the Flood Proposal than the current license agreement (represented by the Revised Baseline), which was modeled to represent the current license agreement flood control rule curve.

Figure 9
Haze Chart for Revised Baseline Ross Lake Elevations

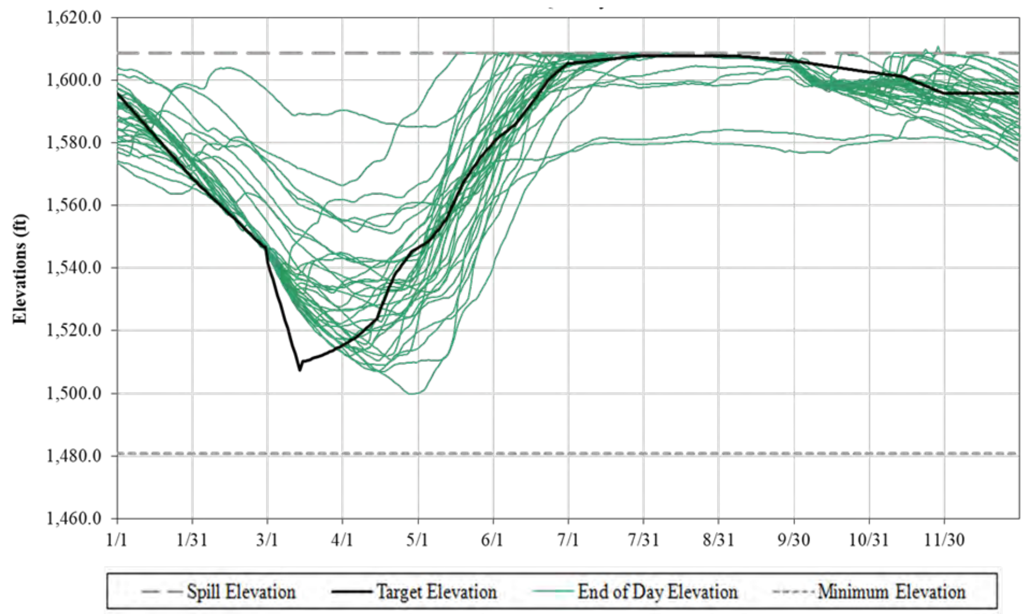


Figure 10
Haze Chart for Flood Proposal Ross Lake Elevations

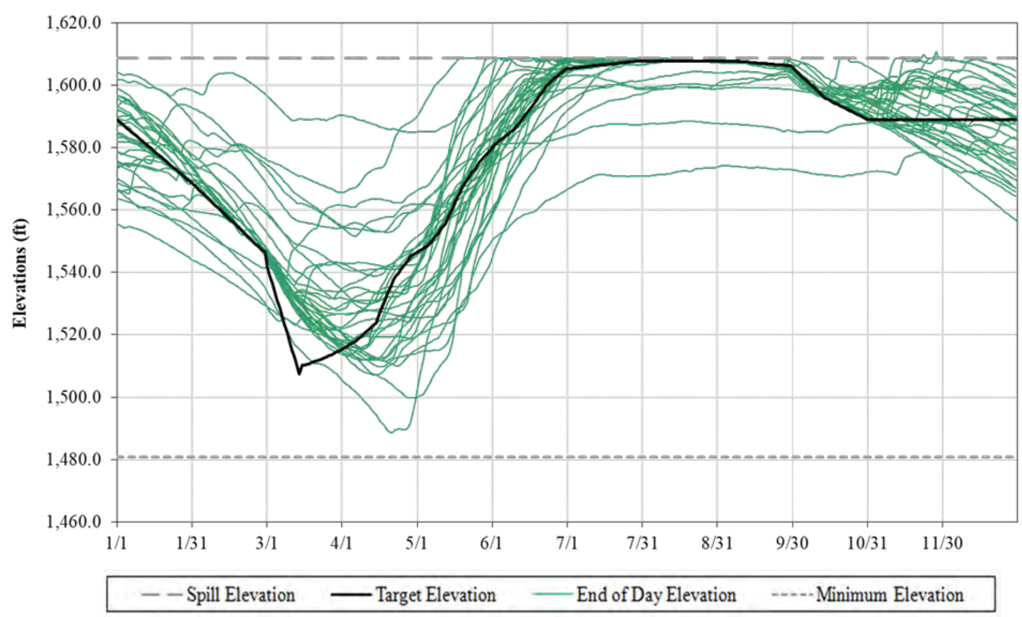


Figure 11
Monthly Average Ross Lake Elevations

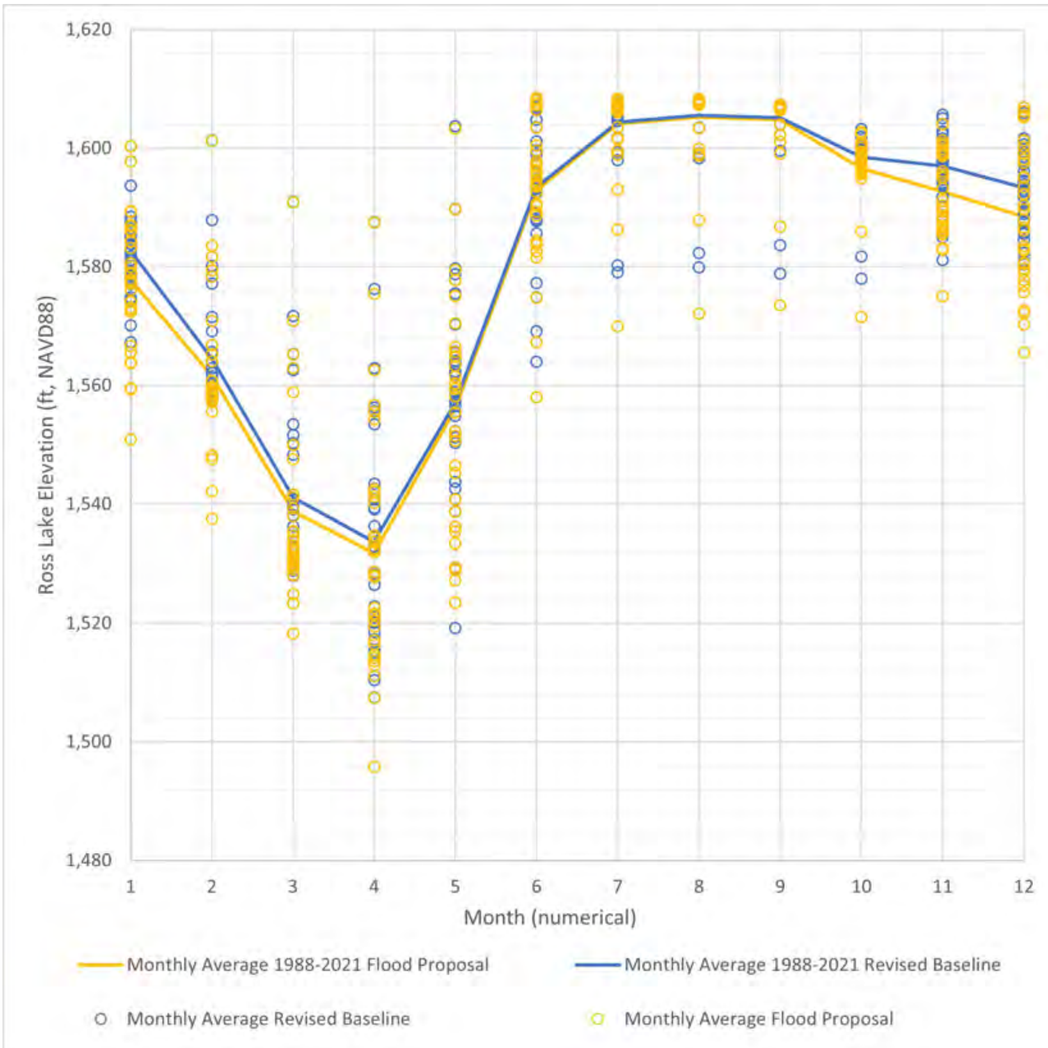


Table 5
Comparison of Monthly Average Elevation for 1988 to 2021 in Ross Lake Flood Proposal to Revised Baseline

Month	USGS Observed Monthly Average Elevation (ft, NAVD88)	Revised Baseline Monthly Average Elevation (ft, NAVD88)	Flood Proposal Monthly Average Elevation (ft, NAVD88)	Percent Difference from Observed to Revised Baseline	Percent Difference from Observed to Flood Proposal
January	1,573.06	1,582.69	1,577.80	0.61%	0.30%
February	1,557.02	1,564.48	1,561.62	0.48%	0.29%
March	1,537.40	1,541.10	1,538.80	0.24%	0.09%
April	1,530.93	1,533.63	1,531.74	0.18%	0.05%
May	1,553.20	1,557.13	1,556.14	0.25%	0.19%
June	1,590.68	1,593.41	1,592.83	0.17%	0.14%
July	1,605.24	1,604.41	1,604.12	-0.05%	-0.07%
August	1,605.36	1,605.56	1,605.27	0.01%	-0.01%
September	1,601.25	1,605.11	1,604.81	0.24%	0.22%
October	1,595.10	1,598.48	1,596.62	0.21%	0.10%
November	1,590.41	1,597.01	1,592.68	0.41%	0.14%
December	1,584.73	1,593.34	1,588.45	0.54%	0.23%

Note:
Revised Baseline represents the current license agreement operations.

2.4.3 Hydropower Generation

Potential hydropower generation was calculated using the CHEOPS model routines for the Baseline R3 scenario, the Revised Baseline scenario, and the Flood Proposal scenario. Table 6 provides the difference in hydropower generation on an average annual basis for the three model runs. The calculations are based upon the CHEOPS-modeled generation for the period of 1988 to 2021. Averages for each month of that period of record were also compared. Table 7 provides the percentage differences in the monthly and annual total hydropower generation for the Revised Baseline scenario compared to the R3 Baseline scenario. Table 8 provides the percentage differences in the monthly and annual total hydropower generation for the Flood Proposal scenario compared to the Revised Baseline scenario. The first comparison was made to establish an estimated amount of hydropower generation under current conditions as the Revised Baseline and R3 Baseline have slightly different operational assumptions. The second comparison reflects the estimated difference in generation with the Flood Proposal.

Table 6
Average Annual Hydropower Generation for R3 Baseline, Revised Baseline, and Flood Proposal

CHEOPs Scenario	Ross Average Annual Generation (MWh)	Diablo Average Annual Generation (MWh)	Gorge Average Annual Generation (MWh)	System Average Annual Generation (MWh)
R3 Baseline	804,563	825,668	1,003,225	2,633,456
Revised Baseline	810,125	833,707	1,007,532	2,651,364
Flood Proposal	807,255	833,722	1,009,463	2,650,440
Difference Flood Proposal – Revised Baseline	-2,870	15	1,932	-923
Percent Difference	-0.4%	0.0%	0.2%	0.0%

Note:
MWh: Megawatt hours

Table 7
Difference in Monthly and Annual Hydropower Generation, Revised Baseline to R3 Baseline

Month	Ross	Diablo	Gorge	Total
Jan	7.8%	6.3%	5.0%	6.3%
Feb	4.8%	4.2%	3.3%	4.1%
Mar	1.4%	0.9%	0.9%	1.1%
Apr	13.1%	10.0%	8.4%	10.2%
May	5.5%	3.0%	2.8%	3.4%
Jun	2.3%	-1.0%	-1.0%	-0.0%
Jul	-2.8%	-2.2%	-1.9%	-2.3%
Aug	-1.5%	-0.8%	-0.8%	-0.9%
Sep	-51.6%	-38.8%	-35.6%	-41.4%
Oct	35.9%	28.0%	22.0%	28.1%
Nov	-7.8%	-2.2%	-2.3%	-4.1%
Dec	-0.2%	2.4%	1.0%	1.0%
Annual	**0.7%**	**1.0%**	**0.4%**	**0.7%**

Table 8
Difference in Monthly and Annual Hydropower Generation, Flood Proposal to Revised Baseline

Month	Ross	Diablo	Gorge	Total
Jan	-5.1%	-4.1%	-3.1%	-4.1%
Feb	-3.6%	-3.1%	-2.5%	-3.1%
Mar	-1.1%	-0.6%	-0.7%	-0.8%
Apr	-3.8%	-2.4%	-2.1%	-2.7%
May	-2.3%	-1.2%	-1.2%	-1.4%
Jun	-2.1%	-0.4%	-0.2%	-0.8%
Jul	-0.1%	0.3%	0.3%	0.2%
Aug	-0.9%	-0.6%	-0.5%	-0.6%
Sep	7.7%	4.2%	3.8%	4.9%
Oct	10.1%	7.9%	7.5%	8.5%
Nov	2.2%	2.5%	2.7%	2.5%
Dec	0.9%	1.2%	1.4%	1.2%
Annual	**-0.4%**	**0.0%**	**0.2%**	**0.0%**

The estimated difference in hydropower generation for all three plants on an annual average basis is negligible with a 0.0% difference in generation on an average annual basis. Additional generation is predicted in fall, while less generation is predicted for winter, spring, and summer. It should be noted that the CHEOPS model required the use of rules for hydropower generation that can't fully represent day-to-day decisions on generation, but the output is generally representative of the potential change in generation with operational changes.

3 Climate Change Impacts

Atmospheric rivers (AR) are the source of most extreme precipitation events on the North American West Coast, including in the Pacific Northwest (Warner et al. 2014). The frequency and magnitude of ARs are indicated by the fraction of days that an AR condition is experienced in a given location, the integrated water vapor transport strength, integrated water vapor (IWV) quantities, and the spatial extent of the AR. Integrated vapor transport (IVT) has been shown to have a close relationship with the amount of orographically produced precipitation along the West Coast (Warner et al. 2014). Precipitation in the Skagit River Basin is an example of orographically produced precipitation because the AR mass lifts to travel over the Cascade Mountains. Warner et al. (2014) examined Coupled Model Intercomparison Project Phase 5 (CMIP5) with RCP 8.5 greenhouse gas emissions scenario simulations to predict the impact of climate change on ARs on the West Coast. They predict that there will be a 26% to 30% increase in extreme IVT (99th percentile) between the historical period (1970 to 1999) and the late century future period (2070 to 2099) and conclude that both winter-average and extreme precipitation events are expected to increase if IVT increases. Espinoza et al. (2018) examines global trends in ARs due to climate change and found that globally, projections indicate that although there will be approximately 10% fewer ARs, ARs will be approximately 25% wider and 25% longer and exhibit a stronger IVT under RCP 8.5 of approximately 50% in the northern midlatitudes.

Espinoza et al. (2018) also reviewed five additional studies of ARs under climate change for the West Coast. These studies used a variety of climate change modeling methods and ensembles including CMIP3 and CMIP5 global climate models (GCMs) and considered ensembles of 10 to 28 GCMs. All studies reviewed in Espinoza et al. (2018) used RCP 8.5 and showed an increase in AR frequency by the end of the 21st century. AR frequency is the number of days at a given location that an AR condition is experienced. The range of increase found for AR frequency in these five studies was between 8% to 600%, with most studies showing an increase in AR frequency of 23% to 50%. Additionally, two of the studies that also examined IVT showed a 30% increase by the end of the 21st century. Because the studies did not utilize the same methods or GCM ensembles, results that all agree that AR frequency and IVT on the West Coast will increase by the end of the 21st century are a strong indicator that winter precipitation will increase in watersheds such as the Skagit River Basin due to climate change.

Studies have also been conducted to examine climate change impacts specifically in western Washington and the Skagit River Basin. Rybczyk et al. (2016) summarizes climate change impacts predicted for the Skagit River Basin and synthesizes research from a number of studies including Salathé et al. (2014), and Lee et al. (2016). The projections described in Rybczyk et al. (2016) confirm the implications of the global and larger regional-scale studies described in Espinoza et al. (2018) and Warner et al. (2014); winter flows are likely to increase while summer low flows will decrease due to changes in precipitation and temperature. The Skagit River Basin is a transient rain-snow watershed (Salathé et al 2014). Tohver et al. (2014) supports the conclusion that climate change will lead to increased winter flows and decreased summer low flows for transient rain-snow watersheds as warming leads to a shift towards rain-dominance.

Salathé et al. (2014) used a RCM developed using dynamical downscaling of the ECHAM5 GCM for the A1B greenhouse gas emission scenario[1] in the Weather Research and Forecasting (WRF) Model, which has been widely evaluated for its use in GCM downscaling because "the model configuration is capable of resolving fine scale structure of storms and their effects on precipitation in complex terrain…" and "successfully simulates important large-scale features of [Pacific Northwest] winter storms, such as atmospheric rivers…" (Salathé et al. 2014). The results of the RCM indicate that transient rain-snow watersheds are more sensitive to warming because the increase in elevation of the freezing-level subjects a larger basin area to rainfall and runoff production during storm events, especially in early winter. For the Skagit River Basin, the RCM developed predicts that seasonal timing of peak flows will shift to earlier in the water year with October and November daily peak flows increasing by about 30% for the 2040 to 2069 period.

Lee et al. (2016) evaluated the impacts of climate change on regulated flows in the Skagit River Basin including for the Skagit River Project. They utilized five GCMs with the A1B greenhouse gas emissions scenario downscaled using the hybrid delta approach, which uses quantile mapping techniques to produce transformed monthly and daily observed climate data from 1916 to 2006 to represent future climate conditions. They then used the Variable Infiltration Capacity hydrologic model to develop streamflow conditions for the future scenario, which drove a daily timestep reservoir model (SkagitSim) operations for the Skagit River Project as well as Upper and Lower Baker dams for climate change conditions. Lee et al. (2016) incorporated an alternative flood storage scenario for the Ross Reservoir for 180,000 acre-feet of flood storage by December 1st. Reservoir simulations for the current license operations (120,000 acre-feet of storage by December 1st) showed that the future 100-year flood magnitude (regulated flow) increased by 23% (-7% to +87%) for the 2040s and 49% (+2% to +119%) for the 2080s relative to the historical regulated 100-year flood. For the alternative flood control scenario, the 100-year flood magnitude increased by 21% (-4% to +65%) for the 2040s and by 42% (+3% to +100%) for the 2080s.

Lee et al. (2016) concludes that, "the alternative flood operations are shown to be largely ineffective in mitigating increased flood risk in the lower basin at daily-time-step." However, the study does not provide any statistical basis for concluding that the change between the existing flood control operations and alternative is ineffective or insignificant. This conclusion relies on broad modeling

[1] The A1B greenhouse gas emissions scenario is part of the 2000 *Special Report on Emission Scenarios*, while RCP 8.5 (mentioned previously) is part of the 2010 Representative Concentration Pathways family of emission scenarios. A1B is similar to RCP 6.0, which represents a moderate greenhouse gas emissions scenario. RCP 8.5 represents a high greenhouse gas emissions scenario (U.S. Global Change Research Program).

efforts and reported ranges without providing evaluation of standard deviations or error. Simply concluding that a magnitude change is insignificant is inconclusive and misleading because apparently minor changes in magnitude may be deemed significant if appropriate statistical analysis is performed. Evaluation of observed operations and resulting streamflow that occurred during the November 15, 2021, flood provides a more substantiated assessment of how increased flood storage results in significant flood risk reduction benefits. The authors conclude that "the current levels of flood storage at the upstream projects are already large enough to capture all but the most extreme climate change floods, and proposed increases in headwater flood storage produce only a minor improvement in two events" (Lee et al. 2016). The November 2021 flood, which was larger than the inflows predicted under climate change scenarios by Bandaragoda et al. (2019) and reported in SCL 2022b (described below), have demonstrated that increased storage at Ross Lake can significantly reduce flood risks in downstream communities.

Furthermore, Salathé et al. (2014), which is cited by Lee et al. (2016), concludes that their results suggest that "flood risk is likely to increase much more than has been shown in earlier studies using GCM projections downscaled by the hybrid delta downscaling and similar techniques," and "the hybrid delta method replicates the same cycles of interannual variability for both the historic and future periods, which underrepresents the true number of degrees of freedom associated with potential changes in natural variability." In other words, Lee et al. (2016) utilizes a downscaling method that had previously been shown to underrepresent changes in magnitude and variability seen in regional climate change models evaluated with more advanced dynamical downscaling methods. Lee et al. (2016) fails to discuss the potential bias and underrepresentation of climate change impacts that could be associated with their results due to the use of the hybrid delta downscaling method. In addition, Lee et al. (2016) misrepresents a portion of the conclusions of the body of climate change research on ARs previously discussed in this section. They state: "These storms [caused by ARs] are warm enough that there is little increase in contributing basin area with additional climate change warming" (Lee et al. 2016.) This conclusion does not have an associated citation and is refuted by research in presented in all other studies reviewed here. In agreement with relevant climate change studies, however, they conclude that, "climate change is likely to cause larger and earlier annual peak flows as warming intensifies through the 21st century" (Lee et al 2016). Considering the failure to adequately discuss potential underrepresentation of climate change impacts, provide basic statistical analysis of the results significance, and misinterpretation of well-established predicted impacts of climate change in the Pacific Northwest, it is difficult to accept the conclusions of Lee et al. (2016) that alternative flood control scenarios would not have an impact on floods in the Skagit River Basin.

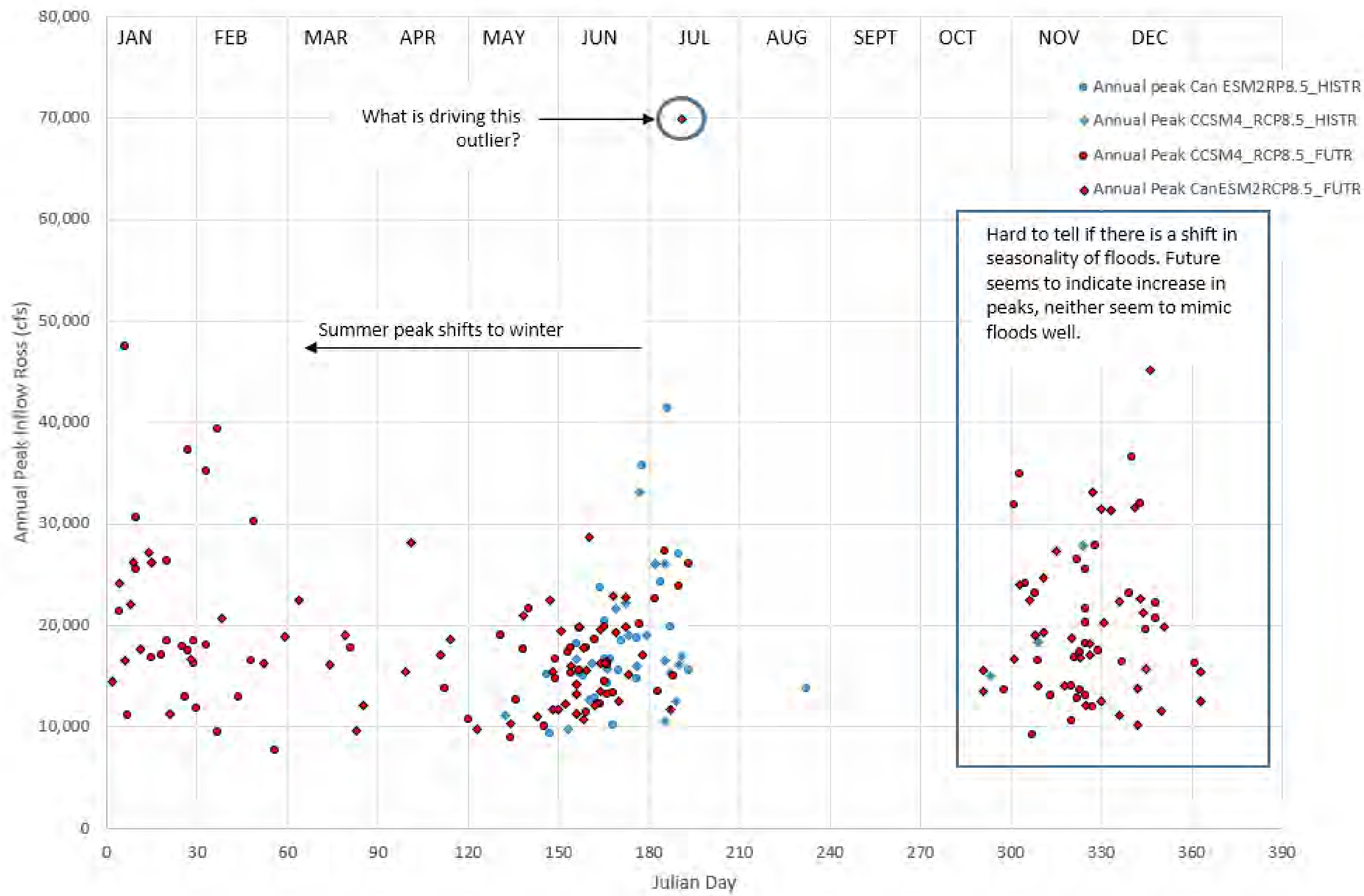
A recent study of the impacts of climate change on the Skagit River Basin was performed as part of the SCL Integrated Resource Plan (IRP; SCL 2022b). The SCL IRP used selection criteria based on representative variability, spatial coverage, and high emissions scenarios (e.g., RCP 8.5) to select two

GCMS, CCSM4 and CanESM2, for further analysis. The GCMs were processed into RCMs in research performed by the University of Washington Climate Impacts Group. Dynamical downscaling methods (i.e., WRF) and bias-correction methods were used to develop the RCMs. The future streamflow for the Skagit River was developed using DHSVM as described in research by Bandaragoda et al. (2019).

The methods used to develop the climate change hydrology inputs used in SCLs IRP studies appear to utilize advanced science and methodologies available for developing GCMs and future streamflow predictions. However, the use of only two GCMs to develop the regional climate change ensemble is less than ideal. While the criteria for GCM selection seems reasonable and limited computational resources is a challenge in developing this type of regional climate modeling, the best practice for developing climate change impacts analysis is evaluation of a larger ensemble of GCMs, such as the CMIP5 ensemble developed by Taylor et al. (2012) for the Pacific Northwest. Use of a larger GCM ensemble allows for a better understanding of the range of possible climate impacts, the average of which is a better representation of the best prediction of climate change impacts that may occur.

It is also notable that the maximum average daily flow in hydrology inputs developed for the CHEOPS model based on the climate change impacts on streamflow appears to include an erroneous result. The maximum daily average inflow to Ross Lake for the CanESM2 RCP 8.5 model of approximately 69,900 cfs occurs in July. Patterns of peak streamflow in transient rain-snow dominated watersheds, such as the Skagit River Basin, have historically had a two-peak annual streamflow system, with a peak occurring during the winter precipitation and a second in the late spring due to snowmelt. It is predicted that due to climate change, warming in these types of watersheds will lead to transition to a rain-dominated watershed, which will have a single annual peak in the winter (Salathé et al. 2014). Therefore, it is unlikely that a peak annual event and event of record would occur in July, and the peak daily average inflow to Ross Lake determined by SCL during July for the period of record (1988 to 2021) was approximately 17,000 cfs (Figure 12). This outlier and possible error are not discussed in the SCL ISR (SCL 2022b). The second largest peak annual daily average Ross inflow in the climate change hydrology data is 45,000 cfs, which is over 10,000 cfs lower than the peak daily average inflow to Ross Lake of 59,777 cfs on November 15, 2021, which was estimated by SCL and used for the CHEOPS model hydrology input. This difference is counter to the accepted understanding based on the body of recent climate change research in the region that climate change will lead to an increased magnitude of peak flood events.

Figure 12
Annual Peak Daily Average Inflow to Ross Lake for Historical and Future Climate Change Simulations



4 Summary and Conclusions

Anchor QEA was retained by the Partnership to review hydrologic and operations modeling performed by SCL in support of the Federal Power Act relicensing process for the Skagit River Project. We were also asked to review the effect of the Partnership and the County's request that SCL incorporate the Flood Proposal into the Final License Application. The Flood Proposal's goal is to increase the flood storage capacity in November by providing 200,000 acre-feet of flood storage on November 1st of each year. That is in comparison to the current license requirement to provide 120,000 acre-feet of flood storage capacity on December 1st of each year.

The latest CHEOPS model scenario presented by SCL in a workshop October 4, 2022, was named Baseline R3. That scenario contains operating rules that are not consistent with the current license. We presume the target elevation used in the model was selected to calibrate the model to observed operations instead of representing the current operating rules. Anchor QEA prepared an alternative scenario that represents the current operating rules named Revised Baseline. A comparison of the performance of both scenarios is contained in this report. The Revised Baseline scenario performed slightly better in representing current operations during floods; however, both Baseline scenarios had large enough errors to conclude the CHEOPS model is not an adequate tool for representing flood operations. The daily average timestep used in the CHEOPS model is a shortcoming because it cannot represent peak flows and operations that occur on a sub-daily basis. The CHEOPS model is better used for long-term analysis of operations.

A third CHEOPS scenario named Flood Proposal was prepared to analyze the effect of the Partnership and the County's request for increasing the flood storage capacity by November 1st of each year. Although it was determined that flood operations couldn't be accurately modeled, the results of the model were reviewed on a long-term basis to review the potential effect of the Flood Proposal on Skagit River flows, Ross Lake water surface elevations, and hydropower generation. Although flows and hydropower generation would increase and Ross Lake levels would decrease in the fall compared to the existing license, it was found that the Skagit River Project is currently operating similar to the Flood Proposal and no effect on flows and Ross Lake levels would result. If compared to the existing license, hydropower generation would increase in the fall but would not be affected on an annual basis.

The best representation of the Partnership and the County's request for increasing flood storage capacity by November 1st of each year is the experience from the November 15, 2021, flood event. Ross Lake water levels followed or were below the Flood Proposal flood control rule curve between August and November. Even though there was a record high inflow on November 15, 2021, to Ross Lake estimated by SCL to be 59,777 cfs on a daily average basis, the peak daily flow at the Newhalem gage was 28,500 cfs on November 17th. The available storage substantially reduced flooding risks in downstream areas.

A review of climate change research and modeling prepared for SCL was performed. The source of extreme precipitation and floods in the Pacific Northwest and the Skagit River Basin are ARs. Anchor QEA disagrees with findings in Lee et al. (2016) that indicate extreme storms caused by ARs are "warm enough that there is little increase in contributing basin area with additional climate change warming" and "the alternative flood operations are shown to be largely ineffective in mitigating increased flood risk in the lower basin at daily-time-step."

Anchor QEA found potential errors in the climate change hydrologic modeling that were not explained by SCL and more recent research in ARs that conflict with SCL reports. The November 2021 flood had a peak flow greater than fall and winter peaks predicted by SCL's climate change modeling for the 2080s, which indicates that the climate change modeling may not be representative of future conditions. More recent literature predicts future ARs to be longer, wider, and have larger water vapor quantities leading to predicted peak flows much greater than currently experienced.

Another critique of SCL's climate change modeling was the use of only two GCMs. It is best practice to use a larger ensemble of GCMs, which would allow a better understanding of the range of potential climate impacts.

Flood operations under future climate conditions may best be represented through the operations that occurred in November 2021. Ross Lake levels were lower than required by the current license, and the storage available in Ross Lake during that flood greatly reduced downstream peak flows and reduced flood risks.

5 References

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Exhibit A Washington State Department of Transportation, 2015 Resilient Transportation Network Study (2015)

Creating a Resilient Transportation Network in Skagit County

Using Flood Studies to Inform Transportation Asset Management

FHWA Pilot Project Report

WSDOT

2015

U.S. Department of Transportation
Federal Highway Administration

Washington State Department of Transportation

This report was developed by the Washington State Department of Transportation in accordance with a grant from the Federal Highway Administration (FHWA). The statements, findings, conclusions and recommendations are those of the author(s) and do not necessarily reflect the views of FHWA or the U.S. Department of Transportation.

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6. AUTHOR(S) Carol Lee Roalkvam

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310 Maple Park Avenue SE , Olympia, WA 98504-7300

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12b. DISTRIBUTION CODE

13. ABSTRACT

This report presents the results of a Climate Resilience Pilot Project conducted by Washington State Department of Transportation (WSDOT) and sponsored in part by the Federal Highway Administration (FHWA). WSDOT received a grant from FHWA to develop options for improving the resiliency of transportation facilities or systems to climate changes and/or extreme weather events. The pilot project set out to meet FHWA's goal of helping further the state of the practice in applying vulnerability assessment results into decision making. This study builds on WSDOT's earlier pilot by examining adaptation options in an area of the state we previously identified as highly vulnerable: the Skagit River Basin (Basin). WSDOT chose this Basin because it is the focus of a major flood study by the U.S. Army Corps of Engineers (Corps). WSDOT knew important decisions about how and where to invest in levees and other flood risk reduction projects were being actively evaluated by the Corps and the local sponsor, Skagit County. WSDOT also knew that state transportation assets were likely to be affected but were not the focus of their study. WSDOT's pilot presented the opportunity to actively engage with the flood study and search for compatible long-term solutions that create a more resilient transportation system throughout the Basin. WSDOT's pilot shows transportation planners and asset managers how to leverage a federal flood study, like the Corps' Skagit River Flood Risk Management General Investigation Study (GI study), to improve the resiliency of our highways. The pilot demonstrates how WSDOT's Vulnerability Assessment results, used in combination with federal flood study data, can reaffirm known vulnerabilities and reveal other vulnerable assets. The pilot identifies adaptation strategies for the Basin and highlights future partnership opportunities with the Corps and local governments. This report includes a series of recommendations and lessons learned that will help other DOTs and regional transportation planning entities reach across jurisdictions and sectors to create integrated asset management strategies.

14. SUBJECT TERMS
climate change, adaptation

15. NUMBER OF PAGES 42

16. ACCOUNTING DATA

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[Figure 1-5](#) shows flood flows over time as well as when the dams were constructed. The dams have reduced peak flows to the extent that recent flows have not exceeded the present dike system capacity. The available flood storage capacity may reduce the 4% ACE flood flow by up to 34,000 cfs and the 1% ACE flood flow by 51,000 cfs.

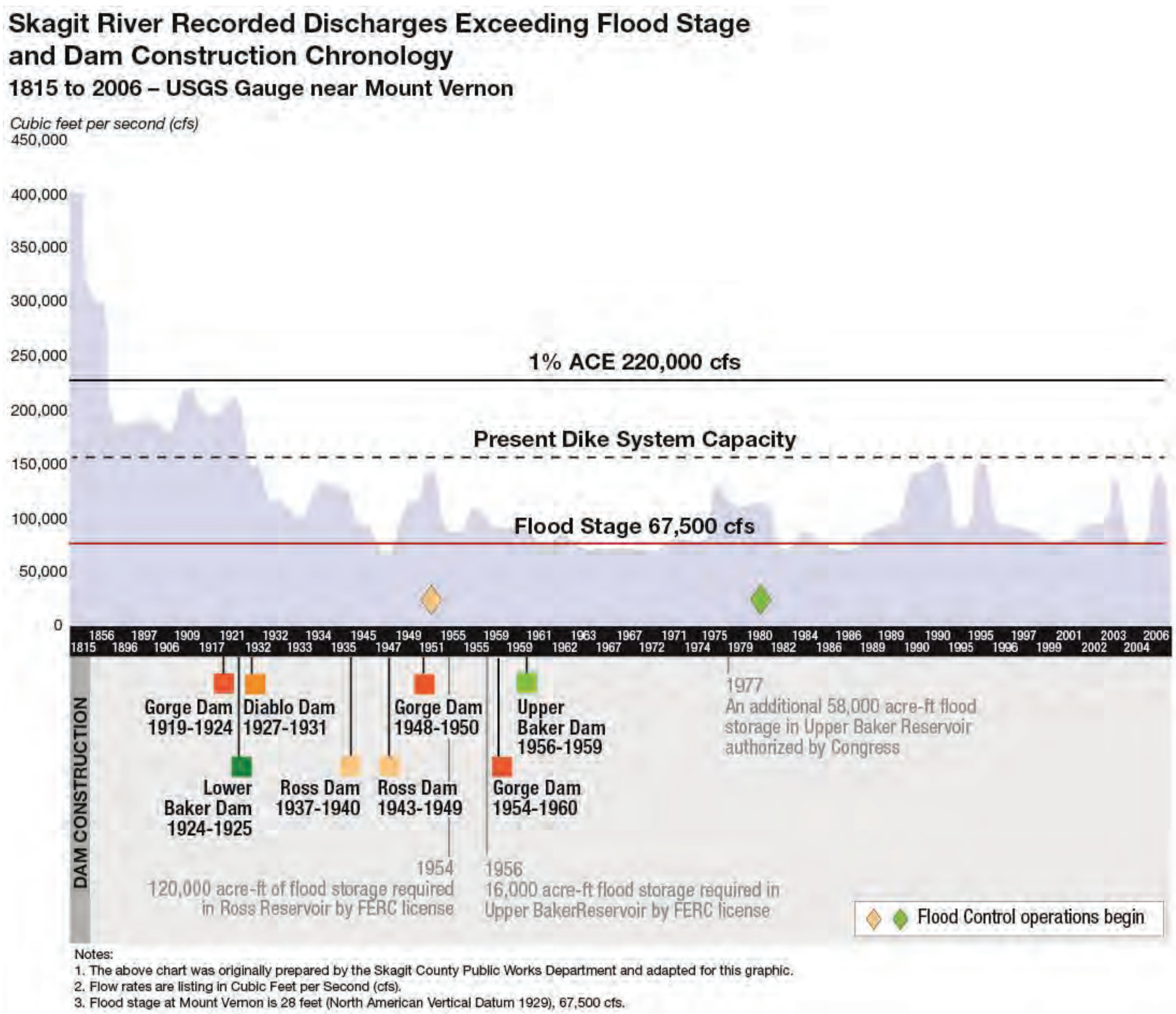

Figure 1-5 Flood Flows and Dam Building throughout the Years

Within the Basin, there are three diking districts responsible for construction, repair, and maintenance of the levee and dike systems, and four flood control zone districts. The Corps started its efforts in the Basin many years ago. In June 2014 the Corps issued the Skagit River General Investigation and Draft EIS outlining its proposed tentatively selected plan (TSP). This provided us with an excellent opportunity to address the known flood-related problems in the area and to create stronger partnerships. WSDOT's work with Skagit County and the Corps will continue into the future as we continue our adaptation and preparation efforts.

Generally, the TSP will reduce flood hazards in urban areas by improving and raising existing levees and by adding new levees. Consequently, the transportation assets in these areas also benefit from the improvements. However, in more rural areas, transportation assets, including portions of I-5, SR 20, SR 11, and SR 9, will remain at risk with implementation of the TSP.[13] Our analysis revealed:

- Without the TSP, we estimate that about 90% of I-5 in Skagit County, as well as the rest of the highway system, is at risk of flooding.
- The TSP will eliminate issues on the southern and central portions of I-5 seen during the existing 1% ACE flood.[14]
- The TSP directs floodwaters to the northern section of I-5 near the Joe Leary Slough. This northern section of I-5, and SR 20 east of Burlington, were not identified in the qualitative vulnerability assessment as areas of high vulnerability.
- The TSP maintains or worsens conditions east of I-5 on SR 538 and SR 9, and west of I-5 on SR 11, SR 20, and SR 536.

3.2 What strategies did we develop?

For the 11 segments of highway that we identified as vulnerable, we developed a list of strategies for the Future without Corps' project, the TSP, and no regrets. Table 3-1 captures the strategies identified for each segment (See Figure 3-1 for map of segments). When we didn't have enough information about whether or not a strategy would work or solve a problem, we put a question mark (?). You can find all the specific details we considered for each segment in the profiles in Appendix C, Segment Profiles.

Generally, the project team brainstormed the following:

- Nonstructural solutions to help reduce impacts during flood events, like active traffic management, detour routes, etc.
- Solutions recommended in the Corps' GI Study and the TSP
- Other basin-wide ideas such as buying more water storage or flood easements
- Highway related solutions such as fixing culverts where potential blockage exists, hardening the road prism to allow the water to flow over it with minimal damage, realignment and/or raising the road out of the floodplain

[13] Corps, 2014
[14] The Corps used CIG data that assumes the current 1% ACE event will become the approximate 4% ACE event by 2085.

Table 3-1 Conceptual Strategies Identified for the 11 Vulnerable Highway Segments

Highway Segments – The Project Team Brainstormed the Following Options (see Figure 3-1)	Strategies		
	Future without Corps' Project	Tentatively Selected Plan	No Regrets
Segment 1: Central I-5 Anderson Road to George Hopper Road			
▪ Work with local agencies and the Corps to purchase additional storage capacity behind the dams run by Puget Sound Energy (PSE) and Seattle City Light.	x	x	x
▪ Work with the City of Mount Vernon to extend the floodwall to protect state highways.	x		x
▪ Raise I-5 above the flood elevation.	x		
Segment 2: SR 20 East of Burlington to Sedro-Woolley			
▪ Reroute traffic onto Cook Road or F&S Grade Road.	?[15]	x	x
▪ Raise the road (or portions) through this segment and install sufficient culverts or bridges to allow the water to pass from the Skagit River over to Joe Leary Slough.	x	x	?
▪ A high number of culvert ends are identified in this segment; it is possible that the other end may be buried or obstructed and not operating properly. If those culverts are not functioning properly now, fixing them might relieve flooding issues in smaller floods.			x
Segment 3: SR 538 Nookachamps Basin – SR 9 to I-5			
▪ Raise the road (or portions). It appears that this could be done to alleviate flooding for the more frequent flood events but may be difficult for the 2% and 1% ACE flood.	x	x	x
Segment 4: I-5 at – George Hopper to Chuckanut (SR 11)			
▪ Raise I-5 above the flood elevation.	x		
▪ Make SR 9 less vulnerable to flooding (see Segments 6 & 8) to serve as an alternate route if I-5 is closed for any reason.	x	x	x
Segment 5: North I-5 – Chuckanut (SR 11) to Samish River			
▪ Raise I-5 above the flood elevation. Raise the road (existing). The TSP sends more water to this segment of roadway, so the road would have to be raised to get above the higher flows as compared to existing flood elevations.	x	x	
▪ Work with other agencies to secure additional water storage. (The Corps includes this strategy in the TSP.)	x	x	x
Segment 6: North SR 9 Skagit River Overflow – Sedro-Woolley to Francis Rd./Old Day Creek Rd.			
▪ Explore options for a new alignment out of the floodway.	x	x	x
▪ Raise the road in the existing alignment.	x	x	x
Note: Either option would eliminate flooding concerns for this segment and add resilience to north-south travel. SR 9 is an alternate route for I-5. Making this route less likely to flood will improve the resilience of the transportation infrastructure and provide an alternate route that would allow limited north-south traffic flow and access for County residents who would otherwise be stranded or face long detours.			
Segment 7: South I-5 Fisher Creek to Anderson Road			
▪ Support the Corps' TSP. Implementing the TSP alleviates flooding in the segment.		x	
▪ Work with the City of Mount Vernon to extend its floodwall to the south to protect I-5. Further study is needed to determine if this option would protect I-5.	x		
▪ Raise I-5 above the flood elevation.	x		

[15] A "?" indicates that more information or analysis of potential benefits is needed.

Exhibit B Washington State Department of Transportation, Chehalis River Basin I-5 Flood Protection Near Centralia and Chehalis study, dated November 26, 2014, relevant excerpts

WSDOT Report

Chehalis River Basin I-5 Flood Protection near Centralia and Chehalis

Final - November 26, 2014

Project Area and History of Flooding

The project area is in the Lewis County cities of Chehalis and Centralia along a 5-mile stretch of I-5. It begins near the 13th Street interchange (Exit 76) and extends north to the Mellen Street interchange (Exit 81). WSDOT evaluated potential inundation during a 100-year flood event from the Rush Road interchange (Exit 72) north to the Mellen Street interchange. No potential was found for inundation from the Rush Road interchange to just south of the 13th Street interchange.

This stretch of I-5 is the midpoint between Seattle and Portland, Oregon, connecting two of the West Coast's major population and industrial centers. I-5 is the West Coast's major north-south transportation corridor. Floods closed I-5 at Chehalis and Centralia for four days in both February 1996 and December 2007, and flooding in January 2009 closed the same stretch for two days. WSDOT estimates the total cost of the closure and delays in 2007 alone in the tens of millions of dollars[2]. The major costs come from limited freight movement through the area, including costs incurred by private companies as a result of that limited movement. Since the two flood events in 2007 and 2009, WSDOT has developed an emergency detour route, for priority shipments only, that takes drivers around I-5 using SR 7 and US 12. WSDOT also developed two other detour routes for trucks: one takes drivers around I-5 using I-84, SR 97, I-82, and I-90, which is the anticipated preferred truck detour; the other route uses I-84, I-82, and I-90, which is a secondary detour for trucks. See Appendix A for a more detailed discussion of the detour routes.

Photo courtesy of *The Chronicle*, Centralia, Washington

[2] Washington State Department of Transportation (WSDOT). 2008. Storm-Related Closures of I-5 and I-90: Freight Transportation Final Report. September, 2008. Available at: http://www.wsdot.wa.gov/research/reports/fullreports/708.1.pdf.

University of Washington – Transportation Research Center (TRAC) Study

The University of Washington Transportation Research Center (TRAC) recently completed a report that estimated the travel costs associated with the closure of I-5, US 12, and SR 6 in the greater Centralia-Chehalis region due to modeled 100-year flood conditions from the Chehalis River. A full copy of the report is provided in Appendix A.

The estimates describe only costs directly related to travel that would otherwise have occurred were it not for flooding closures. These include the added costs of time and vehicle mileage associated with available detour routes, and costs for abandoned trips. The estimated value of travel disruptions directly associated with I-5 for a 100-year flood event without any flood-protection work is approximately $11.9M to $20.6M[4] (5 days) per event. The range of costs is based on the share of through traffic that takes a detour rather than delays a trip. The higher figure of $20.6M assumes that all through traffic would take a detour in the event of a closure. The estimated value of travel disruptions directly associated with US 12 and SR 6 without any flood-protection work is less than $350,000[4] (over 6 days) per event for US 12 and less than $150,000[4] (about 2 days) per event for SR 6. This study helps to inform the cost-effectiveness of any I-5 protection scenario.

How the Report Will Be Used

The results of this report on I-5 protection alternatives, as well as concurrent feasibility analyses related to a water-retention facility, aquatic-species restoration, and small-flood-control projects, will be included in a benefit-cost analysis (BCA) used by the Governor's Work Group when it makes its next set of recommendations to the Governor and Legislature. Alternatives under evaluation include baseline conditions, I-5 alternatives, a flood-retention dam, a multi-purpose dam, small flood projects (including raising residential and commercial structures within the 100-year floodplain that would not be fully protected through the construction of a water retention structure), aquatic-species restoration plan, and combinations of these alternatives.

If an alternative is identified by the Governor's Work Group for I-5 protection, it is for budgetary purposes only. This effort is not intended to preclude the National Environmental Policy Act (NEPA) process where all reasonable alternatives, including a "No Build" alternative, would be carried forward and where a preferred alternative would be selected.

[4] The estimates do not include economic losses associated with delays in the delivery of goods or services due to flood closures, losses in economic activity attributable to travelers being unable to reach their intended destinations, or economic losses associated with the loss of goods because they could not be delivered.

Research Report
Agreement T1461, Task 07
I-5 Chehalis

TRAVEL COSTS ASSOCIATED WITH FLOOD CLOSURES OF STATE HIGHWAYS NEAR CENTRALIA/CHEHALIS, WASHINGTON

by

Mark E. Hallenbeck
TRAC-UW Director

Dr. Anne Goodchild
Associate Professor

Jerome Drescher
Researcher

Washington State Transportation Center (TRAC-UW)
University of Washington, Box 354802
University District Building, Suite 535
1107 NE 45th Street
Seattle, Washington 98105-4631

Washington State Department of Transportation
Southwest Region

Prepared for

The State of Washington
Department of Transportation
Lynn Peterson, Secretary

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WA-RD 832.1		

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7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Mark E. Hallenbeck, Anne Goodchild, Jerome Drescher	
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Washington State Transportation Center (TRAC) University of Washington, Box 354802 University District Building; 1107 NE 45th Street, Suite 535 Seattle, Washington 98105-4631	11. CONTRACT OR GRANT NO. Agreement T1461, Task 07
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Research Office Washington State Department of Transportation Transportation Building, MS 47372 Olympia, Washington 98504-7372 Doug Brodin, Project Manager, 360-705-7972	Research Report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

This report discusses the travel costs associated with the closure of roads in the greater Centralia/Chehalis, Washington, region due to 100-year flood conditions starting on the Chehalis River. The costs were computed for roadway closures on I-5, US 12, and SR 6, and are based on estimated road closure durations supplied by WSDOT. The computed costs are only those directly related to travel that would otherwise have occurred on the roads affected by the flooding closures. The computed costs <u>do not</u> include the economic losses associated with delayed delivery of goods or services, losses in economic activity attributable to travelers being unable to reach their intended destinations, or economic losses associated with the loss of goods because they could not be delivered. The reported costs <u>do include</u> the added costs of time and vehicle mileage associated with available detour routes. Costs were also estimated for each trip that will be abandoned. That is, this study estimated the number of trips that will not be made as a result of road closures.

The researchers also conducted a sensitivity analysis of the findings for the I-5 cost computation. Sensitivity tests were conducted for the value of time, the speeds and level of congestion assumed to occur on the routes used for detours, the values associated with trips that are not made via the expected detours, the percentage of personal trips made for work/business purposes versus those being made for personal reasons, the fraction of cars and trucks willing to detour, the effects of flood closure during the weekend or the summer, and growth in traffic volumes on I-5.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Road closure impacts, flooding traffic impacts, detour costs	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
None	None		

Exhibit C Letter from U.S. Rep. “Scoop” Jackson to U.S. Army Corps of Engineers, dated July 15, 1946

Col Holle, Civil Works

HENRY M. JACKSON
2d Dist. Washington

Executive Secretary:
JOHN L. SALTER

Congress of the United States

House of Representatives

Washington, D. C.

COMMITTEES:
Merchant Marine and Fisheries
Flood Control
Civil Service
Rivers and Harbors
Indian Affairs, Chairman
Select Committee on Small Business
Select Committee on Conservation of Wildlife Resources

ROOM 1422
HOUSE OFFICE BUILDING

July 15, 1946

SE Dist File 800.2251(SE Power Project-Skagit River)23

Chief of Engineers
War Department
Washington 25, D. C.

Dear Sir:

Please find enclosed copies of self-explanatory letters received from the Skagit County Planning Commission, the Board of County Commissioners for Skagit County, State of Washington, and the Federal Power Commission relative to the application submitted by the City of Seattle to the Federal Power Commission for an increase in the height of the Ross Dam.

As you will note, the Skagit County Planning Commission and the Board of County Commissioners have requested that any grant of right to increase the height of the Ross Dam be granted only upon the condition that the upper 15 feet of the dam, as either completed or partially completed, be reserved as storage for flood waters and for flood control purposes.

The Federal Power Commission advises that the plans for the addition to the dam will be submitted to you for approval. I am requesting that you give very careful consideration to the flood control situation in your study of this problem.

I will appreciate your advising me as to the recommendations made by your office on this question.

Sincerely yours,

Henry M. Jackson

Henry M. Jackson, M. C.

HMJ:gp

3 Encs.
cys 3 letters

P 000621

1862

Exhibit D Skagit Project License Amendment No. 4, Order, dated April 29, 1947

UNITED STATES OF AMERICA
FEDERAL POWER COMMISSION

Before Commissioners: Nelson Lee Smith, Chairman; Leland Olds and Harrington Wimberly.

April 29, 1947

In the Matter of)
) Project No. 553
City of Seattle, Washington)

ORDER AUTHORIZING AMENDMENT OF LICENSE (MAJOR)

(1) An application was filed June 6, 1946, and later supplemented, by City of Seattle, Washington, licensee for major Project No. 553, requesting amendment of license as hereinafter specified.

(2) This application contemplates construction of the third step of Ross Dam to raise the dam from elevation 1550 feet to elevation 1620 feet, plus or minus, at the roadway crest with the normal high water level in the reservoir at 1600 feet (top of spillway gates), creating a reservoir with a gross capacity of 1,400,000 acre-feet. The plans provide for two spillway sections near the abutments with fixed spillway crests at elevation 1582 feet, and such accessory or additional facilities as may be necessary.

(3) The licensee proposes to complete the third step of Ross Dam, with the exception of installing spillway gates, by October 1948.

(4) With normal high water level in the reservoir at 1600 feet the area of lands of the United States within the Ross Reservoir will be increased by 3,790 acres.

(5) The Acting Director, U. S. Geological Survey, has recommended that gages and stream gaging stations be constructed, maintained and operated at the following locations:

Lightning Creek near Newhalem
Beaver Creek near Newhalem
Ruby Creek near Newhalem
Ross Dam, records of storage and waste
Thunder Creek near Newhalem
Diablo Dam, records of storage and waste
Stettattle Creek near Newhalem
Skagit River at Newhalem

(6) The Chief, Forest Service, who has supervision over the Mount Baker National Forest, has reported favorably on the application.

(7) The Chief of Engineers and the Secretary of War have approved the plans insofar as they affect navigation, and have recommended that during the period November 1 to April 1 200,000 acre-feet of storage be reserved in Ross Reservoir for the purpose of flood control and that methods of operating the reservoir in the interests of flood control be required as hereinafter provided.

(8) The Assistant Secretary of the Interior has recommended that continued responsibility for the protection of fisheries resources in the Skagit River remain with the State Department of Fisheries.

(9) The construction of the third step of Ross Dam with normal high water level in the reservoir at 1600 feet will cause the reservoir to extend into Canada. The International Joint Commission has authorized the licensee to raise the Ross Dam by stages to elevation 1725 feet on condition that satisfactory arrangements be made with the Province of British Columbia to provide for proper and adequate compensation to the Province for use of Crown lands. However, construction of the third step will affect only privately owned Canadian lands already acquired by the licensee. The Chairman, United States Section, International Joint Commission, has reported that his office has no objection to the granting of the pending application.

The Commission, having considered the application and the project record, finds that:

(10) The license, further amended as hereinafter provided, will not interfere or be inconsistent with the purposes for which the Mount Baker National Forest or any reservation of public lands of the United States were created or acquired.

(11) Although not required by the Act, public notice has been given.

(12) Under present circumstances and conditions, and upon the terms heretofore and hereinafter imposed, the Ross Dam and Reservoir constructed to elevation 1620 feet with the normal high water level at 1600 feet constitutes a part of a comprehensive plan for the development of the Skagit River and will be best adapted to a comprehensive plan for improving and developing the Skagit River for the use and benefit of interstate or foreign commerce, for the improvement and utilization of water power development, and for other beneficial public uses, including recreational purposes.

(13) As a measure for the protection of life, health and property, it is in the public interest to require the licensee to operate Ross Reservoir for the purpose of flood control as hereinafter provided.

(14) The amount of the annual charge to be paid under the license, as further amended, for recompensing the United States for the use, occupancy and enjoyment of its lands, exclusive of lands used for transmission line purposes, is reasonable as hereinafter fixed.

(15) Exhibit L, Sheets R-284 to-286, inclusive, (FPC Nos. 553-105 to-107, inclusive) and Exhibit K, Sheets R-1 to-10, inclusive, and R-16 to-18, inclusive (FPC Nos. 553-38 to-50, inclusive) insofar as it pertains to the operation of Ross Reservoir to elevation 1600 feet, conform to the Commission's rules and regulations.

(16) The licensee should file for approval before starting construction of the third step of Ross Dam Exhibit L drawings showing design details for the control of ice and debris on the Ross Dam.

(17) The licensee should be required to construct, maintain and operate gages and stream gaging stations at the locations specified in paragraph (5).

It is ordered that:

(18) The license be amended to authorize construction of the third step of Ross Dam to elevation 1620 feet, spillway crest at elevation 1582 feet, and the operation and maintenance of the project so constructed, subject to the following special conditions:

(a) The licensee shall begin construction of the third step on or before October 1, 1947, and shall complete such construction, with the exception of installing spillway gates, on or before October 1, 1948. The spillway gates shall be installed at such future date as the Commission may direct.

(b) The licensee shall file for approval before starting construction of the third step of Ross Dam the Exhibit L drawings described in paragraph (16).

(c) The licensee shall construct, maintain and operate gages and stream gaging stations at the locations specified in paragraph (5).

(d) Upon installation of the spillway gates it is provided that during the period November 1 to April 1 200,000 acre-feet of storage space in Ross Reservoir shall be reserved by the licensee for flood control and utilized as prescribed herein. The reservoir level will be drawn down to elevation

1,582.5 by November 1 of each year. When the flow of the Skagit River at the gaging station below Concrete exceeds 25,000 second-feet (gage reading 21.0) on the rising stage of a flood, the licensee shall release only such flows from the Ross Dam as are necessary to the normal production of electric energy at the Ross, Diablo, and Gorge plants. Storing of flood waters shall continue until the water level of the reservoir approaches the top of the gates (elevation 1,600) at which time the spillway gates will be opened gradually so as to hold the reservoir surface at that level or until all gates are completely opened. If all gates are opened fully during the storage period, the discharge shall be uncontrolled until the receding pool level approaches elevation 1,600 at which time the spillway gates shall be closed gradually so that the pool level will be approximately elevation 1,600 by the time the inflow and discharge decrease to 10,000 second-feet. When the flow of the Skagit River at Concrete is 50,000 second-feet (gage reading 26.0) or less on receding flood stages and the pool level is at or below elevation 1,600, the stored flood waters in Ross Reservoir shall be released at a rate not to exceed 10,000 second-feet until the level drops to elevation 1582.5 feet.

(19) Article 24 of the license be amended to change the annual charge for the purpose of recompensing the United States for the use, occupancy and enjoyment of its lands, other than those used for transmission lines only, from $1,191.46 to $1,699.32.

(20) The maps, plans and specifications, specified in paragraph (15) as conforming to the Commission's rules and regulations are hereby approved as part of the license for the project, except that Exhibit K is approved only insofar as it pertains to the operation of Ross Reservoir to elevation 1600 feet.

By the Commission.

Leon M. Fuquay,
Secretary.

Date of Issuance: May 2, 1947

Exhibit E Letter from SCL to Federal Power Commission, dated December 27, 1948

COPY

THE CITY OF SEATTLE
DEPARTMENT OF LIGHTING
E. R. HOFFMAN
SUPERINTENDENT
MEMBER, BOARD OF PUBLIC WORKS
SEATTLE 4, WASHINGTON

December 27, 1948

AIRMAIL

Federal Power Commission
Washington 25, D. C.

Amendment of License - Project
No. 553 - Third Step of Ross Dam

Gentlemen:

Please refer to our letter of January 21, 1948, returning copies of Amendment No. 4 of the license for Project No. 553, which was in accordance with the request contained in the Commission's letter of January 15, 1948. This was for the purpose of allowing the City to study the effects of the flood control provisions contained in the proposed Article 36 of the license as set forth in Amendment No. 4.

The flood control operation, specified in Article 36, of the reservoir created by Ross Dam after completion of the third step and installation of the spillway gates, provides that the water level in the reservoir be drawn down to elevation 1582.5' by November 1 of each year, in order that there shall be 200,000 acre-feet of storage space available for flood retention during the period from November 1 to April 1 of each seasonal year.

Up until the completion of the clearing and removal of timber scheduled for 1951-1952, the amount of reservoir space that will be available for flood control will be considerably in excess of the 200,000 acre-feet specified in the flood control clause. It is planned to install the spillway gates on the dam sometime during the construction of the Ross Power Plant so that the full head can be utilized by the generators when they are ready for operation. We expect now to have the first unit of the power plant ready for operation by the end of 1952.

The design of the Ross Power Plant is now being developed by our consulting engineers, Mr. John L. Savage and Associates. Until the design of this plant is thoroughly investigated, certain characteristics of the plant which are required in the study of the effects of flood control operation of the reservoir will not be available.

P 000625

Because of the many problems connected with the operation of Ross Reservoir, such as insufficient data on flood routing on the Skagit River, the position that the Skagit Project bears to regional power development rather than an isolated project, the fact that it was not the intent of the Commission to request flood regulation until after the spillway gates are installed, and that the installation of the spillway gates is not contemplated until the power plant is constructed, it is respectfully requested that the Commission omit Article 36 from the license for the Third Step of Ross Dam.

In lieu thereof, it is requested that provisions for flood control operation of the project which the Commission may deem necessary be made the subject of a separate amendment of license just prior to the time that such operations will be made possible by the installation of the spillway gates on Ross Dam. This will allow both the City and the Commission more adequate time to study and formulate a plan of flood control operation that will allow the fullest practicable use of the water resources available in the Skagit River for the production of power by this project.

Yours very truly,

E. R. Hoffman

Superintendent of Lighting

ECB:cri

Exhibit F Letter from Army Corps Seattle District to SCL, dated January 26, 1950

NPSGP
BJC/pl
25 Jan 50

800.5(Skagit Riv & Tribs) 26 JAN 1950 26 January 1950

800.5(Skagit Riv & Tribs)19 NPSGP

Mr. E. R. Hoffman, Superintendent
Department of Lighting
Third Avenue and Madison Street
Seattle 4, Washington

Dear Sir:

As you may know this office is preparing a report on the Skagit River, authorized by Congress, to determine the best plan for comprehensive development of the basin with respect to water uses and with particular emphasis being placed on flood control. In any plan for flood control, some amount of storage reservation in Ross Reservoir would be an important component. The value of flood storage at Ross was recently demonstrated during the November 1949 flood when river stages at Mount Vernon were reduced by an estimated three feet through the fortunate availability of sufficient storage above Ross Dam.

The question of flood control storage in Ross Reservoir has been the subject in the past of correspondence between this office and the Federal Power Commission. From time to time informal verbal discussion between representatives of our offices have been held. We are now at the stage where we want to reach a definite conclusion in the studies for determining the amount of flood control storage required and the operational plan for its use. In arriving at a solution I want to mutually consider the various aspects of the problem with your department so as to obtain an equitable plan. Among other factors, the amount of flood control storage is dependent upon its effect on power production and also on the maximum allowable river discharge below Ross Dam. Information on these points can probably best be given by your department. In order to assemble factual data and to formulate opinions on the Ross flood control storage plan to be recommended to the Federal Power Commission I would like to suggest a conference between you or your representative and members of my staff.

The flood storage plan discussed in the previous paragraph could not become effective until the spillway crest gates have been installed, which I understand may not be until sometime in 1952. For the interim period until then I am also interested in the possibility of some

800.225 (1-ny 800.5)

temporary storage plan which might at least give a measure of protection to the valley areas. The technical feasibility of such a plan is not known to us and I would appreciate your consideration of the possibilities of the idea for discussion at the suggested conference.

The place and time for the meeting will be left to your convenience. I feel that full discussion of the flood storage problem between our organizations will lead to the best solution for all concerned.

Very truly yours,

E. C. ITSCHNER
Colonel, Corps of Engineers
District Engineer

cc: Clark, Rpts S.

~~Clark~~
Hopkins
Buswell
~~Little~~
Brown
Sewol
Itschner /s
M&R

P 000603

Exhibit G Letter from SCL to Army Corps Seattle District, dated July 17, 1950

THE CITY OF SEATTLE

DEPARTMENT OF LIGHTING

ELIOT 7600

E. R. HOFFMAN

SUPERINTENDENT

MEMBER, BOARD OF PUBLIC WORKS

SEATTLE, 4, WASHINGTON

Col. D'Arezzo
Col. Itschner
Engr. Div.
Brown
Buswell
Hopkins
Clark
Mok

NPS 800.924 (Skagit River) 9

July 17, 1950

Colonel E. C. Itschner
District Engineer
U. S. Corps of Engineers
4735 East Marginal Way
Seattle 4, Washington

Dear Colonel Itschner:

1. Reference is made to your letter of February 10, 1950, in which it is suggested that the Lighting Department of the City of Seattle prepare certain estimates of the resources that would be obtained by operating the reservoir created by Ross Dam on the Skagit River in the interests of flood control.

2. Following your suggestion the Department has made a study of the operations of the reservoir to effect flood control in the amount of 200,000 acre-feet to be made available continuously from December 1 through February 15 of each seasonal year. In this study it was assumed that the Skagit River plants would be operated as a part of the Northwest Power Pool. It was also assumed that the flood control storage space of 200,000 acre-feet would be used as follows:

(1) The full amount of storage space would be available by December 1 of each year.
(2) Drawdown to make available the flood storage space would start not later than November 1.
(3) Except during flood periods, the full 200,000 acre-feet of storage space would be maintained until February 15.
(4) The flood storage space could be filled starting February 15 with at least a 30-day uniform refill period.
(5) When flood storage space becomes filled or partially filled from flood waters, the excess water stored would be released following the flood crest at a rate of 25,000 cfs.

Following the above listed assumptions, estimates were prepared showing the power revenue loss (or increase in power operating expense) over a 35-year period which represents the period for which streamflow data were available.

File
[illegible]

3 In this study 15 years out of 35 years of record were analyzed. These years were selected because of the relatively large amounts of power required from sources other than the Skagit River in order to carry the system loads which have been assumed. During these fifteen years a study of the purchase of surplus hydro electric power in August, September and October of each year under normal operation without flood control and under flood control operation requiring 200,000 acre-feet of flood control space, indicates that the purchases of power required during the period from January 1 to April 30, when power is at a premium, could be reduced by normal operation as compared with flood control operation by 426,823,000 kwh. The various annual amounts of these reductions in the purchase of premium power are shown on the attached tabulation.

4 It has been assumed from study of reports of the Bonneville Power Administration that relatively large blocks of surplus hydro energy will be available from the Government's Columbia River Projects each year during the period from May 1 to October 31. By purchasing such surplus energy from the Columbia River System in the months of August through October, Ross reservoir could be held full up to the first of November. Such purchases could be made under present rates at 2.5 mills per kwh. This energy could be used to displace necessary purchases of energy during the period from January 1 to May 1 when there would be no surplus hydro energy available. Energy requirements during this period would have to come from relatively high cost steam generating sources. The City's existing steam resources are inefficient compared with present-day standards, energy costs running from 1.3¢ to 2¢ per kwh depending on the load factor of the operation. From presently available information it appears that a modern steam generating plant would produce energy at a cost of about 8.5 mills per kwh on a 57% annual load factor basis. The energy requirements in this study are at a much lower load factor than this so that it has been assumed that the average cost for such energy when produced by a modern oil fired steam plant would amount to 1¢ per kwh. As mentioned above, in fifteen years out of 35 years of record, 426,823,000 kwh of energy could, under normal operation, be purchased at a rate of 2.5 mills per kwh or $1,269,142.50 which, with 200,000 acre-feet of flood control reserve in Ross reservoir would have to be supplied from steam resources at a rate of 1¢ per kwh or $4,268,230.

5 The difference in the two costs would be $3,201,172.50 which, spread over a 35-year period would amount to an annual cost (increased operating expense) of $91,462 chargeable to the supply of flood control space in Ross reservoir.

6 In connection with the reserve of 100,000 acre-feet of flood control space, our analysis indicates that there would be very little difference between operating with this amount of flood control reserve and operating with no flood control space. Apparently supplying a 100,000 acre-feet of flood control reserve would result in no increase in operating expense.

7 At this point it is suggested that further consideration be given to the rate at which accumulated flood waters should be released after a flood crest. The City has just completed a new diversion dam at the Gorge plant intake. There are two sluice gates at this dam capable of discharging a total of 16,000 cfs with a forebay elevation of 490 feet. In addition to the sluice gates there is an overflow spillway 180 feet long containing 36 flashboards 5 feet in width by 10 feet in height. The discharge over the flashboards with a forebay elevation at 490 feet would amount to 3,000 cfs. The total capacity that can be discharged through the tunnel and powerplant will amount to 6,000 cfs. This would give a total discharge capacity at this installation of 25,000 cfs. Due to the fact that we may not be able to maintain full load on the power plant at all times, it appears that our discharge at this point would be limited to 20,000 cfs. Any amount greater than this might take out the flashboards at the diversion dam, replacement of which would represent a fair item of additional operating expense. It is suggested, therefore, that in connection with the discharge of accumulated flood waters, the maximum rate of flow be limited to 20,000 cfs at the Newhalem gaging station. Allowing for sidestream discharge between this point and Ross dam, a discharge of about 17,000 cfs could be maintained at Ross dam. About 4,000 cfs of this amount would represent Ross reservoir inflow, giving a net discharge from storage of about 13,000 cfs. At this rate it would take about 8 days to dissipate the full 200,000 acre-feet of accumulated flood waters. It might be added that in extreme emergencies when it appears that a second flood is probable, the flashboards at the Gorge dam could be washed down and discharges could then be made up to 40,000 cfs without seriously damaging City Light installations. The rate of discharge which could be handled downstream from our Gorge plant without damage is unknown to us. We have no surveys of the River below that point.

8 There are being mailed to you under separate cover, prints of our Drawing No. ST-84 which outlines graphically the results of the foregoing study. We shall be glad to discuss this matter with you and your staff after you have had time to go over our estimates.

Yours very truly,

Superintendent of Lighting

ECB:gdr

Encl. Tabulation

ROSS RESERVOIR FLOOD CONTROL STUDY
SUMMARY OF ENERGY IN MEGAWATT-HOURS

Periods	PURCHASES OF ENERGY			PRODUCTION OF SURPLUS ENERGY			ENERGY WASTED		
	With Flood Control	Without Flood Control	Difference	With Flood Control	Without Flood Control	Difference	With Flood Control	Without Flood Control	Difference
1914-1915									
Aug-Dec	210 326	210 326	0	99 000	3 237	95 763	83 405	0	83 405
Jan-Apr	247 587	62 641	184 946	0	0	0	0	0	0
May-Jul	269 120	269 120	0	0	0	0	0	0	0
Total	727 033	542 087	184 946	99 000	3 237	95 763	83 405	0	83 405
1915-1916									
Aug-Dec	223 326	223 326	0	71 737	71 737	0	0	0	0
Jan-Apr	0	0	0	0	0	0	0	0	0
May-Jul	0	0	0	257 143	257 143	0	290 231	290 231	0
Total	223 326	223 326	0	328 880	328 880	0	290 231	290 231	0
1916-1917									
Aug-Dec	186 711	186 711	0	108 733	57 228	51 505	0	0	0
Jan-Apr	54 392	378	54 014	0	0	0	0	0	0
May-Jul	0	0	0	106 829	106 829	0	89 492	89 492	0
Total	241 103	187 089	54 014	215 562	164 057	51 505	89 492	89 492	0
1925-1926									
Aug-Dec	292 016	292 016	0	17 658	0	17 658	0	0	0
Jan-Apr	80 162	61 963	18 199	0	0	0	0	0	0
May-Jul	280 879	280 879	0	0	0	0	0	0	0
Total	653 057	634 858	18 199	17 658	0	17 658	0	0	0
1926-1927									
Aug-Dec	232 808	232 808	0	59 543	60 420	- 877	468	0	468
Jan-Apr	0	0	0	0	0	0	0	0	0
May-Jul	0	0	0	108 533	108 533	0	42 165	42 165	0
Total	232 808	232 808	0	168 076	168 953	- 877	42 633	42 165	468

Periods	PURCHASES OF ENERGY			PRODUCTION OF SURPLUS ENERGY			ENERGY WASTED		
	With Flood Control	Without Flood Control	Difference	With Flood Control	Without Flood Control	Difference	With Flood Control	Without Flood Control	Difference
1928-1929									
Aug-Dec	211 439	211 439	0	52 803	0	52 803	0	0	0
Jan-Apr	79 104	24 548	54 556	0	0	0	0	0	0
May-Jul	228 738	228 738	0	0	0	0	0	0	0
Total	519 281	464 725	54 556	52 803	0	52 803	0	0	0
1929-1930									
Aug-Dec	307 573	307 573	0	9 665	9 665	0	0	0	0
Jan-Apr	0	0	0	0	0	0	0	0	0
May-Jul	23 175	23 175	0	0	0	0	0	0	0
Total	330 748	330 748	0	9 665	9 665	0	0	0	0
1930-1931									
Aug-Dec	264 396	264 396	0	42 343	42 343	0	0	0	0
Jan-Apr	0	0	0	0	0	0	0	0	0
May-Jul	121 123	121 123	0	0	0	0	0	0	0
Total	385 519	385 519	0	42 343	42 343	0	0	0	0
1935-1936									
Aug-Dec	198 576	198 576	0	25 795	25 795	0	0	0	0
Jan-Apr	0	0	0	0	0	0	0	0	0
May-Jul	0	0	0	112 818	112 818	0	0	0	0
Total	198 576	198 576	0	138 613	138 613	0	0	0	0
1936-1937									
Aug-Dec	304 525	304 525	0	10 095	0	10 095	0	0	0
Jan-Apr	10 424	0	10 424	0	1 187	- 1 187	0	0	0
May-Jul	0	0	0	96 429	96 429	0	32 191	32 191	0
Total	314 949	304 525	10 424	106 524	97 616	8 908	32 191	32 191	0
1938-1939									
Aug-Dec	287 889	287 889	0	91 376	133 999	-42 623	41 624	0	41 624
Jan-Apr	0	0	0	0	0	0	0	0	0
May-Jul	0	0	0	176 198	176 198	0	39 580	39 580	0
Total	287 889	287 889	0	267 574	310 197	-42 623	81 204	39 580	41 624

Periods	PURCHASES OF ENERGY			PRODUCTION OF SURPLUS ENERGY			ENERGY WASTED		
	With Flood Control	Without Flood Control	Difference	With Flood Control	Without Flood Control	Difference	With Flood Control	Without Flood Control	Difference
1939-1940									
Aug-Dec	257 926	257 926	0	71 203	0	71 203	13 431	0	13 431
Jan-Apr	13 536	0	13 536	0	0	0	0	0	0
May-Jul	202 614	121 780	80 834	0	0	0	0	0	0
Total	474 076	379 706	94 370	71 203	0	71 203	13 431	0	13 431
1940-1941									
Aug-Dec	208 672	208 672	0	56 589	0	56 589	0	0	0
Jan-Apr	191 492	131 733	59 759	0	0	0	0	0	0
May-Jul	269 418	269 418	0	0	0	0	0	0	0
Total	669 582	609 823	59 759	56 589	0	56 589	0	0	0
1942-1943									
Aug-Dec	336 376	336 376	0	46 991	46 991	0	0	0	0
Jan-Apr	0	0	0	0	0	0	0	0	0
May-Jul	0	0	0	256 104	256 104	0	88 466	88 466	0
Total	336 376	336 376	0	303 095	303 095	0	88 466	88 466	0
1943-1944									
Aug-Dec	222 888	222 888	0	30 348	368	29 980	0	0	0
Jan-Apr	191 532	160 143	31 389	0	0	0	0	0	0
May-Jul	300 288	300 288	0	0	0	0	0	0	0
Total	714 708	683 319	31 389	30 348	368	29 980	0	0	0
TOTAL PERIOD									
Aug-Dec	3745 447	3745 447	0	793 879	451 783	342 096	138 928	0	138 928
Jan-Apr	868 229	441 406	426 823	0	1 187	- 1 187	0	0	0
May-Jul	1695 355	1614 521	80 834	1114 054	1114 054	0	582 125	582 125	0
TOTAL	6309 031	5801 374	507 657	1907 933	1567 024	340 909	721 053	582 125	138 928

ECB:gdr
7-18-50

Exhibit H Original Skagit Project License with Amendments, Amendment No. 9 (revising Article 36), dated September 17, 1954

AMENDMENT NO. 9
INSTRUMENT NO. 13

FP-179

UNITED STATES OF AMERICA
FEDERAL POWER COMMISSION

Before Commissioners: Jerome K. Kuykendall, Chairman; Claude L. Draper, Nelson Lee Smith, Seaborn L. Digby and Frederick Stueck.

In the Matter of	)	
	)	Project No. 553
The City of Seattle	)	

ORDER REVISING ARTICLE 36 OF LICENSE (MAJOR)

Request was filed April 13, 1954 by The City of Seattle, Washington, licensee for major Project No. 553, for revision of Article 36 of the license for the project pertaining to flood control operation of Ross Reservoir so as to reflect therein revised detail regulations for use of flood control storage prepared by the United States Corps of Engineers.

The Corps of Engineers has reported that the revision is the result of studies made by its Seattle District in the State of Washington and has been mutually agreed to by the licensee and the Corps.

The Commission finds:

It is in the public interest to revise Article 36 of the license for Project No. 553 in conformity with the above-mentioned detail regulations.

The Commission orders:

(A) Article 36 of The City of Seattle's license for Project No. 553 is hereby revised to read as follows:

Article 36: The Licensee shall reserve a maximum of 120,000 acre-feet of storage space in Ross Reservoir for flood control during the period October 1 to March 15. The required storage space, if not previously obtained through power withdrawals, shall be provided by drawing down the reservoir at a rate equalling or exceeding a uniform draw-down rate from zero on October 1 to 60,000 acre-feet on November 15 and similarly drawing down, but at a more rapid rate to provide the full 120,000 acre-feet on December 1, with the reservoir level at elevation 1,589.4 feet. Whenever the United States Weather Bureau forecasts that the discharge at the gaging station near Concrete will equal or exceed 90,000 second-feet in eight hours on a rising stage of a flood, the Licensee shall, as a maximum, release only such flows from Ross Dam as are necessary to the normal production of electric energy at the Ross, Diablo and Gorge plants, but not more than a mean daily discharge of 5,000 second-feet, plus or minus 20 percent allowance for operational latitude. If the reservoir pool should reach the elevation of 1,600 feet before the flood recession occurs, the gates shall be operated to induce maximum surcharge storage to effect maximum reduction of discharge downstream. If surcharge storage is induced, it shall be maintained as long as possible, or until flood recession occurs. After flood recession starts, releases from Ross Reservoir shall be increased until discharge equals inflow. Storage shall be evacuated as rapidly as possible without endangering downstream installations as soon as the discharge at Concrete recedes to 90,000 second-feet and a falling trend is forecast. "Details of Regulation for Use of Storage Allocated for Flood Control in Ross Reservoir, Skagit River, Washington (Revised March 15, 1954)" is incorporated by reference as a part of this article.

(B) This order shall become final within thirty (30) days from the date of its issuance unless application for rehearing shall be filed as provided by Section 313 (a) of the Federal Power Act, and failure to file such an application shall constitute acceptance of this instrument. In acknowledgment of the acceptance of this instrument, it shall be signed for the licensee and returned to the Commission within sixty (60) days from the date of issuance of this order.

By the Commission.

Leon M. Fuquay,
Secretary.

Adopted: September 17, 1954

Issued: September 22, 1954

IN TESTIMONY OF ACCEPTANCE of all the provisions, terms and conditions of this instrument, The City of Seattle, Washington, this 15th day of October, 1954, has caused its corporate name to be signed hereto by PAUL J. RAVER, its ____________ Superintendent of Lighting, and its corporate seal to be affixed hereto and attested by W. C. THOMAS, its City Clerk ~~xxxxxxxx~~ pursuant to a resolution of its Board of Public Works duly adopted on the 6th day of October, 1954, a certified copy of the record of which is attached hereto.

THE CITY OF SEATTLE

____
Superintendent of Lighting

Attest:

____
City Clerk ~~xxxxxxxx~~

Exhibit I U.S. Army Corps of Engineers, Seattle District, "Army Corps of Engineers dam operations significantly reduced downstream flood risk," November 19, 2021

US Army Corps of Engineers

Seattle District, USACE

News Release

Army Corps of Engineers dam operations significantly reduced downstream flood risk

Published Nov. 19, 2021

SEATTLE --

As U.S. Army Corps of Engineers' flood response teams were supporting local communities in Skagit, Whatcom and Snohomish counties over the weekend, Seattle District water managers were busy regulating flows at five dams to reduce downstream flood risk. Without those efforts, levees in Mount Vernon would have overtopped, leading to catastrophic flooding.

Seattle District's Reservoir Control Center worked 24-hour operations during the flood events to monitor and regulate Howard Hanson, Mud Mountain, Upper Baker, Ross and Wynoochee dams. The Corps owns and operates Howard Hanson and Mud Mountain dams and directs operations of the utility-owned projects during flood events per established agreements.

In the Skagit River Basin, Corps water managers began actively directing operations at Puget Sound Energy-owned Upper Baker Dam and Seattle City Light-owned Ross Dam November 14.

Corps operations at these two upper Skagit River dams stored inflows and decreased peak flow by 40 percent, reducing the peak river stage at Concrete, Washington, by more than eight feet and preventing the overtopping of levees in Mount Vernon, Washington.

The flood event included back-to-back atmospheric rivers – long, flowing columns of condensed water vapor that act like a conveyor belt, carrying vapor for thousands of miles from out over the ocean. When an atmospheric river hits the West Coast, it can generate a series of storms, with each storm producing inches of rain.

This flood with its corresponding atmospheric rivers brought heavy precipitation to the region and broke inflow records in the upper Skagit River. Inflows to Ross Dam were the highest on record at approximately 60,000 cubic feet per second (cfs) and have a 0.2 percent chance of occurring any given year. Inflows to Upper Baker Dam also broke records with inflows of 41,000 cfs, which has a 1 percent chance of occurring any year. Outflow from both dams were significantly reduced during the peak of the flood, lowering downstream flows by as much as 80,000 cfs.

Ross Dam and Upper Baker Dam are mandated to provide storage space in their reservoirs for use by the Corps during the flood season in Western Washington. Both PSE and SCL are proactive partners and often provide additional non-required storage space. During this event, Ross Dam was able to provide more than twice the required storage space which was integral to reducing the peak flood flow. Additionally, Corps water managers proactively conserved critical reservoir space early in the event to be able to reduce flows during the peak of the flood. Without this additional storage and careful reservoir management, the flood peak at Mount Vernon would have overwhelmed the levee and flood wall system.

The reservoir at Ross Dam peaked within 3 inches of the normal full level and the reservoir at Upper Baker Dam peaked within 9 inches of the normal full level. Both reservoirs are currently lowering as water stored during the flood is released. “This causes the Skagit River level to stay more elevated than it would naturally,” said Sonja Michelsen, Seattle District’s Western Washington senior water manager. “However, flows will remain much lower than the peak flow seen on Monday, November 15.”

The Corps began regulating City of Aberdeen-owned Wynoochee Dam November 15 for approximately 8 hours before returning control to Tacoma Public Utilities, which operates the dam. During peak operations the inflows to the dam were almost 10,000 cubic feet per second (cfs) and Corps water managers held back some of the flow, releasing 7,000 cfs. The peak river flow observed at Montesano was 13,800 cfs.

At Howard Hanson Dam, Green River inflows rose above 10,000 cfs and Corps water managers held back over 5,000 cfs during the event’s peak. Mud Mountain Dam inflows for the White River were above 13,600 cfs and managers targeted releases below 6,000 cfs. Releases are being managed at both dams to evacuate stored water from last week's flood event.

“Public safety is our number one priority, and our next concern is reducing the reservoir pools,” said Michelsen. “It’s important to quickly empty the storage space in the reservoirs after a flood to remain prepared for future flood events.”

###

Contact
Scott Lawrence
206-764-6896
aaron.s.lawrence@usace.army.mil

Release no. 21-014

Seattle District flood response Skagit River

Exhibit J Espinoza, V., D.E. Waliser, Bin-Guan, D.A. Lavers, F. M. Ralph (2018). Global Analysis of Climate Change Projection Effects on Atmospheric Rivers

AGU100 ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

RESEARCH LETTER
10.1029/2017GL076968

Key Points:
- Globally, atmospheric rivers (ARs) are ~10% fewer, ~25% longer, ~25% wider, and with stronger moisture transport under the RCP8.5 scenario
- In the midlatitudes where ARs are most frequent, AR conditions are ~50–60% more frequent and AR transport is ~20% stronger in the future
- Systematic low biases exist in the midlatitudes in historical AR frequency (~10%), zonal (~15%), and meridional (~25%) moisture transport

Supporting Information:
- Supporting Information S1

Correspondence to:
D. E. Waliser,
duane.e.waliser@jpl.nasa.gov

Citation:
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Global Analysis of Climate Change Projection Effects on Atmospheric Rivers

Vicky Espinoza[1,2], Duane E. Waliser[2], Bin Guan[2,3], David A. Lavers[4], and F. Martin Ralph[5]

[1]Sonny Astani Civil and Environmental Engineering Department, University of Southern California, Los Angeles, CA, USA, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, [3]Joint Institute for Regional Earth System Science and Engineering, University of California, Los Angeles, CA, USA, [4]European Centre for Medium-Range Weather Forecasts, Reading, UK, [5]Center for Western Weather and Water Extremes, Scripps Institution of Oceanography at University of California, San Diego, CA, USA

Abstract A uniform, global approach is used to quantify how atmospheric rivers (ARs) change between Coupled Model Intercomparison Project Phase 5 historical simulations and future projections under the Representative Concentration Pathway (RCP) 4.5 and RCP8.5 warming scenarios. The projections indicate that while there will be ~10% fewer ARs in the future, the ARs will be ~25% longer, ~25% wider, and exhibit stronger integrated water vapor transports (IVTs) under RCP8.5. These changes result in pronounced increases in the frequency (IVT strength) of AR conditions under RCP8.5: ~50% (25%) globally, ~50% (20%) in the northern midlatitudes, and ~60% (20%) in the southern midlatitudes. The models exhibit systematic low biases across the midlatitudes in replicating historical AR frequency (~10%), zonal IVT (~15%), and meridional IVT (~25%), with sizable intermodel differences. A more detailed examination of six regions strongly impacted by ARs suggests that the western United States, northwestern Europe, and southwestern South America exhibit considerable intermodel differences in projected changes in ARs.

Plain Language Summary Atmospheric rivers (ARs) are elongated strands of horizontal water vapor transport, accounting for over 90% of the poleward water vapor transport across midlatitudes. These "rivers in the sky" have important implications for extreme precipitation when they make landfall, particularly along the west coasts of many midlatitude continents (e.g., North America, South America, and West Europe) due to orographic lifting. ARs are important contributors to extreme weather and precipitation events, and while their presence can contribute to beneficial rainfall and snowfall, which can mitigate droughts, they can also lead to flooding and extreme winds. This study takes a uniform, global approach that is used to quantify how ARs change between Coupled Model Intercomparison Project Phase 5 historical simulations and future projections under the Representative Concentration Pathway (RCP) 4.5 and RCP8.5 warming scenarios globally. The projections indicate that while there will be ~10% fewer ARs in the future, the ARs will be ~25% longer, ~25% wider, and exhibit stronger integrated water vapor transports under RCP8.5. These changes result in pronounced increases in the frequency (integrated water vapor transport strength) of AR conditions under RCP8.5: ~50% (25%) globally, ~50% (20%) in the northern midlatitudes, and ~60% (20%) in the southern midlatitudes.

1. Introduction

Atmospheric rivers (ARs) are elongated strands of horizontal water vapor transport, accounting for over 90% of the poleward water vapor transport across midlatitudes (Zhu & Newell, 1998). These "rivers in the sky" have important implications for extreme precipitation when they make landfall, particularly along the west coasts of many midlatitude continents (e.g., North America, South America, and western Europe) and especially when encountering orographic lifting (e.g., Neiman et al., 2009; Ralph et al., 2004). ARs are important contributors to extreme weather and precipitation events, and while their presence can contribute to beneficial rainfall and snowfall (Dettinger et al., 2011; Guan et al., 2010), which can mitigate droughts (Dettinger, 2013), they can also lead to flooding (e.g., Lavers et al., 2011; Leung & Qian, 2009; Neiman et al., 2011; Ralph et al., 2006, 2013; Ralph & Dettinger, 2011) and extreme winds (Waliser & Guan, 2017). These important impacts have motivated a number of climate change studies on ARs, with studies to date focusing mainly only on the west coasts of North America (Dettinger, 2011; Gao et al., 2015; Hagos et al., 2016; Payne &

Table 1
Comparison of Mean Changes in AR Frequency (Percent of Time Steps) and IVT ($kg \cdot m^{-1} \cdot s^{-1}$) Between the Current Study and Previous Studies for the Western U.S. and Western Europe

Publication	Historical period	Projection period	Geographic region	AR Freq (± %)	AR IVT (± %)
Dettinger (2011)	**1961–2000**	**2046–2065; 2081–2100**	**CA Coast**	**+30**	**+10**
Pierce et al. (2013)	**1985–1994**	**2060s**	**CA Coast**	**+25–100**	**--**
Warner et al. (2015)	**1970–1999**	**2070–2099**	**U.S. West Coast**	**+230–290**	**+30**
Payne and Magnusdottir (2015)	**1980–2005**	**2070–2100**	**U.S. West Coast**	**+23–35**	**--**
Gao et al. (2015)	**1975–2004**	**2070–2099**	**U.S. West Coast**	**+50–600**	**--**
Hagos et al. (2016)	**1920–2005**	**2006–2099**	**U.S. West Coast**	**+35**	**--**
Shields and Kiehl (2016a)	**1960–2005**	**2055–2100**	**U.S. West Coast**	**+8**	**--**
Espinoza et al. (2018, current study)	**1979–2002**	**2073–2096**	**U.S. West Coast**	**+45**	**+30**
Lavers et al. (2013)	*1980–2005*	*2074–2099*	*W. Europe*	*+50–100*	--
Gao et al. (2016)	*1975–2004*	*2070–2099*	*W. Europe*	*+127–275*	*+20–50*
Ramos et al. (2016)	*1980–2005*	*2074–2099*	*Europe*	*+100–300*	*+30*
Shields and Kiehl (2016a)	*1960–2005*	*2055–2100*	*North Atlantic*	*+4*	--
Espinoza et al. (2018, current study)	*1979–2002*	*2073–2096*	*W. Europe*	*+60*	*+30*

Note. The bold (italic) region is previous studies focusing on the U.S. West Coast (western Europe). The studies are ordered from oldest to most recent within each geographic region (bold and italic). Note that each of the studies mentioned above differ in their methodologies, models used, and their study periods limiting their comparability.

Magnusdottir, 2015; Pierce et al., 2013; Radić et al., 2015; Shields & Kiehl, 2016a, 2016b; Warner et al., 2015) and Europe (Gao et al., 2016; Lavers et al., 2013; Ramos et al., 2016; Shields & Kiehl, 2016a).

The first climate change study on ARs was conducted by Dettinger (2011) and focused on landfalling ARs in California using seven Coupled Model Intercomparison Project (CMIP) Phase 3 models with the A2 greenhouse-gas emissions scenario. This study found AR frequency increases of about 30% depending on the model by the end of the 21st century and noted increases in storm temperature, length of AR season, and peak AR intensity values. Note that climate change studies on ARs have generally defined AR frequency as the fraction of days a particular grid point has an AR detected over it. Warner et al. (2015) extended the consideration to a larger area along the west coast of North America using 10 CMIP5 (Taylor et al., 2012) models for a historical period (1970–1999) and projection period (2070–2099) for the Representative Concentration Pathway (RCP) 8.5 warming scenario. This study conducted a multi-model mean (MMM) analysis with results indicating ~230–290% increase in AR days. The analysis also showed that there would be an increase in extreme values of integrated water vapor transport (IVT) magnitude and IWV of ~30%. Precipitation values for the MMM showed ~15–39% increase. Using more CMIP5 models (a total of 24), Gao et al. (2015) indicated an ~50–600% increase in AR days under RCP8.5, depending on the season and landfall location along western North America. Another study by Payne and Magnusdottir (2015) using 28 CMIP5 models found 23–35% increases in projected AR landfall dates in this region under RCP8.5. Hagos et al. (2016) showed increases in projected AR landfall days by 35% under RCP8.5 based on a 29-member ensemble of the National Center for Atmospheric Research Community Earth System Model. Other studies have also examined projected AR changes in western North America, as summarized in Table 1.

For the European region, Lavers et al. (2013) used five CMIP5 models, comparing historical (1980–2005) and projection (2074–2099) periods for the RCP4.5 and RCP8.5 scenarios. This study also used an IVT-based threshold approach for detecting ARs. This study found that AR frequency approximately doubled in Britain under RCP8.5 and determined that the change was dominated by the thermodynamic (moistening) response to warming rather than from the influence of wind changes. Gao et al. (2016) conducted a study with a focus on comparing the influences of thermodynamic and dynamic effects on ARs and the quantification of the number of AR days across the European sector. By using 24 CMIP5 models, this study found that AR frequency increased by ~127–275% by the end of the century under RCP8.5. Not only did the study find that the projected increases in AR frequency were influenced by thermodynamic processes but found that variability in wind speed and direction related to shifts in the midlatitude jet stream played a dominant role in the changes of ARs in the European sector. Other studies have also examined projected AR changes in Europe, as summarized in Table 1.

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While all the studies discussed and cited above have tended toward the same general conclusions (Table 1), that is, finding an increase in AR frequency and IVT, they have been limited to two regions in the Northern Hemisphere. A uniform global assessment of climate change impacts on ARs has not been performed despite the global presence and impacts of ARs (Guan & Waliser, 2015; Waliser et al., 2012; Waliser & Guan, 2017; Zhu & Newell, 1998). For example, despite the number of studies performed on western North America and western Europe, the differences in data sets and methodologies used make it challenging to use these studies to compare impacts of climate change effects on ARs in these two regions. This study addresses this research gap by analyzing climate change impacts on AR frequencies and IVT using a globally consistent approach on historical climate simulations and future projections of climate change from CMIP5.

2. Models and Methodology

2.1. CMIP5 Model Data

IVT values were constructed from daily values of 3-D wind and water vapor model outputs at four pressure levels between 500 and 1,000 hPa inclusive, namely, the data described in Lavers et al. (2015; their Table S1). We used 21 out of the 22 models examined in that study because the IVT data for one model were not available at the time of this analysis. The horizontal resolution of the models ranges from 1.125° to 2.813°. The study periods were 1979–2002 from the historical simulations and 2073–2096 from the RCP4.5 and RCP8.5 scenarios, determined as a time frame that contains the maximum number of overlapping years among all the models and one that spans the same number of years for the historical and the two RCP runs. The more stringent requirement on the consistency in data set period resulted in three fewer years included for analysis relative to Lavers et al. (2015).

2.2. AR Global Detection Algorithm

The AR global detection algorithm introduced in Guan and Waliser (2015) was used. Notable AR criteria used in the algorithm include IVT magnitude at each grid cell within a contiguous region ("object") being above the 85th percentile for that grid cell and season, the length of the object being greater than 2000 km, and the length-to-width ratio greater than 2. For a given model, AR detection for the historical simulation and future projections (RCP4.5 and RCP8.5) are all based on the IVT 85th percentile derived from the historical simulation. AR detection and subsequent calculation of AR frequency and IVT are based on the respective horizontal resolution of each individual model. Regridding to a common grid is done only when calculating the multimodel ensemble mean. It is expected that the inherent differences between different models are much larger than the sensitivity of the results to the choice of horizontal resolution used for AR detection and subsequent calculations (e.g., Guan & Waliser, 2017). In that regard, the step at which regridding is introduced into the calculations (e.g., before or after AR detection) is not an important consideration in the current analysis. AR detection results based on the Guan and Waliser (2015) algorithm was found to be consistent with regional AR detection methods developed for western North America (Neiman et al., 2008), Britain (Lavers et al., 2011), and East Antarctica (Gorodetskaya et al., 2014), with over ~90% agreement in detected AR landfall dates.

2.3. AR Frequency and IVT Analysis

The AR frequency is calculated as the number of AR days detected at each grid cell for the given historical or future projection period normalized by the total number of days in the given period. Mean AR IVT at each grid cell is based on averaging the IVT values over the days detected as ARs. Once AR frequency and IVT have been computed for each individual model, they are (bi-linearly) interpolated to a common 1.5° × 1.5° grid (which matches the grid of the ERA-Interim reanalysis used as the observational reference) to create MMM maps.

To illustrate the calculation procedures, a set of histograms, shown in Figure 1a, are created for a single location in the southeast Pacific Ocean (61°S, 216.25°E) from the Geophysical Fluid Dynamics Laboratory Coupled Model 3 (GFDL-CM3) model simulations. The red (blue) histogram includes all IVT values at that point for the historical (RCP8.5 projection) period. The number of IVT values sampled in each histogram is shown in the plot's legend. Additional histograms delineate the IVT values of the detected ARs for the historical (pink) and RCP8.5 (light blue) simulations—with both using the IVT 85th percentile derived from the historical period for detecting ARs. For this location and model, the histograms show that the RCP8.5 scenario results in a significant increase (~140%) in the number of AR days given the historical IVT threshold. An additional

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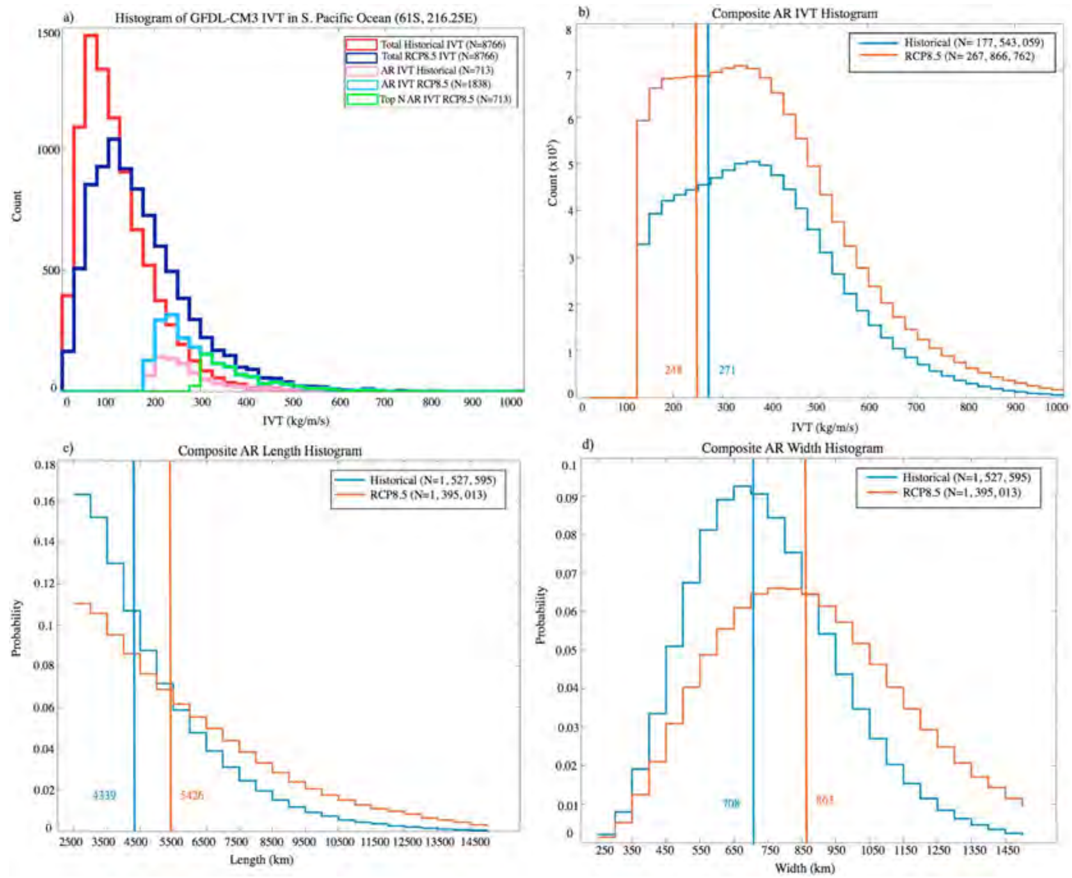

Figure 1. (a) Histograms of IVT values (kg · m^{-1} · s^{-1}) at a single grid point (61°S, 216.25°E) in the South Pacific Ocean from the GFDL-CM3 simulations. The red (dark blue) histogram includes all (i.e., both AR and non-AR grid cells) IVT values for the historical period, that is, 1979–2002 (RCP8.5 period, i.e., 2073–2096). The pink (light blue) histogram includes the IVT values associated with only AR events in the historical period (AR events in the RCP8.5 scenario based on the AR IVT threshold from the historical period). The green histogram includes the top N AR IVT values for the RCP8.5 scenario, where N is determined by number of AR events from the historical simulation (i.e., 713). Thus, the number of IVT values contributing to the pink and green histograms is the same. Multimodel ensemble histograms of (b) IVT values at each grid cell within the ARs, (c) AR lengths (km), and (d) AR widths (km) for the historical (blue) and RCP8.5 (orange) simulations, with vertical bars representing the overall mean. N values in (b) are the total number of AR grid cells; N values in (c) and (d) are the total number of AR objects.

histogram (green) shows the top N AR IVT values from the RCP8.5, where N is determined by the number of AR days in the historical simulation; thus, the pink and green histograms have the same number of AR IVT values.

The AR frequency results discussed in section 3 (e.g., shadings in Figure 2) are essentially referring to AR frequencies as represented by the light blue and pink histograms. The AR IVT values discussed below (e.g., vectors in Figure 2) are based on averages of the IVT values within the pink and green histograms. Thus, the mean AR IVT to be compared below between the historical and future scenarios is based on averaging over the same number of the most extreme IVT values from each simulation.

3. Results

3.1. Historical Simulations

AR frequency and IVT for the historical, RCP4.5 and RCP8.5 simulations are shown in Figure 2. Also shown is the ERA-Interim AR frequency and IVT for 1979–2002 (Figure 2a; cf. Guan & Waliser, 2015) as the observational

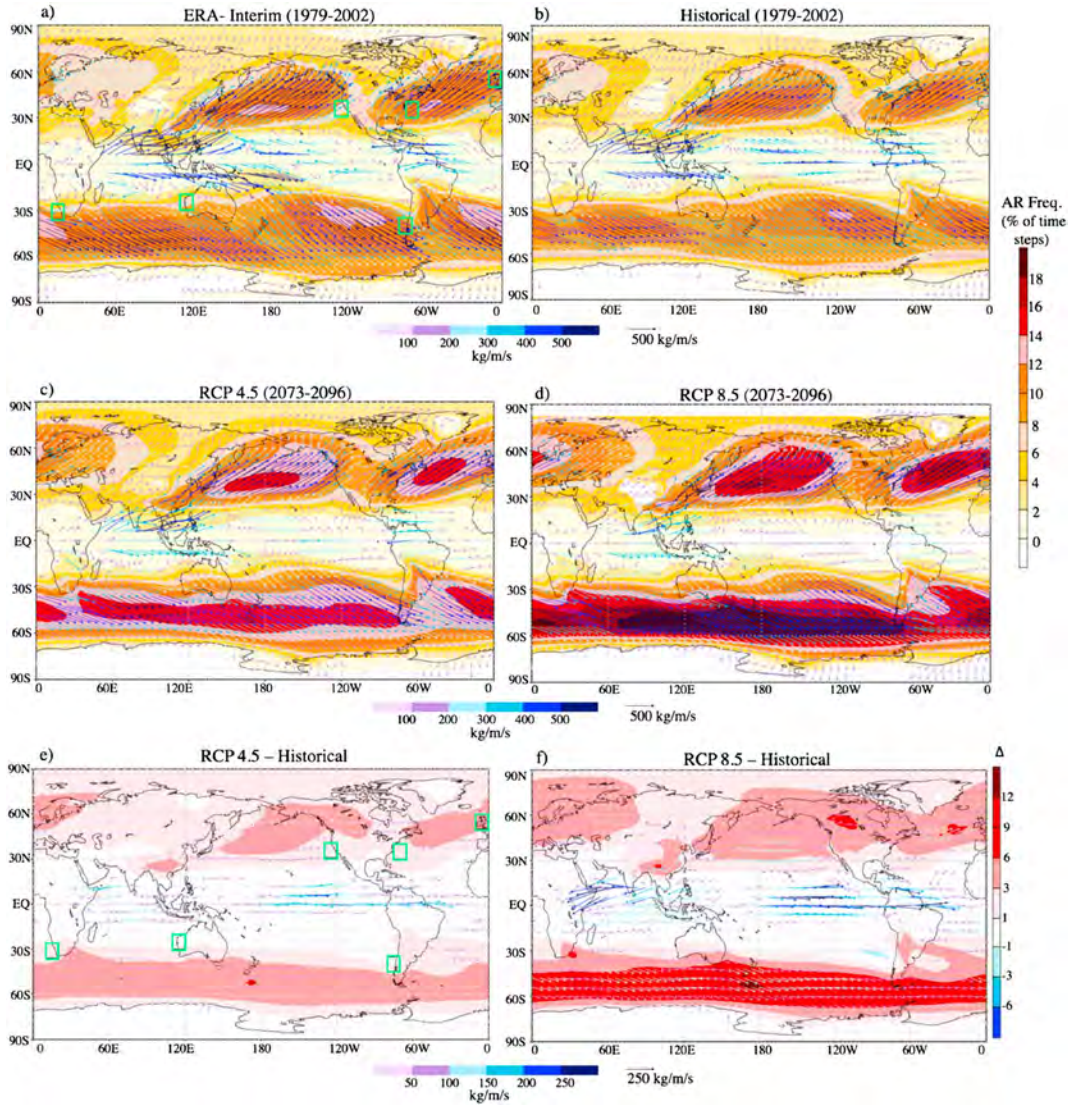

Figure 2. AR frequency (shading; percent of time steps) and IVT (vectors; kg · m^{-1} · s^{-1}) for (a) ERA-Interim reanalysis for the historical period (1979–2002) with six green boxes depicting regions analyzed in Figures S2 and S3, (b) the MMM for the 21 CMIP5 models analyzed in this study for the historical period (1979–2002), (c) RCP4.5 warming scenario (2073–2096), and (d) RCP8.5 warming scenario (2073–2096), (e) the difference between (c) and (b) with six green boxes depicting regions analyzed in Figures S2 and S3, and (f) the difference between (d) and (b). Vector magnitudes are indicated by both their length and their color based on the blue color bar.

reference. Comparing Figures 2a and 2b shows that the MMM is a good representation of the observational reference. For AR frequency, and zonal and meridional IVT components, the spatial correlations (root mean square error) between the historical simulation and the reference are 0.98, 0.93, and 0.97 (0.93%, 93.14 kg · m^{-1} · s^{-1}, and 51.79 kg · m^{-1} · s^{-1}), respectively. The good quantitative agreement between Figures 2a and 2b mainly stems from the MMM capturing the strong latitudinal dependence of the AR frequency and IVT values and the dominant zonal asymmetries of the midlatitude patterns (see red and blue lines in Figures 3c, 3f, and 3i). Direct comparison of the MMM with ERA-Interim shows that the AR frequencies are generally biased low by ~10% in midlatitude regions, with zonal (meridional) IVT biased low by ~15% (25%), particularly in the Southern Ocean. The relatively good MMM representations of AR frequency and IVT provide some confidence to now consider the MMM projected changes in AR frequency and IVT (section 3.2). Subsequent to that will be a discussion of the intermodel differences in historical simulation biases (section 3.3) and projected changes (section 3.4) in AR frequency and IVT.

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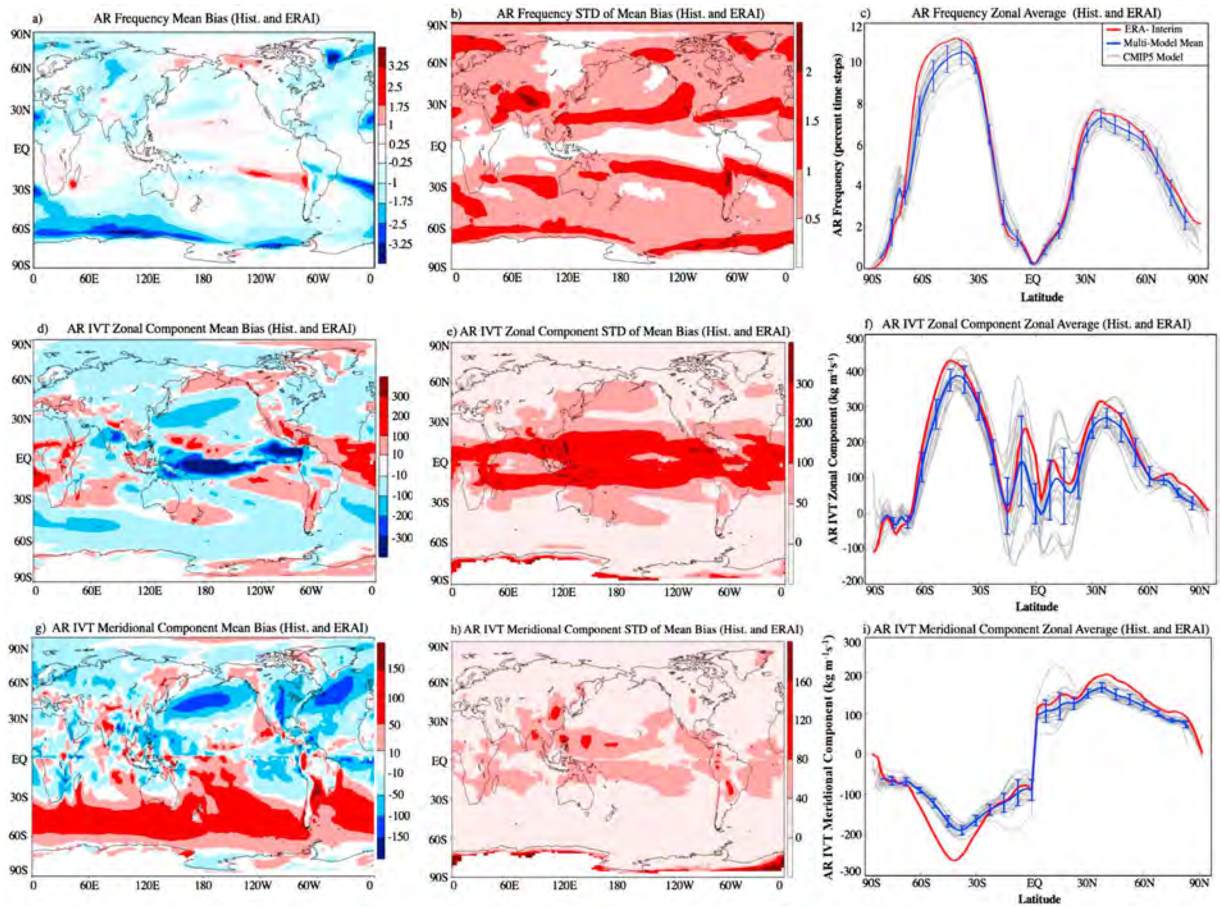

Figure 3. (a) Multimodel mean (MMM) of the individual model biases in AR frequency (percent of time steps) relative to ERA-Interim. (b) Intermodel standard deviation (STD) of the individual model biases around the MMM bias in AR frequency. (c) Zonally averaged AR frequency for individual models (grey), the MMM with standard error of mean (blue), and ERA-Interim (red). (d–f) As (a)–(c) but for AR zonal IVT ($kg \cdot m^{-1} \cdot s^{-1}$). (g–i) As (a)–(c) but for AR meridional IVT ($kg \cdot m^{-1} \cdot s^{-1}$). The errors bars in (c), (f), and (i) represent the standard errors of the MMM.

3.2. Future Projections

Figures 2c and 2d illustrate the MMM AR frequency and IVT values for the RCP4.5 and RCP8.5 simulation. For the RCP8.5 warming scenario, the global mean AR frequency and IVT increase by 49% and 23%, respectively. Most evident is the considerable increase in AR frequency in the midlatitudes, with values, for example, along the Southern Ocean (i.e., 30–60°S area average) rising from around 6–12% for the historical simulations to 12–16% and 14–20% for the RCP4.5 and RCP8.5 simulations, respectively. For the North Pacific (i.e., 30–60°N, 120–240° area average) and North Atlantic (i.e., 30–60°N, 270–360° area average), the AR frequency changes from around 10–12% for the historical simulations to 14–16% and 16–18% for the RCP4.5 and RCP8.5 simulations, respectively. Similarly, there are marked increases in IVT magnitude. For example, IVT values in the North Pacific and North Atlantic, rise from about 350 $kg \cdot m^{-1} \cdot s^{-1}$ in the historical simulation to about 420 $kg \cdot m^{-1} \cdot s^{-1}$ for RCP8.5 scenario. In the Southern Ocean, the IVT values change from 364 to 434 $kg \cdot m^{-1} \cdot s^{-1}$ between the historical and RCP8.5 simulations.

Figures 2e and 2f show the changes between the RCP4.5 and RCP8.5 warming scenarios and the historical simulation, respectively. Referring to the histograms in Figure 1a (see section 2.3), the AR frequency differences in Figure 2f refer to the differences between the example pink and light blue histograms. The IVT differences refer to the differences in the average IVT between the events associated with the green (i.e., RCP8.5) and pink (i.e., historical) histograms. These difference maps indicate AR frequency increases by ~50% globally, ~60% in the Southern Ocean, and ~50% in the Northern Hemisphere (Figure 2f). Moreover, in these same regions, the mean magnitude (in terms of IVT of the strongest of events) increases by 25% globally and by 20% in the northern and southern mid-and-high latitudes for RCP8.5 (Figure 2f). There are also considerable increases in eastward (westward) tropical AR IVT in the eastern Pacific (Indian) Oceans—although the frequency of ARs is very low in the tropics. Comparing these results with earlier studies on western North America and western Europe (Table 1) shows that these increases are similar, albeit more moderate in a number of cases, to previous studies. It is noted that the different detection and analysis methods used across these earlier studies make it difficult to compare them, and the uniform approach used here not only highlights areas not previously considered but also allows more judicious comparison across different regions.

Figures 1b to 1d highlight additional aggregate measures of projected changes in future AR characteristics. Figure 1b shows model ensemble average histograms of the AR IVT values from the historical and RCP8.5 simulations. Consistent with the increases in AR frequency in Figure 2f is the overall increase in the number of values across the range of IVT, and importantly the approximate doubling of extreme AR IVT events. The model ensemble average histograms of AR lengths and AR widths in Figures 1c and 1d illustrate that these increases in the frequency of AR conditions in Figures 1b and 2f arise from an increase of ~25% in both the lengths and widths of future ARs, despite an ~10% reduction in the number of ARs in the future under the RCP8.5 scenario (see Figures 1c and 1d legend).

3.3. Intermodel Differences in Historical Simulations

As a means to consider model fidelity and projection uncertainty, we illustrate and discuss intermodel differences against the observational reference and among the projections. Figure 3 summarizes comparisons between the historical simulations and the ERA-Interim observed reference values for AR frequency, zonal IVT, and meridional IVT (rows 1, 2, and 3, respectively). In each row, the left (middle) map shows the MMM (standard deviation) of the individual model biases. The right map shows the zonal averages of AR frequency or IVT for each individual model, the MMM, and the ERA-Interim reanalysis. For AR frequency, the figure shows little systematic bias across the model ensemble (Figure 3a), although rather significant disagreement in the subtropics are found (Figures 3b and 3c) as in Payne and Magnusdottir (2015) for ARs in the northeastern Pacific in CMIP5. The intermodel differences suggest considerable model uncertainty in some areas heavily impacted by ARs (e.g., California, Chile), although natural variability is an important factor to consider when interpreting these intermodel differences because the analysis period (i.e., 24 years) may not be long enough to average out decadal to interannual natural variability. For the zonal IVT, most of the areas of considerable systematic bias and larger standard deviation about the bias occur in the tropics (Figures 3e and 3f), where the frequency of ARs is considerably smaller and thus will not be elaborated on more here. For the meridional IVT, there is a clear systematic bias in the simulations; namely, the poleward AR transports are too weak by ~25% (Figures 3g and 3i).

3.4. Intermodel Differences in Future Projections

Figure 4 is similar in layout to Figure 3, although in this case it reflects the difference between the RCP8.5 and historical simulations (i.e., projected changes), as opposed to the difference between the historical simulation and reanalysis (i.e., biases); thus, it shows elements of model agreement across their projected changes in ARs. Figure 4a represents similar information as Figure 2f (i.e., AR frequency mean change) with a different color scale, with Figures 4b and 4c indicating that the greatest intermodel difference in the projected AR frequency changes is in the midlatitudes (~ ±2% and ±4% for Northern and Southern Hemispheres, respectively) where the highest changes in AR frequency occur (~5% and 10% for Northern and Southern Hemispheres, respectively). In these regions, the magnitude of the intermodel differences is roughly 40% of the multimodel ensemble mean. Based on the Community Earth System Model large ensemble, Hagos et al. (2016) estimated natural variability, represented by one standard deviation of the individual ensemble members, to contribute 23% uncertainty in the multimember ensemble mean in projected changes in AR frequency over the western North America from years 1980–1999 to 2080–2099. The much larger model uncertainty shown here (i.e., 40%), represented by one standard deviation across the different models, suggests that natural variability may not fully explain the intermodel differences in projected changes in AR frequency. Figures 4d and 4f show that overall the models uniformly project stronger eastward zonal AR IVT in the midlatitudes, with increases of about 20% in the southern and northern midlatitudes (i.e., compare Figures 3f and 4f). There is a modest weakening of zonal AR IVT in the tropics, particularly the westward transports in the eastern Pacific Ocean—although it is worth noting that this region has very low AR frequency and large intermodel spread. Figures 4g and 4i indicate that the meridional AR export of moisture out of the tropics slightly

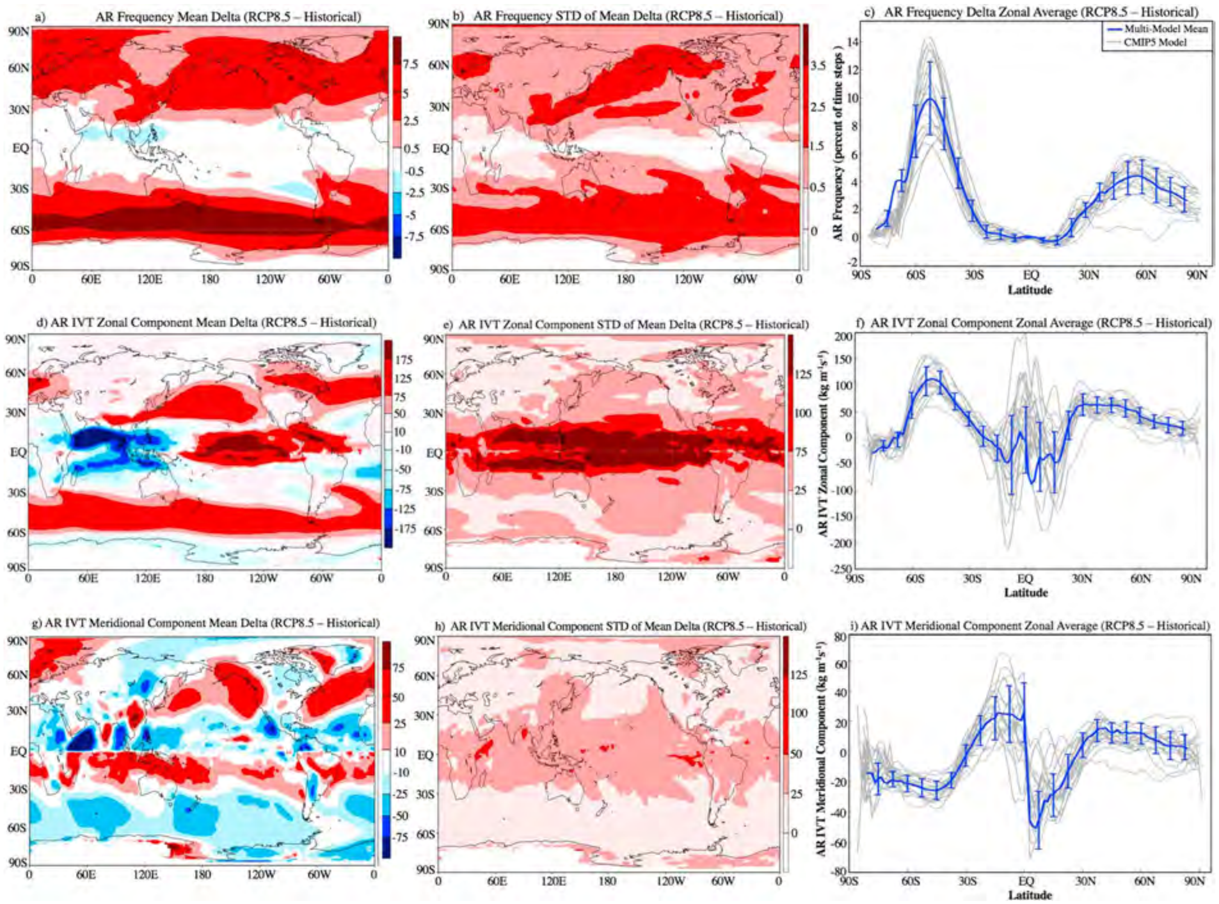

Figure 4. As Figure 3 but for the changes in AR frequency (percent of time steps) and IVT ($kg \cdot m^{-1} \cdot s^{-1}$) between historical and RCP8.5 simulations.

weakens but strengthens considerably in the midlatitudes. Specifically, the projected changes in the mean zonal and meridional AR IVT are about 60 and 10 $kg \cdot m^{-1} \cdot s^{-1}$, respectively, in the northern midlatitudes and 100 and $-$ 25 $kg \cdot m^{-1} \cdot s^{-1}$, respectively, in southern midlatitudes. These results indicate that there is about a 30% projected increase in zonal AR IVT and 5–10% in meridional AR IVT for the RCP8.5 scenario. While Figures 4e and 4h show pronounced intermodel variability in the tropics, it is important to note again that this is a region with very low AR frequency (Figure 3c).

More precise quantitative comparisons of model fidelity and projection uncertainties across the models for a number of regions impacted by ARs are given in Figures S2 and S3. These include California, the U.S. east coast, the UK, and southwestern regions of Africa, Australia, and Chile (see green boxes on Figures 2a and 2e). Notable is the degree that California, the UK, and Chile stand out among these regions in the uncertainty of simulated AR frequency for the historical period and projected changes in AR frequency and IVT.

4. Conclusions

This study represents the first global examination of the climate change impacts on ARs associated with future warming scenarios, based on the application of an AR global detection algorithm (Guan & Waliser, 2015) to outputs from 21 CMIP5 models. AR detection for the historical simulation and future projections (RCP4.5 and RCP8.5) are all based on the IVT 85th percentile derived from the historical simulation. Comparisons between the observational reference and multimodel historical values of AR frequency and IVT show that the MMM represent the reference patterns reasonably well, especially the variation with latitude and dominant zonal asymmetries (Figures 2a, 2b, 3, and S1). The results from the analysis of the projections indicate that for the most part AR frequency and IVT values will increase globally. More specifically, for the RCP8.5 warming scenario, AR frequency increases by ~50% globally, ~60% in the Southern Ocean, and ~50% in the Northern Hemisphere (Figure 2f). Moreover, in these same regions, the mean magnitude (in terms of IVT of the strongest of events) increases by 25% globally and by 20% in the northern and southern mid-and-high latitudes for RCP8.5 (Figure 2f). Notable are the results that for the RCP8.5 scenario, the number of ARs are projected to decrease slightly by ~10%, yet the ARs will be ~25% longer and ~25% wider, leading to an overall increase in the frequency of AR conditions (i.e., Figure 2f), and exhibit more extreme IVT values (Figure 1b). Moreover, examination of the intermodel difference in projected changes suggests agreement among the models on the general increase in AR frequency globally, and the stronger enhancements to AR frequency and IVT in the midlatitudes, particularly the Southern Ocean (Figures 4, S1, S2, and S3). Previous investigations focused on western North America and Europe, along with a related study on IVT in general (Lavers et al., 2016), have illustrated that thermodynamic response (i.e., moistening) of the atmosphere to the warming dominates, and dynamical effects (e.g., increases in wind speeds) are small. The results reported here for climate change impacts on AR frequency and IVT are generally consistent with previous studies that mainly have focused on western North America and western Europe (a number of which are shown in Table 1). A virtue of the present study is not only highlighting the climate change impacts on ARs beyond these two regions but also providing a means to more soundly compare, given the uniform global data sets and methodology, the projected changes, for example, between two given regions (e.g., western North America and western Europe).

Apart from the general agreement in AR frequency and IVT patterns and values between the multimodel historical simulations and observation reference, there are considerable intermodel variations in terms of AR representation and projected changes that suggest caution in terms of the projected changes to ARs. These warrant additional focused efforts on model evaluation and improvement for AR characteristics. Also notable is that there are a couple of regions that exhibit differences in the sign of the AR frequency change, with a few models projecting decreases in AR frequency in the subtropical Pacific regions near North/South America and the western Pacific (Figures 3, 4, S1, and S2). These are expected to be due to shifts in storm track or subtropical jet features, such as those diagnosed by Hagos et al. (2016), Shields and Kiehl (2016a), and Gao et al. (2016) in their studies for western North America and western Europe sectors, although more in-depth study in these regions is warranted. Overall, the results suggest fairly robust agreement at global scales across the models for the climate change impacts on AR frequency and IVT, relatively good agreement in terms of latitudinal dependencies, and relatively poor agreement at regional scales (Figures 3, 4, S2, and S3).

The intermodel differences in projected AR changes, particularly at regional scales, may not be fully explained by natural variability. Better constraining these models in terms of their AR projections is needed given the large societal impacts of these storms. Further works on field experiments, process studies, and model evaluation and improvement (e.g., Guan & Waliser, 2017; Hagos et al., 2015; Payne & Magnusdottir, 2015; Ralph et al., 2016; Wick et al., 2013) need to be undertaken to improve the model fidelity and reduce the uncertainty in the projections.

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Exhibit K USACE, Skagit River Basin General Investigation Flood Risk Reduction Hydraulic Analysis Final Study Report, August 2013

SKAGIT RIVER BASIN GENERAL INVESTIGATION
FLOOD RISK REDUCTION – HYDRAULIC ANALYSIS

FINAL STUDY REPORT

Prepared for:

US Army Corps of Engineers
Seattle District
4735 East Marginal Way South
Seattle, WA 98134

Prepared by:

Northwest Hydraulic Consultants Inc.
16300 Christensen Road, Suite 350
Seattle, WA 98188

August 2013

NHC project #200074

provide PSE with operational flexibility while avoiding, to the extent possible, incursion into the formal flood control storage space at Upper Baker. PSE operates the reservoirs to try to maintain water levels toward the low end of these buffers (water levels are generally maintained 2 to 3 feet above the bottom of the buffer), however there is no formal operating policy for the buffers. It should also be noted that the USACE only manages flood control space at the Upper Baker project.

It was noted in the course of discussion with PSE staff that the flood control storage requirements at Upper Baker as described in the WCM differ slightly from the storage required per the project's FERC license. Under the FERC license, which PSE views as the controlling document, 16,000 acre-feet of storage is required at Upper Baker between 15 October and 1 November. Under the current WCM, flood control storage would be increased from 0 acre-feet on 1 October to 16,000 acre-feet on 1 November. Comment from the USACE (e-mail from Dan Johnson dated 7 June 2010) confirms that PSE will be required to provide 16,000 acre-feet of storage in Upper Baker by 15 October per the current FERC license.

While future operations at Upper Baker are expected to differ from past operations in a number of respects, for current purposes it is assumed that future operations will be most similar to operations in the 20-year period 1984-2003.

3.1.2 Ross

The situation at Ross is less clear than at Upper Baker. As discussed later in this section, Ross Reservoir often provides significantly greater storage early in the flood control season than is required under the terms of its operating license. According to a representative from SCL, Ross reservoir elevations in the early fall are driven by a combination of factors including summer/fall weather conditions, energy demand, fisheries compliance requirements, and conditions in the energy market in general. SCL stressed that while no significant changes in operational practices were anticipated in the foreseeable future, there was also no guarantee that early flood control season storage at Ross would be greater than required in the future. Considering trends in energy demand, SCL suggested that reservoir data from the period 1990 through present would be more indicative of future operations than data from earlier periods.

3.1.3 Analysis of Reservoir Elevation and Storage Data

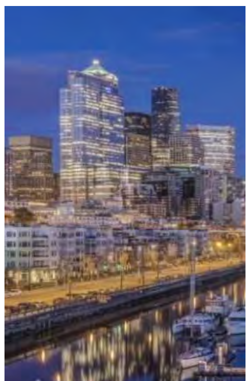
Data for the periods 1984-2003 at Upper Baker and 1990-2009 at Ross were analyzed to produce summary "hydrographs" and duration curves of reservoir elevation and available storage. Summary hydrographs are provided in Figure 3-1 through Figure 3-4, while duration curves are provided in Figure 3-5 through Figure 3-8.

The summary hydrographs (Figure 3-1 through Figure 3-4) show percentiles of stage or available volume on a given day of the year, as well as the existing and, for Upper Baker, optional flood storage requirements from Table 3-1 and Table 3-2. The Upper Baker plots (Figure 3-1 and Figure 3-2) show that from October 1 to November 15 the median available flood storage is much less than the full 74,000 acre-feet required under existing regulation only after November 15. While this is consistent with the

Exhibit L Seattle City Light Climate Change Vulnerability Assessment and Adaptation Plan Summary, 2016, relevant excerpts

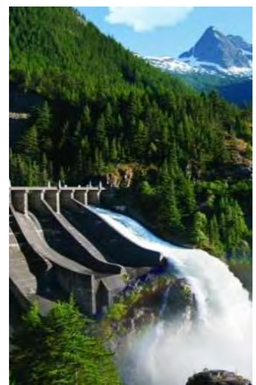
Seattle City Light
Climate Change Vulnerability Assessment and Adaptation Plan

Shoreline Infrastructure



Electricity Demand

Transmission and Distribution



Hydroelectric Project Operations

Fish Habitat Restoration

Prepared by Crystal Raymond
Climate Adaptation Strategic Advisor
Environmental Affairs and Real Estate Division
For more information contact: Crystal.Raymond@Seattle.gov | (206)-386-1620

Seattle City Light

Electricity Demand

Electricity Demand

Seattle City Light provides power to over 360,000 residential customers and 40,000 non-residential customers. Customer load (i.e. demand) is grouped into three sectors: industrial (10 percent), commercial (56 percent), and residential (34 percent); each sector's load could respond differently to climate change. The utility is winter-peaking, meaning more power is used by retail customers in winter than in summer and the highest hourly peaks in electricity use occur with cold temperatures in winter. The commercial sector has higher load in summer because of heating, cooling, and ventilation systems, whereas the residential sector currently has low use of air conditioning.

Summary of Impacts

An increase in electricity demand for cooling in summer, which could cause summer peaks to approach winter peaks in localized areas of the distribution system with high commercial loads.

A decrease in electricity demand for heating in winter, which could cause lower retails sales and financial consequences for the utility.

Potential Adaptation Actions

- Expand Seattle City Light's analysis of the relationship between warming temperatures, seasonal base and peak load, and air conditioning use in the residential and commercial sectors. Include an evaluation of potential ways to address any revenue loss from warmer temperatures.
- Identify and evaluate potential co-benefits of existing energy-efficiency programs to reduce electricity demand for cooling in summer, in addition to current efforts focused on electricity use for heating.
- Assess the potential of demand response for reducing peak commercial load on the hottest days in summer for localized areas of the distribution system that currently have limited capacity and experience high peak loads during hot temperatures.

Are other electric utilities adapting to climate change?

Seattle City Light is one of 18 electric utilities in the nation participating in the U.S. Department of Energy *Partnership for Energy Sector Climate Resilience.* The partnership agreement signed by the utilities expresses a commitment to increasing resilience to climate change. The companies in this partnership collectively represent about 20 percent of the nation's generating capacity and 25 percent of customers. Seattle City Light's Climate Change Vulnerability Assessment and Adaptation Plan is the most comprehensive effort by an electric utility to assess and prepare for the impacts of climate change and it represents a decade of progressive action by the utility on this issue.