Water Resources Program and Office of Columbia River Grant Special Terms and Conditions Quality Assurance Project Plan (QAPP) Template for Projects Without Water Quality Sampling

DEPARTMENT OF
ECOLOGY
State of Washington

Publication 18-11-018

General Information

This document presents a template for Quality Assurance Project Plans (QAPPs) described in Ecology Publication No. 17-11-013.

According to the General Terms and Conditions found in Ecology grant and loan agreements, recipients must prepare a QAPP when a project involves the collection and/or use of environmental measurement data. Those requirements further specify that this QAPP must be developed based on Ecology Publication No. 04-03-030, Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (Ecology, 2004).

For work funded under Water Resources Program or Office of Columbia River grants, the QAPP can be developed based on the requirements described in Publication No. 17-11-013 and presented in this template, provided the projects involve the collection of environmental measurement data with no water quality sampling. Examples of such projects are those involving streamflow gauging, lake-level monitoring, groundwater-level monitoring, well/aquifer capacity testing, etc.

If a project involves water quality sampling then a QAPP should be developed based on the guidelines in Publication No. 04-03-030.

In general the size, cost, and complexity of the QAPP must be in proportion to the magnitude of the sampling effort and intended use of the data. Once the QAPP has been submitted, Ecology must approve this prior to start of the work. The information provided in the QAPP must be sufficiently detailed to allow reviewers and those who implement the plan to understand what is to be done and the reasons for doing so.

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Special Accommodations
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Quality Assurance Project Plan

Dungeness River Off-Channel Reservoir Water Budget Water Modeling
Streamflow Restoration Grant WRSRP-2019-ClCoCd-00083

November 2024

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Table of Contents

List of Figures and Tables

Figures

Tables

1.0 Background and Project Description

1.1   Project Description

Low flow in the Dungeness River is a significant limiting factor affecting the survival of four species of endangered or threatened salmon and steelhead. For more than a century the Dungeness Valley has been irrigated with water directly from the Dungeness River. In the last 20 years, Dungeness irrigators and water management partners have invested considerable resources to conserve and enhance flow in the river. However, in low snowpack years there is still not enough flow in the river to support salmon and meet out-of-stream water rights. To address these limitations, a large off-stream reservoir is proposed to store water during winter and spring when flows are plentiful, saving this water for use later in the year.

Over the years, stakeholders have raised questions relating to water supply, climate projections, and reservoir operations. A water model as presented through the Water Evaluation and Planning (WEAP) tool can integrate quantitative data from operations as well as water availability data and can be used to answer stakeholder questions. This will help stakeholders understand the impacts on water supply and instream flow benefits in coming years. The goal of this tool is to assist in the management of the reservoir for years to come.

The model will provide quantitative calculations for when Maximum Allocation Water is physically available based on climate projection streamflow data. It will also calculate how long it will take for the Reservoir to fill, how much water will be diverted to the Reservoir during certain years, and how the Dungeness River flows will be impacted by the Reservoir. Decisions that are likely to be made using the project data include: timing of when to fill the Reservoir using Maximum Allocation Water, size of the diversion, and how much water can be restored instream for ecological benefit.

The key questions that we aim to answer using the WEAP model are as follows:
1. How much and how often does the reservoir fill under historical conditions, in climate projected years, and under alternative scenarios?
2. How does the reservoir meet current irrigation demand? With different demand scenarios?
3. What is the benefit to the flow in the river with the reservoir in climate future projected streamflows?
4. Is there excess storage in the reservoir that can be used for alternative purposes?

The study area of this project includes areas in and around Sequim, Washington, east of the Dungeness River (Figure 1). The draft WEAP model schematic is shown below in Figure 1. Draft WEAP model schematic. The Off-Channel Reservoir Project is proposed for construction on Clallam County tax parcel No. 043036-210000 located between River Road and the Dungeness River approximately 1.5 miles south of Highway 101. The proposed reservoir will distribute stored water through the existing irrigation ditch system located north and east of the proposed reservoir location.

1.2　　Project Background

The Dungeness River is a 28-mile-long river located in the Olympic Peninsula in Clallam County, Washington. It rises near Mount Constance in the Olympic Mountains within the Olympic National Park and empties into the Strait of Juan de Fuca at Dungeness Bay, behind the Dungeness Spit. The Dungeness River Valley is underlain by as much as 2,000 feet of unconsolidated Quaternary deposits that are mostly of glacial origin. Prior to the arrival of European settlers, the narrow stretch of forest and prairie between the Olympic Mountains and the Strait of Juan de Fuca where Sequim is located was the domain of the Klallam (S'Klallam) Tribe. Located in the rain shadow of the Olympic Mountains, the Dungeness River basin is part of a region that receives less rainfall and more sunshine than any place in Puget Sound.

The data sets incorporated into the model are:
1. Streamflow data from the USGS gauge (station 12048000) and Ecology Schoolhouse gauge (station 18A050)
2. Dungeness River Instream Flow Rule from WAC 173-518-090 Table IIA.
3. Historical Dungeness Water Users Association irrigation diversions provided by the Dungeness Water Users Association, and reviewed by Ecology.
4. Climate change projections provided by the Point No Point Treaty Council (PNPTC).
5. Maximum allocation water availability from WAC 173-518-090, which will be calculated based on streamflow availability and flow requirements.
6. Downstream hydrology gains and losses from the Simonds and Sinclair 2002 report[1]
7. Reservoir design criteria provided by Anchor QEA including:
    a. maximum diversion rate
    b. inflow and outflow rates to the Reservoir
    c. seepage and evaporation rates
    d. total volume of storage in the reservoir

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[1] Simonds, F. W., & Sinclair, K. A. (2002). Surface Water-Ground Water Interactions Along the Lower Dungeness River and Vertical Hydraulic Conductivity of Streambed Sediments, Clallam County, Washington, September 1999-July 2001.12 U.S. Geological Survey Water-Resources Investigations Report 02-41613. Washington State Department of Ecology Report 02-03-027. Retrieved from
https://apps.ecology.wa.gov/publications/documents/0203027.pdf

Figure 1. Vicinity Map
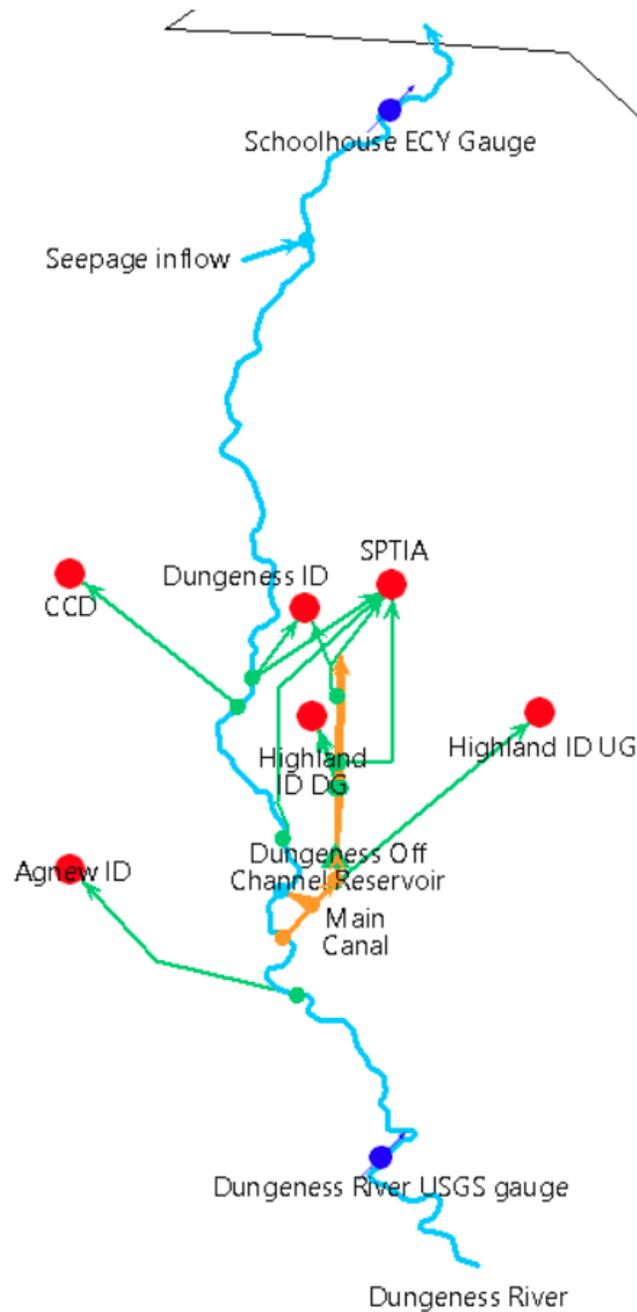
Figure 2. Draft WEAP model schematic.

The following tasks for the model development are drawn from the scope of work between the Washington Water Trust (WWT) and the Stockholm Environment Institute (SEI) to create the model using SEI's WEAP software. The following tasks will be conducted:

1. Global Circulation Model (GCM) (RCP 8.5) scenarios: In this task, SEI will create approximately 10 GCM RCP 8.5 flow projection scenarios in the WEAP model. Each GCM scenario will use an alternative set of inflows provided by the PNPTC. SEI will run the model with the historical and RCP 8.5 flow projections and show results only for the time horizon of 2030-2060, and 2050-2080, and 5 operations scenarios as further requested by the Work Group.
2. Reservoir inactive and alternative demand scenarios: In this task, SEI will build a toggle in the model to switch the potential reservoir to be simulated as active or inactive and include a reservoir inactive scenario.
3. Downstream hydrology dataset: The estimated cumulative streamflow gains and losses will be defined based on data from Simonds and Sinclair (2001) to better connect the flow requirement compliance point at the Ecology Schoolhouse gage with the reservoir intake operations upstream, as well as to predict the streamflow downstream under the scenarios.
4. Model refinements: SEI will confer with Anchor QEA to identify discrepancies between their spreadsheet model and the WEAP model. SEI will implement a prioritized list of changes (list included below), budget permitting, that will improve WEAP model to reflect the Anchor QEA design such as changes to reservoir intake and release rules, inflows, and demand patterns.
   - Include flow limit to reservoir when USGS gage reaches 1,700 cfs flow to manage sediment load of the diversion operations and preserve channel-forming flows.
   - Portion out the upper Highland Irrigation District (HID) service area from the HID service area served by the H1 lateral and reservoir. (50-70% of HID not served by reservoir.)
   - 25 CFS limit into Main Canal is the current design limit
   - Move fish bypass closer to the intake
   - Reservoir release modeled to be unlimited
   - Update schematic to be visually consistent with project
   - Add stockwater rates
   - Allow for modification of the size of the reservoir
   - Measure carryover water from year to year to determine excess water available for other uses
5. Refine agriculture demand data: SEI will input one year of representative demand data provided by the Work Group. This year of demand data will be cycled through all the simulation years of the model to see how the model is able to supply the current level of irrigation demands.
6. Organize model result favorites and scenario explorer dashboards into a user-friendly interface: In this task, SEI will organize the results from the WEAP model to into an accessible, visual format to aid in communication for decision-support. SEI will communicate with WWT to identify the most important set of results. Based on the feedback, SEI will create a set of result favorites and scenario explorer dashboards to enable users to easily view the results.
7. Create five operations scenarios as requested by the Dungeness Reservoir Work Group.
   a. Create one scenario where the unused portion of the Highland ID diversion water right (Highland and Eureka) is used towards filling the reservoir.

b. Create up to 3 new scenarios which modify the reservoir intake conduit capacity to the reservoir, including modifying the existing diversion intake from 25 cfs capacity to 35 cfs and the size of the reservoir.

c. Create 1 new scenario to capture excess water able to serve aquifer recharge, additional irrigation demands, and/or river flow restoration purposes. Account for the volume and timing of excess water. Refine the operations to ration reservoir releases if storage is low.

8. Calibrate model operations: In this task, SEI will calibrate the model operations to reproduce the downstream flow estimates provided by WWT. This task will involve the refinement of the operation rules of the potential reservoir, the diversions, as well as the demands.

9. Document and present model to the Dungeness Reservoir Work Group: In this task, SEI will write a model documentation report, which describes the model input data, assumptions, and results as well as guides users to operate the model. In addition, SEI will create slides present the model, assumptions, and results to WWT.

10. On-call follow up and training: Provide training to WWT and County staff on how to operate the WEAP model; respond to follow-up requests; participate in additional meetings at the direction of the WWT Project Manager.

2.0 Organization and Schedule

WWT initiated the WEAP model due to questions from the local stakeholders on the reservoir's impact on the Dungeness River water balance. Laura Garza Diaz (formerly of WWT) built the structure of the Reservoir WEAP model by creating the transmission links, demand sites, and input parameters. Washington Water Trust contracted with professionals at SEI to finalize the WEAP model.

Proposed Project Schedule
The proposed project timeline is listed below in Table 1. Proposed project timeline.

Table 1. Proposed project timeline.

Activity	Organization/Individual Responsible For Completion	Estimated Completion Date
Produce model QAPP	SEI, WWT, Clallam County	September 2024
Review QAPP	WA Department of Ecology	October 2024
Approve QAPP	WA Department of Ecology	November 2024
Model input request from DRWG at October DRWG Meeting	SEI, WWT, Clallam County, DRWG	October 28, 2024
Refine model operations	SEI, WWT	November 2024
Create new operations scenarios	SEI	October 2024

Refine agriculture demand data and scenarios	SEI, WWT, DWUA	October 2024
Refine climate scenarios	SEI, PNPTC	October 2024
Refine downstream hydrology	SEI, DRWG	October 2024
Document and present model	SEI	October 28, 2024
Train WWT staff	SEI	December 2024
On call follow-up	SEI	December 2024
Model Calibration	SEI	December 2024

Time constraints include timing of Ecology data from the Freshwater Datastream website and meeting with the DRWG.

Staffing who will be involved in this project are listed in Table 2. Key project staff.

Table 2. Key project staff.

Staff	Title	Responsibilities
Steve Gray Clallam County Public Works 360-417-2290 (office) steve.gray@clallamcountywa.gov	Deputy Director	Review WEAP model documentation.
Rhiana Barkie Clallam County Public Works 360-417-2424 rhiana.barkie@clallamcountywa.gov	Project Coordinator	Prepares and reviews QAPP. Review WEAP model documentation. Participate in WEAP training for future model management.
Laura Garza Diaz Washington Water Trust (former)	Project Manager	Creates the framework for the Dungeness Reservoir WEAP model by entering the model schematic based on Anchor QEA designs and uploading USGS streamflow data for past 100 years, climate projected flows, and irrigation demands.
Hannah McDonough Washington Water Trust 206-900-3689 hannah@washingtonwatertrust.org	Project Manager	Prepares and reviews QAPP. Packages the streamflow data, downstream hydrology, and for SEI. Facilitates discussions between stakeholders and SEI. Manages SEI's workflow to meet project deadlines and assess for data quality control. Participate in WEAP training for future model management.

Doug Chalmers Stockholm Environment Institute +1 (301) 233-8438 doug.chalmers@sei.org	Research Scientist	Prepares and reviews QAPP. Leads WEAP model and analysis. Enters the data into the model, writes a model documentation report, which describes the model input data, assumptions, and results as well as guides users to operate the model. Helps guide WWT staff to use or further refine the model, help fix future issues as they appear, or train WWT staff in water resources modeling.
Charles A. Young Stockholm Environment Institute Senior Scientist +1 (530) 304-6436 chuck.young@sei.org	Senior Scientist	Supervises WEAP model analysis.
David Rice, P.E. ANCHOR QEA, LLC 206.287.9130 drice@anchorqea.com	Principal Water Resources Engineer	Provides spreadsheet model data for model calibration. Review WEAP model results.
Bob Montgomery ANCHOR QEA, LLC rmontgomery@anchorqea.com	Principal Water Resources Engineer	Provides spreadsheet model data for model calibration. Review WEAP model results.
Tyler W. Burks Washington State Department of Ecology Environmental Assessment Program (360) 764-3260 tyler.burks@ecy.wa.gov	Hydrologist	Provides validated Ecology streamflow data for requested years.
Ryan D Murphy Point No Point Treaty Council (360) 297-6504 rmurphy@pnptc.org	Climate Change Action Analyst	Provides climate projected streamflow data and processes to incorporate data into WEAP model.
Ben Smith Dungeness Water Users Association 360 460-9499 ben@olypen.com	President	Provides irrigation demand data. Reviews WEAP model results.
Dungeness Reservoir Work Group		Provides feedback on the model. Provides input into WEAP scenario selection. Reviews WEAP model results.

Key team project personnel have previous experience developing and applying WEAP models.

Table 3. Special training and certificates.

Person	Specialized Experience	Years of Experience
Doug Chalmers Stockholm Environment Institute	Water resources modeling in WEAP, analyzing water rights, and developing water allocation decision support systems	8
Charles A. Young Stockholm Environment Institute	Water management issues, river basin planning, groundwater modelling, crop growth simulations and rainfall-runoff hydrology.	30
Hannah McDonough Washington Water Trust	Data analysis and review	5
Laura Garza Diaz Washington Water Trust	Water resource modeling in WEAP.	4
David Rice, P.E. ANCHOR QEA, LLC	Water resource engineering	25
Bob Montgomery ANCHOR QEA, LLC	Water resource engineering	40
Ryan D Murphy Point No Point Treaty Council	Climate modeling	8

3.0 Quality Objectives

The objectives of the Dungeness River WEAP model are to compare streamflow and water availability for agriculture and potential reservoir storage under conditions of pre and post off-channel reservoir constructions. The modeled changes from the pre versus post off-channel reservoir operations on the water volume delivered to agriculture and storage and the downstream flow at the Schoolhouse gauge should be accurate enough to quantify the expected water supply and fisheries benefits of the potential reservoir project.

To assess the quality of modeling results in meeting these objectives, the modeled streamflow will be validated against observed flows downstream at the Ecology Schoolhouse gauge. The validation period will take place during the recent period of years where the agriculture diversion data is both most representative of current conditions and most reliable, based on input from the Dungeness Water Users Association. Given that the model focuses on watershed operations rather than hydrology rainfall-runoff alone, the validation criteria will be adapted from Moriasi, et al., 2015[2]. The model validation will compare daily values of R^2, Nash-Sutcliffe efficiency (NSE), and percent bias (PBIAS) for observed versus modeled streamflow at the Ecology Schoolhouse gauge during the validation period. As described by Moriasi et al., these three values are most common in validating watershed operation models and provide a complimentary set of criteria to determine if the model is effectively reproducing the observed streamflow. In this study, it will be desired to meet the satisfactory criteria listed in Table 4 below for streamflow, consisting of > 0.6 R^2, > 0.5 NSE, and < 15 PBIAS. In addition, to gain further insight on model performance during seasonal periods, monthly values for each criteria will be compared against the thresholds. If the model achieves satisfactory criteria, then it will support that the model results are satisfactory in predicting flow at the Schoolhouse gauge. If the model is unable to achieve satisfactory criteria, then the model results should be interpreted to represent the magnitude of the change in streamflow under various conditions rather than used to predict the streamflow itself.

Table 4. Final performance evaluation criteria for recommended statistical performance measures for watershed- and field-scale models. From Moriasi et al., 2015.

Measure	Output Response	Temporal Scale[a]	Performance Evaluation Criteria			
			Very Good	Good	Satisfactory	Not Satisfactory
Watershed scale						
R^2	Flow[b]	D-M-A	$R^2 > 0.85$	$0.75 < R^2 \le 0.85$	$0.60 < R^2 \le 0.75$	$R^2 \le 0.60$
	Sediment/P[c]	M	$R^2 > 0.80$	$0.65 < R^2 \le 0.80$	$0.40 < R^2 \le 0.65$	$R^2 \le 0.40$
	N	M	$R^2 > 0.70$	$0.60 < R^2 \le 0.70$	$0.30 < R^2 \le 0.60$	$R^2 \le 0.30$
NSE	Flow	D-M-A	NSE > 0.80	$0.70 <$ NSE ≤ 0.80	$0.50 <$ NSE ≤ 0.70	NSE ≤ 0.50
	Sediment	M	NSE > 0.80	$0.70 <$ NSE ≤ 0.80	$0.45 <$ NSE ≤ 0.70	NSE ≤ 0.45
	N/P[c]	M	NSE > 0.65	$0.50 <$ NSE ≤ 0.65	$0.35 <$ NSE ≤ 0.50	NSE ≤ 0.35
PBIAS (%)	Flow	D-M-A	PBIAS $< \pm 5$	$\pm 5 \le$ PBIAS $< \pm 10$	$\pm 10 \le$ PBIAS $< \pm 15$	PBIAS $\ge \pm 15$
	Sediment	D-M-A	PBIAS $< \pm 10$	$\pm 10 \le$ PBIAS $< \pm 15$	$\pm 15 \le$ PBIAS $< \pm 20$	PBIAS $\ge \pm 20$
	N/P[c]	D-M-A	PBIAS $< \pm 15$	$\pm 15 \le$ PBIAS $< \pm 20$	$\pm 20 \le$ PBIAS $< \pm 30$	PBIAS $\ge \pm 30$

Building the water allocation model will not involve primary data collection. Instead, existing datasets will be used as input into the model. The only modifications to these datasets as part of

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[2] D. N. Moriasi, M. W. Gitau, N. Pai, P. Daggupati, 2015. HYDROLOGIC AND WATER QUALITY MODELS: PERFORMANCE MEASURES AND EVALUATION CRITERIA. American Society of Agricultural and Biological Engineers. Vol. 58(6): 1763-1785. DOI 10.13031/trans.58.10715

the model construction process will be to interpolate between measurement dates and remove outliers from the agriculture diversion flows, and to interpolate and create seasonal averages from the downstream flow gains and losses. These data methods are further described in Section 5.1.

4.0 Study Design

In this study, the decision-support tool will be constructed as a water allocation model using the WEAP platform, developed by SEI. WEAP is a practical tool for water resources planning, which incorporates both surface and groundwater supply, instream flows, and water demands. WEAP simulates water system operations within a river system with basic principles of water accounting on a user-defined time step; it computes water mass balance for every node and link in the system for the simulation period. The simulation allows the evaluation of multiple scenarios to test different water management strategies, water policies, water conservation programs, demand projections, hydrologic change, new infrastructure, instream flow requirements etc. (SEI 2007).

The Dungeness Reservoir model has been fully documented in a written report, which will be updated as the model is completed. The following is a summary of the model design. Inflows enter the model domain at the USGS Dungeness River gauge, with different simulations using either historical USGS observed gauge flows or projected inflows under future climate from the PNPTC. This water is then allocated to the agriculture demands and reservoir storage based on their defined allocation priority and supply constraints used to represent water right delivery limits within the water right documents as well as the irrigation turn-down schedule based on a 2012 Memorandum of Agreement with Ecology, and reservoir operation rules defined by Anchor QEA and clarified by Ecology and the Dungeness Reservoir Work Group. The remaining water not diverted to agriculture or to storage is combined with losses or gains based on a USGS study from Simonds and Sinclair between the points of diversion and the Ecology Schoolhouse gauge to compute the downstream flow at the Ecology Schoolhouse gauge.

The model will be run on a daily timestep, across an ensemble of simulation scenarios. Various climate scenarios will include either historical inflows or one of 10 future projected inflows. Each climate scenario will be run in combination with one of several operation scenarios, which capture conditions of no reservoir storage, reservoir construction, and different reservoir operation rules based on input from the Dungeness Reservoir Work Group. The key results will be the water supply volume delivered to agriculture and to reservoir storage as well as the downstream flow at the Ecology Schoolhouse gauge. The changes in these results between the different operation scenarios will quantify the expected benefits of the reservoir for fisheries and water supply across each of the ten future climate conditions. This information will go on to further inform the feasibility, design, and operation of the Dungeness Off-Channel Reservoir.

The main datasets, any methods performed on them, and their anticipated accuracy are shown in Table 5 below. Table 5 lists known uncertainties in the accuracy of several datasets. The agriculture diversion data will be verified by the Dungeness Water Users Association and the Dungeness River Work Group to confirm that it is representative of recent agriculture demands. The downstream flow gains and losses documented by Simonds and Sinclair, while being the best available data, are limited seasonal snapshots from 2000-2001 and may need to be calibrated to provide a better fit between observed and modeled flows at the Ecology Schoolhouse gauge.

In this calibration process, the years which contain both the most reliable recent agriculture diversion data and streamflow data would be divided into two halves for calibration and validation. The downstream flow gains and losses would be adjusted, likely on a monthly timescale and across water years of dry versus wet conditions, to align the modeled streamflow with observed streamflow at the Ecology Schoolhouse gauge. Then, the model performance would be observed based on the validation criteria discussed in Section 3 to achieve satisfactory performance. Finally, the PNPTC future projected daily inflows should be interpreted to depict general flow conditions across at least a 30-year climatic cycle period, rather than accurately predicting flows on a given day in the future.

Table 5. Key datasets

Dataset	Description and Methods	Anticipated Accuracy
USGS Dungeness River daily streamflow (2006-2022)	Data published from USGS and used as is. Data collected from USGS flow/height meter.	Likely a range of error at high and low flows. Operational limits of flow gauge from 1.5 feet to 12 feet of river depth.
Ecology Dungeness River (Schoolhouse Guage) daily streamflow (2006-2022)	Data published from Ecology and used as is. Data collected from telemetry meter.	Likely a range of error at high and low flows. Explicit margins of error not published on Ecology site.
Agriculture diversion flows (2000-2022)	Dataset collected from Ecology flow gauges. SEI and WWT and the Dungeness Water Users Association to manually interpolate between measurement dates and remove outlier measurement readings.	Range of error with lower flows and uncertainty of flows between reading dates.
Downstream flow gains and losses (2000-2001)	Data used from Simonds and Sinclair USGS and Ecology 2002 study of surface water-ground water interactions in the Dungeness River. SEI to use seasonal flux data in Figure 13, averaging the April fluxes and interpolating between the April and October readings.	High degree of uncertainty in how snapshot flows in April 2000, October 2000, and April 2001 are applicable to current conditions and what the fluxes would be in other months without readings.
Reservoir size and operation rules	Design and operation rules provided from Anchor QEA. Interpretation of the dataset confirmed with meetings with Anchor QEA, DWUA and the Dungeness Reservoir Workgroup.	Model should exactly match design surface volume and nearly exactly (+/- 1%) match operation flow limits.

| PNPTC Council Projected future daily inflows at USGS gauge (2006-2099) | Data published by PNPTC and used as is. Simulations ran using 10 individual RCP 8.5 projections and then results averaged after, per instructions from PNPTC: "**It is recommended to run a separate simulation for each GCM, then average the outcomes to get a representative ensemble forecast**. Finally, it is recommended to aggregate results over a multi-decadal (e.g., 30-yr) period to get a representation of future conditions that can account for the variability between GCMs." | Projections do not represent accurate predictions of streamflow on a given day. Rather, the ensemble of 10 projections ran over a 30-year climatic cycle period represent general climate trends. Notes from the PNPTC: "The results and conclusions from these models should be used as a general guide to understand how climate change could potentially impact the study area given the current scientific understanding of climate projections and how ecosystems might respond to these scenarios." |

5.0 Quality Control

5.1 Steps in preparation

When preparing the input datasets, listed in Table 5. Key datasets in Section 4 above, they will be saved into a .csv (comma-separated value) spreadsheet file, with the units of the values in the title and a description of the data source in the file. This will ensure the correct units and implementation into the model. In addition, the prepared data will be spot-checked against the original source to ensure it was formatted correctly.

As listed in Table 5. Key datasets in Section 4, most of the main datasets will be entered into the model without modifying the values. The methods used to modify any datasets which will be refined during the model construction process is described here. The agriculture diversion data contains snapshot daily measurements of streamflow in the agriculture diversion conduits provided by Ecology flow meters. WWT, SEI, and the Dungeness Water Users Association (DWUA) will propose a series of assumptions which will be confirmed by the Dungeness Reservoir Work Group (DRWG) to represent recent agriculture diversions. These assumptions will include the start and end dates of the irrigation season and diversion values between measurement dates when there are no readings. Linear interpolation between measurement dates will be used as a default method, with judgement from the DWUA to assess if different values should be used instead on days without readings. The agriculture data diversions will be checked for outliers, which are determined on a qualitative basis as values which visually significantly deviate from the patterns in the preceding and following values, and/or lie outside of the range of values for 99% of other readings. If staff with the workgroup and irrigation districts do not have a reasonable explanation for why any outlier readings would be correct, then the value would be removed, or modified to fit a linear interpolation between preceding and following values.

The model implementation of reservoir operations, and their interaction with the irrigation turn-down schedule and agriculture diversions will be discussed with Anchor QEA and confirmed with DWUA and the DRWG. Finally, the downstream gains and reaches from Simonds and Sinclair, 2002, being a small set of seasonal snapshots, will need to be refined to accurately simulate gains and reaches throughout the year. Based on input from WA DFW and USGS, a calibration procedure described in Section 4 will modify the downstream gains and reaches, using the Simonds and Sinclair values as a starting point, to better match observed flow.

5.2 Steps taken in use of model

The model results will be scrutinized to ensure the correct implementation of the inputs and operations. The input time-series values, including inflows and demands will be confirmed to match between the results view in WEAP, showing how it was implemented, versus the original data sources. In addition, the operations, involving the reservoir, agriculture demands, and streamflow will be verified in the model results. This will involve checking that the simulated division to storage, diversion to agriculture, and streamflow follow all operation rules. The logic behind each operation element will be confirmed. For example, for the irrigation turn-down

schedule, the diversion to the agriculture demands will be checked against the streamflow to confirm that the allowed diversions do not exceed the limits under periods of low flow.

6.0 Data Management Procedures

The management of datasets used during the study with WEAP involves several steps to ensure the proper handling, storage, and accessibility of the data. The steps that will be followed for data management are the following:

1. **Data Collection**: Results data will be saved in a standardized Time-Series Result template using a .csv file format to ensure consistency and compatibility. Each csv file will list the units of the data in its title and include a description of the data within the file.
2. **Archiving**: Modeling results will be submitted in memorandums and the feasibility study, which will all be backed up in the WWT main server. Model files will be shared with Clallam County upon completion via the Box Drive online file sharing platform.

7.0 Reporting and Modeling Assessments

The design of the model will be thoroughly documented both internally within the WEAP model as well as in a written documentation report. Within the WEAP model's Notes tab, the description of each model element as well as associated data sources and assumptions will be documented by SEI. In addition, SEI will write a model documentation report, which describes the model input data, assumptions, and results as well as guides users to operate the model. Finally, SEI will create slides to present the model, assumptions, and results to WWT, Clallam County, and the DRWG.

8.0 References

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9.0 Appendix A

Point No Point Treaty Council's Dungeness Streamflow Projections: Data Use & Limitations

August 25, 2023

Point No Point Treaty Council's Dungeness Streamflow Projections: Data Use & Limitations

This document pertains to the following provided data and any associated PNPTC data products:

> Daily streamflow projections, in cubic feet per second, under 10 separate GCM scenarios (RCP 4.5 and RCP 8.5 for each GCM), at the Dungeness River USGS and WA Department of Ecology stream gages, for water years 2007-2099.

This data should not be shared with other parties or agencies without direct permission from the Point No Point Treaty Council. These data are available for use by the Washington Water Trust with regards to the proposed 2023 Dungeness River off-channel reservoir modeling effort in conjunction with the WEAP model. PNPTC reserves the right to review any use or misuse of the data provided in applications outside the original scope of the project.

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Data Origin:
Streamflow projections for the Dungeness River were generated using the distributed hydrology soil vegetation model (DHSVM). The DHSVM is a physically based, spatially distributed hydrology model that requires explicit physical characteristics of the watershed, including topography, land cover, soil type, estimated soil thickness, and a stream network. The digital spatial inputs were acquired largely from publicly available sources (e.g., USGS, NLCD, and NRCS) and processed in ArcGIS and Python into 50-meter grids. More information about modeling methodology can be found in the Phase 1 technical summary report of the PNTPC stream modeling project (*http://climate.pnptc.org/our-research/reports-and-publications/*).

Assumptions within the Modeling Framework:
Some assumptions were made within the modeling framework used in this study. For example, this model used static vegetation canopies (and land-use types), soil depths, soil types, and stream network geometries (i.e., they did not change over time). The model also assumed that stream morphology did not change throughout the simulation period. Additionally, while the DHSVM is a comprehensive and fully-distributed watershed hydrology model that takes into account most of the pertinent mass and energy balance hydrological processes found in mountainous watersheds (e.g., shallow subsurface flow, snowmelt, canopy interception, evapotranspiration, etc.), it does not contain a true groundwater component. As such, stream systems that are significantly influenced by discharge or recharge to or from deep groundwater aquifers may not have been simulated appropriately. Likewise, there is no reservoir or lake component to the model, so calculations in the water balance for watersheds with larger non-riverine waterbodies may contain errors. Finally, DHSVM is a natural watershed processes

model, and was not set up to account for engineered waterways or human-induced changes to the water balance (e.g., diversions, drawdowns from wells, etc.).

Important Data Use Constraints:
Streamflow projections are not intended to make predictions for exact times in the future but rather are intended to allow for the analysis of likely trends compared to historical baseline conditions over long time periods (generally 30 years or more). These predicted flow measurements are not attempting to predict exact streamflow magnitude at any specific time or date (e.g., October 1st, 2053), because predicting exact weather at a specific future date, especially decades into the future, is not possible at this time.

The PNPTC stream modeling study used 10 statistically downscaled global circulation model (GCM) climate forecasts from 1950-2099. Downscaling was performed using the multivariate adaptive constructed analogs method (MACA). GCMs were developed by research groups who have different modeling criteria and research goals from one another. GCMs often rely on different assumptions and use different spatial resolutions and validation periods. This leads to significant variability between individual GCM projections, even for the same geographic location. To account for this variability, aggregated results of an ensemble of projections should be used for forecasting purposes, rather than relying on an individual model run. **It is recommended to run a separate simulation for each GCM, then average the outcomes to get a representative ensemble forecast**. Finally, it is recommended to aggregate results over a multi-decadal (e.g., 30-yr) period to get a representation of future conditions that can account for the variability between GCMs.

Potential uncertainties are introduced with the climate forecasts since each GCM makes generalizations about many climate parameters at a coarse resolution. Adjusting parameters of finer-scale processes undoubtedly introduces assumptions that do not hold true in the natural climate system and are not necessarily consistent between GCMs. Additionally, because the MACA downscaled climate forecasting relies on historical weather grids as the training dataset, some historical weather patterns and weather event regularities are assumed to remain consistent into the future. Errors in the historical weather data can be replicated or even enhanced in the downscaling process. Additionally, many assumptions are made in an effort to estimate future global climate trends, but there remain uncertainties related to economic projections, technological advancements, and global population trends which all influence greenhouse gas emissions. Results from multi-model ensembles are examined collectively instead of individually in an effort to reduce some of the variability between GCMs and to not bias results too heavily toward any single GCM scenario. However, uncertainty still exists with this method. As such, the results and conclusions from these models should be used as a general guide to understand how climate change could potentially impact the study area given the current scientific understanding of climate projections and how ecosystems might respond to these scenarios.