

# Dungeness River WEAP Model Documentation

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December 2024

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## Acronyms

AF: Acre-feet

Agnew ID: Agnew Irrigation District

CCD: Clallam-Cline Irrigation District and Company

cfs: Cubic feet per second

DID: Dungeness Irrigation District

ECY: Washington Department of Ecology

HID: Highland Irrigation District

HID UG: Highland Irrigation District Upgradient service area, which includes members served by the main canal and properties located to the northeast of River Road

HID DG: Highland Irrigation District Downgradient service area, which includes members served by the H1 Lateral ditch and properties located to the northwest of River Road

LP: Linear programming

MAW: Maximum Allocation Water, as described in WAC 173-518-090.

NSE: Nash-Sutcliffe efficiency

PBIAS: Percent bias

RCP: Relative concentration pathway

SEI: Stockholm Environment Institute

SPTIA: Sequim Prairie Tri-Irrigation Association.

USGS: United States Geological Survey

WEAP: Water Evaluation and Planning

WWT: Washington Water Trust

WY: Water year

## 1. Introduction

The Stockholm Environment Institute (SEI) has constructed a water allocation model of the Dungeness River using the Water Evaluation And Planning (WEAP) software platform for the Washington Water Trust (WWT). This documentation report describes the assumptions that went into the model and the main functions of the model as of December 2024.

The Dungeness River WEAP model was built to provide decision-support regarding the construction of a potential off-channel reservoir and its impact on water supply and instream habitat. The WEAP model explores streamflow and agriculture water supply in the Dungeness River under varying conditions of reservoir operations and upstream inflows tied to future climate.

A general note: the results of the model operations are projections, not certainties. The usage of RCP 8.5 climate scenarios instead of RCP 4.5 scenarios was to project the more likely conditions assuming worldwide carbon emissions continue at recent historic rates, as well as the “worst possible” conditions with more severe challenges of diminished snowpack and reduced summer streamflow. In contrast, the “historical data” represents contemporary hydrologic patterns from 2007-2022. RCP 8.5 and historical data may be thought of as ends of a spectrum illustrating different hydrologic scenarios. For more details on data selection and vetting, please review the Ecology-approved Quality Assurance Project Plan for the WEAP model.

## 2. Model overview

### 2.1. Water Evaluation and Planning (WEAP) tool

The WEAP software is a water allocation tool that has been under development by SEI for over 20 years. The software provides a comprehensive suite of tools for simulating water resources systems including rainfall-runoff hydrology, water resources infrastructure, agricultural, urban, and environmental demands, and the ability to apply complex operating rules and constraints to the water allocation problem. The water allocation problem is solved using linear programming (LP) defined by user-specified demand priorities and water supply preferences. The software is well-documented and has a well-developed training tutorial provided on the WEAP21 website. Comprehensive information on the software and download links are available at [www.weap21.org](http://www.weap21.org).

### 2.2. Model overview

The WEAP model for the Dungeness River considers a daily timestep, ran from 2030-2080 for future projections or 2007-2022 for historical climate, for water flow and allocation. The model calculates daily results for streamflow, reservoir fill, reservoir storage, excess fill available, water demand, supply delivered, and supply deficit, all under customizable operation assumptions across different simulation scenarios. The model schematic contains the WEAP model object types of rivers, diversions, demand sites, transmission links, flow requirements, and streamflow gauges. The complete schematic, including the upstream United States Geological Survey (USGS) gauge and downstream Ecology Schoolhouse gauge (ECY), is shown below in Figure 1. A zoomed in schematic highlighting the operations is shown in Figure 2 for the configuration with no reservoir, and in Figure 3 for the configuration with the reservoir. These schematic objects, described in section 3, interact during WEAP’s water allocation calculations to generate the results. The schematic objects are populated with many inputs stored under WEAP’s key assumptions, described in section 4. The other assumptions described in section 5 are used to help

populate the result metrics. The inputs are modified across each of the simulation scenarios, described in section 6, which, after the hydrology calibration in section 7, were compared across the results in section 8.

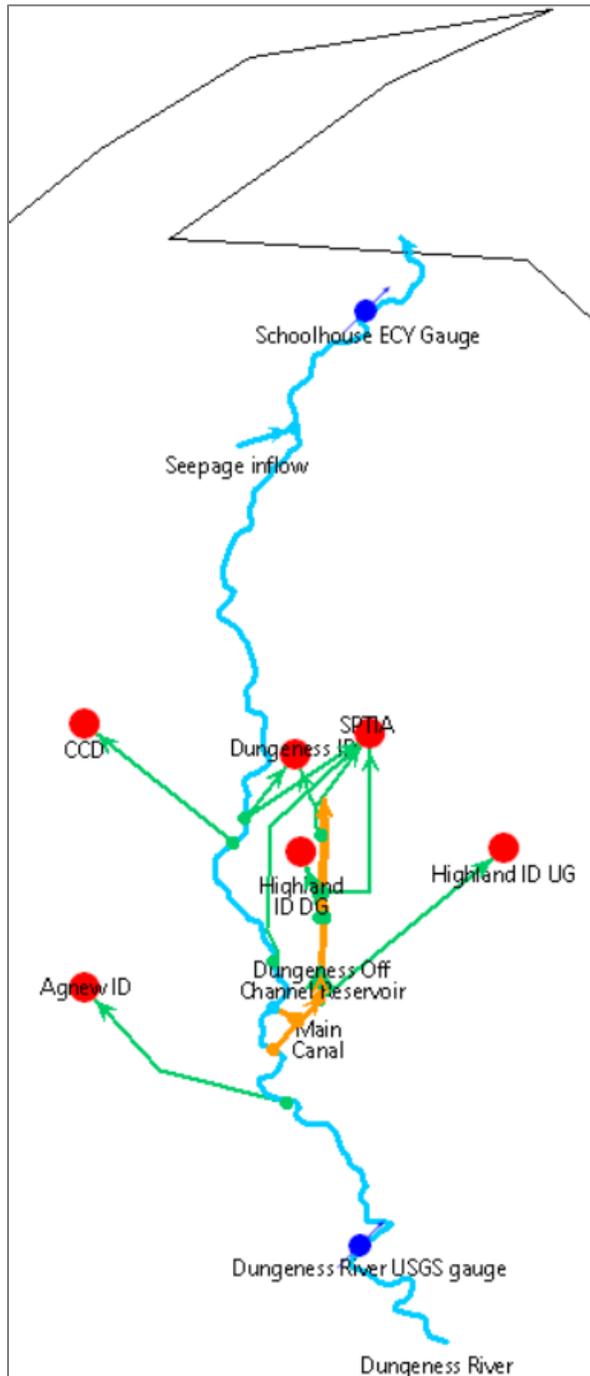


Figure 1. Complete WEAP model schematic

Red dots = demand nodes. Green lines = transmission links. Green dots = withdrawal nodes. Orange lines = diversions. Blue circle = streamflow gauge. Blue lines = rivers. Green triangle = reservoir.

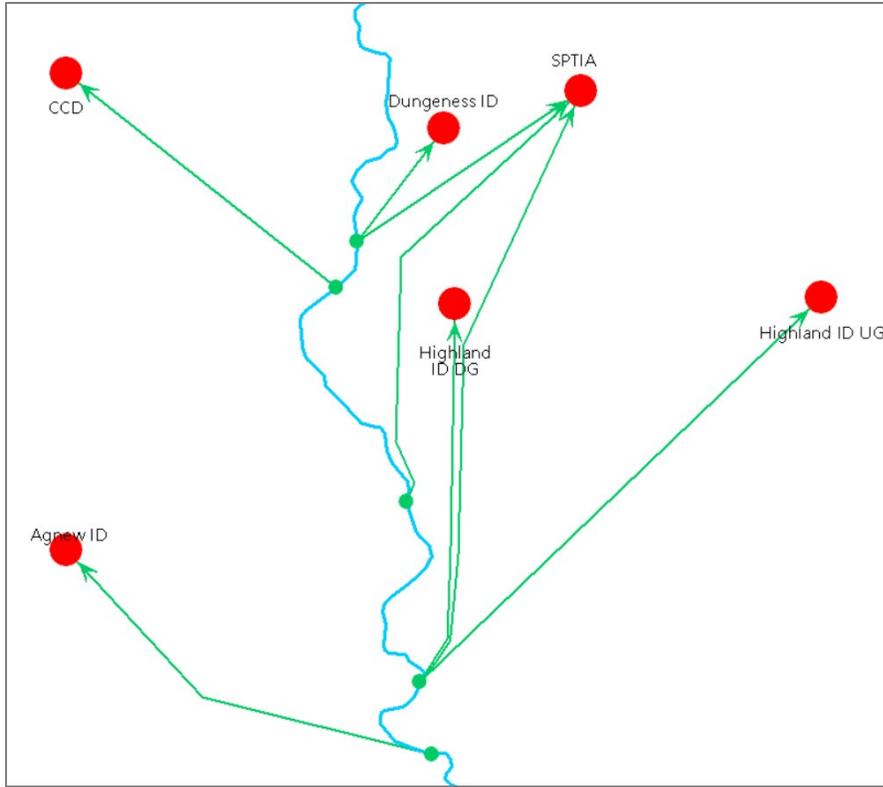


Figure 2. Model schematic zooming into operations (no reservoir)

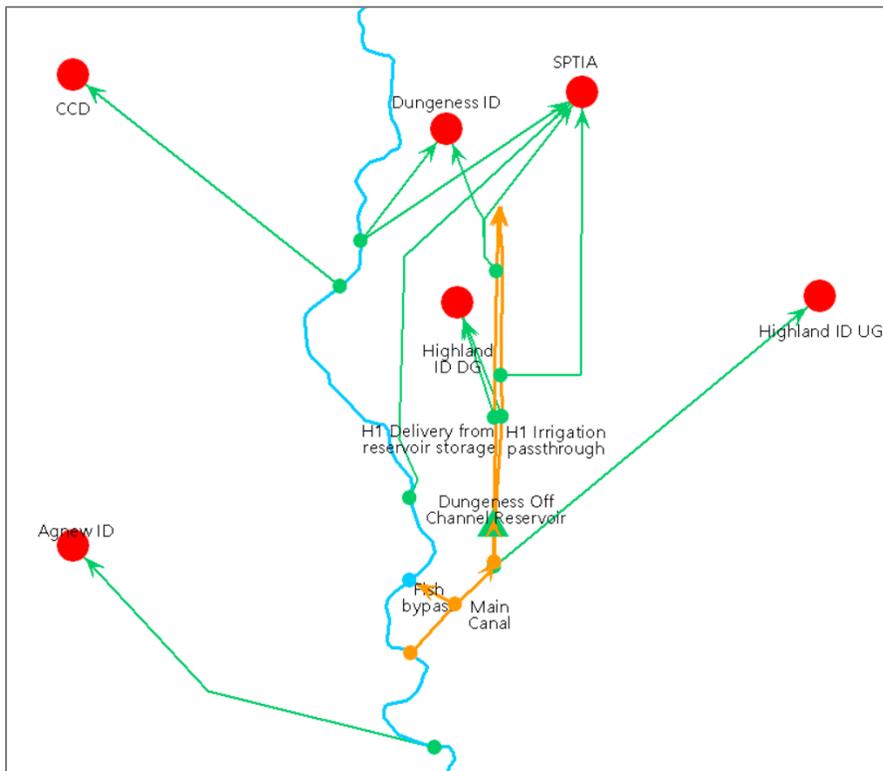


Figure 3. Model schematic zooming into operations (with reservoir)

In general, the streamflow of the river (3.1) is calculated under inflows associated with various future climate projections (4.1) and the flow is allocated to the reservoir storage (3.3), demand sites (3.4) representing the irrigation district demands, and the minimum flow requirements (3.6). The diversion objects (3.2) represent water conveyances through the Main Canal, fish bypass, and H1 lateral through the reservoir, while the transmission links (3.5) represent water withdrawals from the rivers and diversions to supply the demand sites. The allocation is performed according to the operation rules of these objects, which set parameters such as maximum conveyance and operational timing. The allocation is also performed in order of demand priority (4.4.12), with a more senior priority needing to receive its full allotment of water before the next priority receives any water. Demand nodes will attempt to withdraw all water demand from transmission links with a higher supply preference (4.3.10) before any transmission links with a lower supply preference are used.

The model operations throughout the year are summarized below in Table 1, described further in section 3. In this table, MAW refers to maximum allocation water, and HID refers to unused portion of the Highland Irrigation District water right.

*Table 1. Summary of model operations*

	Sep 16- Nov 15	Nov 16- April 14	Apr 15- Apr 30	May 1- Jul 14	Jul 15- Aug 14	Aug 15- Sep 15
<b>Irrigation demands</b>	Off-season stockwater		Irrigation season			
<b>Irrigation source</b>	River + passthrough only					Reservoir first, then river
<b>Reservoir fill</b>	no fill	25 cfs MAW	25 cfs MAW + 5-10 cfs HID	35 cfs MAW + 5-10 cfs HID	5-10 cfs HID	No fill, must empty

In this document references to expressions within the WEAP model’s data tree (Figure 4) (accessed by clicking on “Data”) are italicized while references to external files, stored within the WEAP model folder in Windows Explorer are underlined.

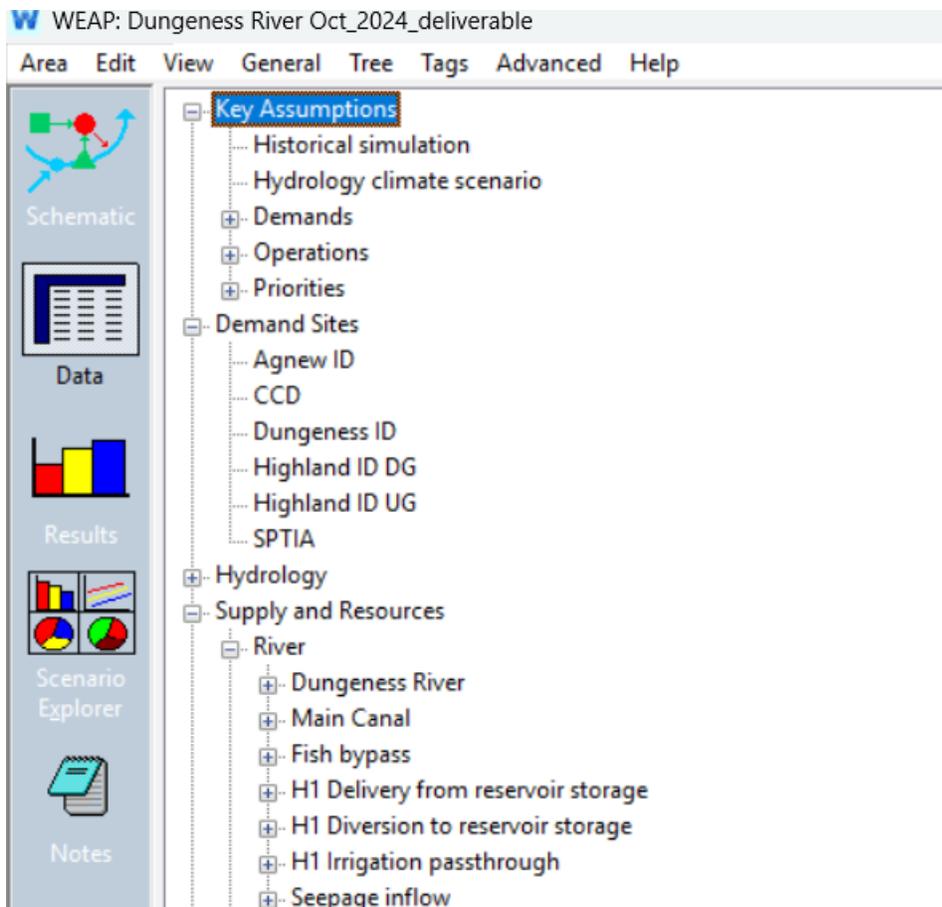


Figure 4. Screenshot of WEAP data tree

Note: Complete data tree has additional objects in the list beyond the limit of this figure.

### 2.3. Tag filter

The model schematic and data tree views can be customized to show only those objects active under model scenarios when the reservoir is active, or only when there is no reservoir. To do so, enter the following tag filters in the lower left hand corner of the WEAP schematic view (Figure 5):

- Show only objects active when reservoir is active: Tag <> No reservoir
- Show only objects active when there is no reservoir: Tag <> Reservoir active
- Show all objects: [leave blank]

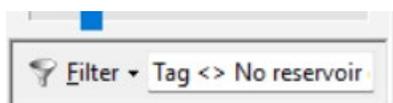


Figure 5. Tag filter in WEAP schematic

## 3. Schematic objects

The Dungeness River model uses the following WEAP schematic objects shown in Figure 6 below. Each set of objects is described within this section. Many of the object inputs are populated using key assumptions described in section 4. When the key assumptions are used, this section references the

location of the corresponding key assumption within section 4. The operations of the overall model are further described in the priority section (4.5), which describes the relative allocation priority of each model object.



Figure 6. Schematic objects used in the Dungeness model

### 3.1. Rivers

The *Dungeness River* mainstem is represented by the river object in the WEAP schematic. The *Headflow* expression reads in a time-series of daily inflows at the USGS gauge location, upstream of the model diversions, taken from [Hydrology\Streamflow\\_proj\\_USGS\\_cfs](#). This file contains a set of daily streamflow projections in cubic feet per second (cfs) at the Dungeness River USGS stream gauge, for WY (water year) 2007-2099 provided by the Point No Point Treaty Council. The future streamflow projections are provided for 10 different Global Climate Models, bcc-csm1-1-m, Can ESM2 (rcp8.5 only), CCSM4, CNRM-CM5, CSIRO-Mk3-6-0, HadGEM2-CC365, HadGEM2-ES365, IPSL-CM5A-MR, MIROC5, NorESM1-M, under the different emission simulations for RCP (Relative Concentration Pathway) 4.5 and 8.5. As of this report writing, the model results have only ran the RCP 8.5 inflows and have not used the RCP 4.5 inflows. The flow projections are documented in Point No Point Treaty Council’s Dungeness Streamflow Projections: Data Use & Limitations August 25, 2023.

The file also contains historical data for USGS Gauge 12048000 on the Dungeness River. The historical data is looped, using 2007-WY 2022 data. The inflow data simulated in WEAP is set according to *Key\Hydrology climate scenario* (4.1), which varies across scenarios.

The river model object for *seepage inflow*, located between the most downstream agriculture diversion point and the lower ECY Schoolhouse gauge, represents the surface water inflow and surface-groundwater exchange that occurs between the USGS and Schoolhouse gauges. The seepage inflow was set based on a calibration process, detailed in section 7. The calibrated seepage inflow used in the model is shown in Table 2 below and varies between 1.5 to 68 cfs of inflow, increasing as the headflow at the USGS gauge increases.

Table 2. Calibrated seepage inflow based on USGS inflow.

Headflow at USGS gauge (cfs)	Seepage inflow (cfs)
=<200	1.5
225	24
275	43.9
325	56.2
>=350	68

### 3.2. Diversions

In the Dungeness River WEAP model, diversion objects in the schematic are used to represent the water conveyance through the Main Canal, fish bypass, reservoir, and H1 lateral. The names and functions of the five diversion objects together with the reservoir object are depicted as the orange lines below in Figure 7.

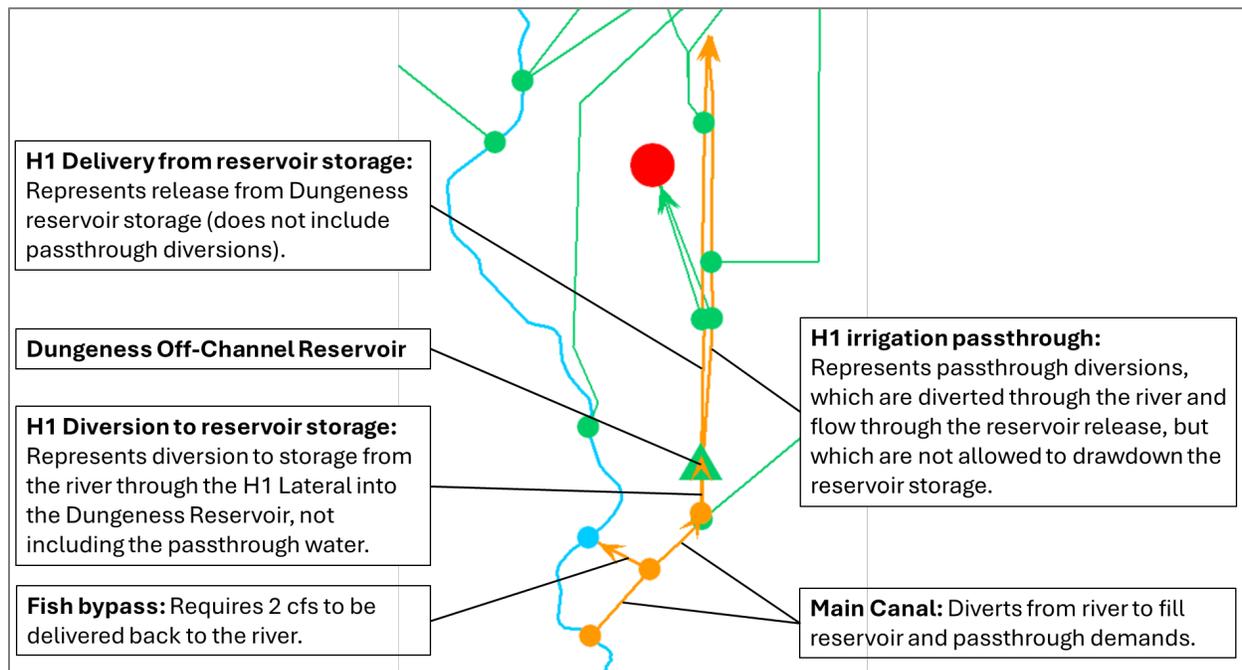


Figure 7. Diversion objects in model.

Generally, in the operation configuration with the reservoir active, the diversion to reservoir storage and the irrigation direct diversions which draw from the Main Canal and the H1 lateral divert the water through the Main Canal. A portion of the diversion through the Main Canal returns back to the river via the fish bypass (4.4.3). Downstream of the fish bypass, the Highland Irrigation District (HID) upgradient portion diverts out of the Main Canal where the Main Canal intersects with the H1 lateral (shown as a green line out of the Main Canal in Figure 7). The H1 lateral represents one physical structure, but is split into 3 objects in the WEAP model. The H1 irrigation passthrough delivers water to the Sequim Prairie Tri Irrigation Association (SPTIA) and HID downgradient portion. This passthrough water travels through the reservoir, but does not add or deplete reservoir storage. Separate from the passthrough water, the H1

diversion to reservoir storage diverts water out of the Main Canal and into the reservoir storage. The H1 delivery from reservoir storage delivers drawdown of reservoir storage to HID downgradient, SPTIA, and Dungeness Irrigation District (DID) demands.

A more detailed description of the modeled operating rules of each diversion object is as follows:

- *Main Canal:*
  - This diversion object represents diversions from the river through the main canal. The *maximum diversion* expression for this object sets that the diversions must follow:
    - 1. No water is diverted if the reservoir is not operational in the given scenario.
    - 2. No water is diverted if the headflow at the USGS gauge exceeds the river high flow limit for reservoir diversion (set under *Key\Operations\Peak river flow limit for reservoir diversion cfs* in section 4.4.12).
    - 3. The diversions may not exceed the main canal capacity limit (set under *Key\Operations>Main canal max capacity cfs* in section 4.4.7).
- *Fish bypass:*
  - The fish bypass is designed to allow fish caught in main canal to safely return to stream. The bypass returns water from the Main Canal back to the river. It is only active in scenarios where the reservoir is active.
  - The *maximum diversion* is set to the fish bypass flow of 2 cfs set under *Key\Operations\Fish bypass flow cfs* (4.4.3), implemented through the Fish bypass requirement minimum flow requirement object (3.6).
- *H1 Irrigation passthrough:*
  - Represents passthrough diversions, which are diverted through the river and flow through the reservoir release, but which are not allowed to drawdown the reservoir storage.
  - *Maximum diversion* is set to only allow flow in scenarios where the reservoir is operational. The combined release limit of the H1 Delivery from reservoir storage and the H1 Irrigation passthrough is stored under *Key\Operations\Reservoir release capacity cfs* (4.4.10) and is implemented using the *User Defined LP Constraints\Reservoir release capacity cfs* (5.4).
- *H1 Diversion to reservoir storage:*
  - Represents diversion to storage from the river through the H1 Lateral into the Dungeness Reservoir, not including the passthrough water to HID and SPTIA. No diversions occur in scenarios when the reservoir is not operational.
  - In addition to the rules imposed on the Main Canal diversion object maximum diversion, the *maximum diversion* of this object is limited to the sum of:
    - The Maximum Allocation Water (MAW) (set under *Key\Operations\Maximum Allocation Water cfs* in section 4.4.8)
    - The unused portion of the HID right (set under *Key\Operations\HID water available for reservoir fill cfs* in section 4.4.6).

- *H1 Delivery from reservoir storage*
  - Represents release from Dungeness reservoir storage (does not include passthrough diversions).
  - *Maximum diversion* is set to only allow flow in scenarios where the reservoir is operational. The combined release limit of the H1 Delivery from reservoir storage and the H1 Irrigation passthrough is stored under *Key\Operations\Reservoir release capacity cfs* (4.4.10) and is implemented using the *User Defined LP Constraints\Reservoir release capacity cfs* (5.4).

In addition to the information in this section, the diversion objects reference many values within *Key\Operations* (4.4), as referenced within this section. In addition, the diversion object operations are highly connected with the reservoir object (3.3) and the flow requirement objects for *HID reservoir fill* and *Fish bypass* (3.6). In addition, the transmission link objects supply the demand sites (3.4) through the transmission link (3.5) objects. The water allocation calculations across these objects are described within the demand priority section (4.5).

### 3.3. Reservoir

The potential Dungeness River off-channel reservoir is represented by a reservoir object in WEAP, depicted by the green triangle in Figure 7 on page 12 above. In general, the reservoir fills up in the fill season, as it is able according to its priority (4.5) until it is full. The fill season timing and volume are determined by the *maximum flow volume* of the *H1 diversion to reservoir storage* diversion object (3.2).

The water rights used to supply the reservoir fill are both the MAW (4.4.8) and the unused portion of the HID right (4.4.6). The MAW is implemented through the *H1 Diversion to reservoir storage* diversion object's (3.2) *maximum diversion* as well as the priority (4.5) of the reservoir object. The MAW is junior in priority to the *Dungeness water rule* flow requirement object (3.6), meaning that the flow at the Schoolhouse gauge must surpass the minimum amount required by the Dungeness water rule in order for the reservoir to store water using the MAW water right. The unused portion of the HID right is senior in priority to the *Dungeness water rule*, but is set as junior in priority to the other demands. This means that all other demands must be filled and the right is subject to the turn-down rules (4.4.4) before the reservoir may store water using the HID right, but that the *Dungeness water rule* does not need to be met to use this right.

During the reservoir release season from August 15 to September 15, the reservoir will release its storage to meet those downstream demands (3.4) connected to the reservoir release, the downgradient portion of HID, SPTIA, and DID, until the reservoir is fully depleted. The release season and flow limit are determined by the *maximum flow volume* of the *H1 delivery from reservoir storage* diversion object (3.2). Based on the *supply preference* of the transmission links (3.5), those demand sites connected to the reservoir will irrigate using reservoir storage if available, and will only divert from the river if the reservoir storage is not available during this period. Because no carryover storage is allowed, a simplified method will deplete all remaining storage on Sep 16 each year via the *loss to groundwater* expression for the reservoir. The excess storage volume and excess fill are tracked under *Other\Results* (5.2). The fill and release are affected by the restrictions of the connected mentioned diversion objects and transmission links (3.5).

The reservoir is populated with the following properties in the model.

- **Storage Capacity:**
  - Determines the maximum volume the reservoir can fill to.
  - Set to 0, 959, or 1,610 acre-feet (AF) according to *Key\Operations\Reservoir storage capacity AF (4.4.11)*.
- **Volume Elevation Curve:**
  - Used to calculate the surface area, used to ultimately calculate the *loss to groundwater* and *net evaporation*.
  - Taken from Anchor worksheet WaterBalance - Working - 2022-03-14.xlsx.
- **Net evaporation:**
  - Sets the depth of evaporative loss each day from the reservoir storage. Is multiplied by the *surface area* to calculate the volume loss.
  - Taken from Anchor QEA worksheet WaterBalance - Working - 2022-03-14.xlsx within the tab named "Tables" . Net evaporation data came in monthly format and is converted to daily here.
- **Maximum Hydraulic Outflow:**
  - Sets the maximum release possible from the reservoir to 25 cfs.
  - Set under *Key\Operations\Reservoir release capacity cfs (4.4.10)*.
- **Surface area:**
  - Used to calculate the *net evaporation* loss and *loss to groundwater* based on the volume elevation curve.
  - Surface area taken from Anchor QEA worksheet WaterBalance - Working - 2022-03-14.xlsx.
- **Loss to groundwater:**
  - Sets the water loss to groundwater which depletes the reservoir storage.
  - Calculated by multiplying the seepage estimate of 0.0340 in/day from Anchor worksheet WaterBalance - Working - 2022-03-14.xlsx by the *surface area* in the previous day of the reservoir.
  - Expression has been additionally modified to force the complete draining of storage on September 17 of each year, because no carryover storage is allowed.
- **Observed volume:**
  - Set to the results calculated in the Anchor QEA water balance model for comparison.
- **Priority:**
  - Determines the priority which the reservoir fill occurs at in the water allocation.
  - Set according to *Key\Priorities (4.5)*.

In addition to the information in this section, the reservoir operations reference many values within *Key\Operations (4.4)*, as referenced within this section. In addition, the reservoir operations are highly connected with the diversion objects (3.2) which convey the fill and release flow, as well as with the flow requirement objects (3.6). The reservoir ultimately supplies the demand sites (3.4) through the transmission link (3.5) objects. The water allocation calculations across these objects are described within the demand priority section (4.5). Many of the results related to the reservoir fill and storage are stored within the Other assumptions (5).

### 3.4. Demand Sites

Demand sites in WEAP, depicted as red dots in the WEAP schematic shown in Figure 1, withdraw water from river (3.1) and diversion (3.2) objects via transmission links (3.5). The transmission links define the withdrawal limit and timing of the demand sites. The supply preference of the transmission links defines

that any demand nodes connected to the reservoir will withdraw from the reservoir storage first, if during the reservoir release season from August 15 to September 15, withdrawing from the river only if the reservoir storage is depleted. The demand sites are senior in priority (4.5) to the *Dungeness water rule* flow requirement object (3.6), meaning they can divert regardless of if the requirement is met. The demand sites are also senior to the reservoir filling (3.3), meaning that the demand sites need to be fully supplied first before any water is diverted to reservoir storage. However, the demand sites are subject to the irrigation turn down rules (4.4.4), which restrict the water diversion from the river as the inflow at the USGS gauge goes below 120 cfs, with no irrigation withdrawal from the river allowed once the flow goes below 65 cfs. The turn down rules are implemented via the *maximum flow volume* of the transmission link objects.

In the Dungeness model, the 6 demand sites represent irrigation demands for the following irrigation districts listed in Table 3 below.

Table 3. Model demands

Irrigation District	WEAP Demand Node name	Description	Sub-districts (SPTIA only)	Irrigation Sources	Paper Water Right (cfs)	Observed demand time-series: Irrigation season	Observed demand time-series: Off-season
Agnew Irrigation District	Agnew ID			River	24.5	Agnew Irrigation District [daily readings]	
Clallam-Cline Dungeness	CCD	A group comprised of the Clallam Ditch Company, Cline Irrigation District, and Dungeness Group (formerly known as the Dungeness Irrigation Company)		River	23.3	Clallam-Cline-Dungeness [daily readings]	N/A
Dungeness Irrigation District	Dungeness ID			Reservoir, river	12.7	Dungeness Irrigation District [weekly reports]	Sequim Prairie and Dungeness Irrigation District [daily readings]* 0.7
Highland Irrigation District upgradient	Highland ID UG	The portion of HID which lies upgradient of the reservoir		H1 lateral	14 * 0.79	(Highland Irrigation District and Eureka [daily readings] - Eureka Irrigation Company [weekly reports])*0.79	(Highland Irrigation District and Eureka [daily readings]-0.8)*0.79 [with a minimum value of 0]
Highland Irrigation District downgradient	Highland ID DG	The portion of HID which lies downgradient of the reservoir		Reservoir, H1 passthrough	14 * 0.21	(Highland Irrigation District and Eureka [daily readings] - Eureka Irrigation Company [weekly reports])*0.21	(Highland Irrigation District and Eureka [daily readings]-0.8)*0.21 [with a minimum value of 0]
Sequim Prairie Tri-Irrigation Association	SPTIA	A group comprised of Sequim Prairie, Eureka, and Independent districts	Sequim Prairie	Reservoir, river	7.5	Sequim Prairie and Dungeness Irrigation District [daily readings] - Dungeness Irrigation District [weekly reports]	Sequim Prairie and Dungeness Irrigation District [daily readings]* 0.3
			Eureka	Reservoir, H1 passthrough	2.2	Eureka Irrigation Company [weekly reports]	Highland Irrigation District and Eureka [daily readings] [up to a maximum value of 0.8]
			Independent	Reservoir, river	9.3	Independent Irrigation District [daily readings]	Independent Irrigation District [daily readings]

The demand sites are assigned the following properties in the model:

- *Daily demand:*
  - The daily demand may be calculated using different methods based on the setting of *Key\Demand method toggle* (4.3.1). Generally, it will either read in values from the observed record of irrigation withdrawal from Observed historical irrigation diversion cfs.csv, or it will use the paper water right limit set by *Key\Demands\Paper water right limits cfs* (4.3.9).
- Consumption: Assumed consumption of 100% for all demands, meaning no return flows back into the system.
- Priority = Set by *Key\Priorities* (4.5). All demand nodes are set to the same priority.

The Observed historical irrigation diversion cfs.csv file contains a historical time-series of demands based on the daily (when available) headgate gauge readings or weekly reports. Complete readings for all districts have been populated for WY 2014-2022. The columns read in from this file for each district are listed above in Table 3. Daily outtake readings were used when possible, but some of the outtakes only had flow recorded from weekly reports. Some arithmetic was involved in order to determine the outtake volume of individual districts using outtake data that recorded the outtake for multiple combined districts (as described in Table 3). Gaps in the historical record for off-season stockwatering diversion were filled in using the average diversion for the same month from the previous and following years. Gaps in the daily historical record were filled in using weekly outtake report data. Finally, the observed withdrawal data for the week of September 10, 2020 during a curtailment period was scaled up to create a total demand of 38 cfs. This was done to reflect the theoretical demand disregarding the effect of the curtailment which occurred that week. These modifications are recorded in the metadata file, Demand modifications.xlsx.

In addition to the information contained within this section, the demand nodes are supplied through the transmission link objects (3.5), which contain supply limit rules through their *maximum flow volume*, including the irrigation turn down rules (4.4.4), as well as *supply preference* (4.3.10) expressions to define the sources of water used first. The demand nodes supplied by the reservoir (3.3) have operations connected to the diversion objects (3.2). The allocation of water across all these objects is defined within the priority section (4.5). The demand nodes reference many expressions stored within *Key\Demands* (4.3), as referenced within this section.

### 3.5. Transmission Links

In WEAP, transmission links represent water withdrawals to supply demand nodes (3.4). The transmission links connect a demand site to its water diversion source located along a river (3.1) or diversion (3.2) object. In the WEAP schematic, the view may be toggled to show only objects active when the reservoir is active, when the reservoir is off, or both (see 2.3). The withdrawal nodes (shown as green circles in the WEAP schematic) and their names under each setting are shown below in Figure 8 along with the transmission links (green lines).

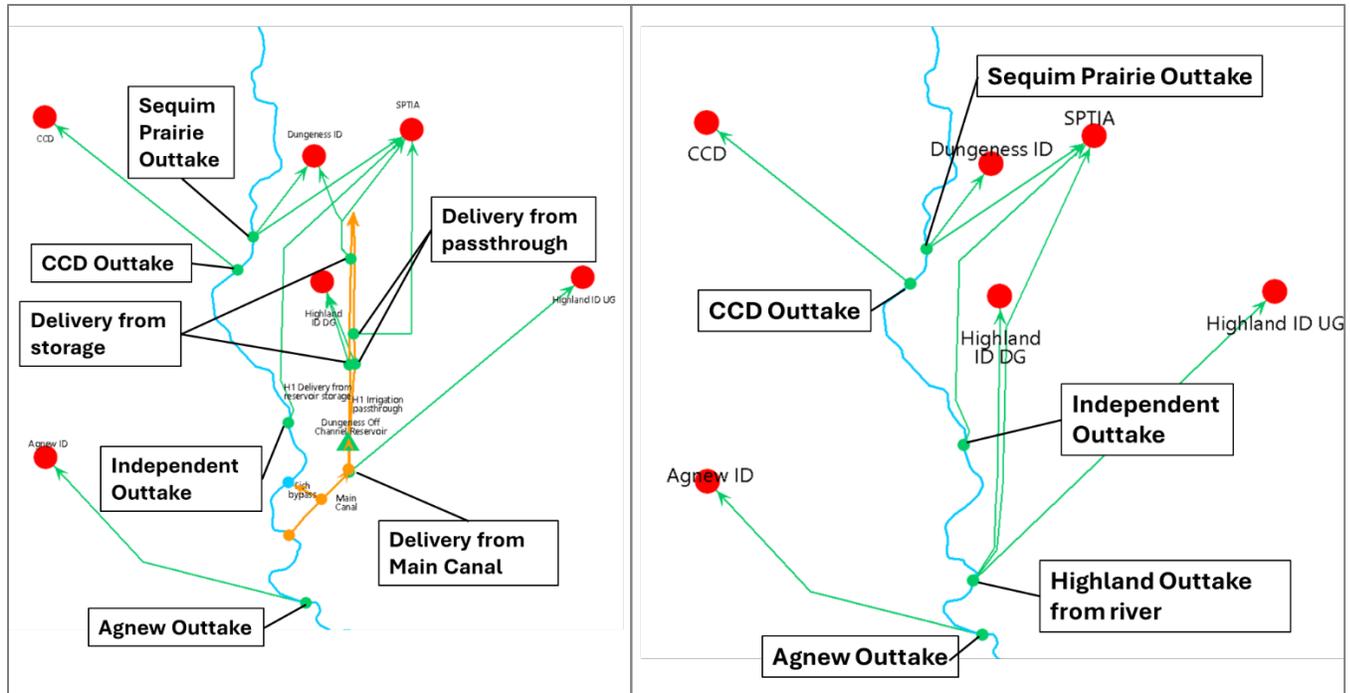


Figure 8. Withdrawal nodes under reservoir active setting (left) and reservoir off setting (right)

The transmission links define diversion restrictions and rules through the *maximum flow volume*. The *maximum flow volume* defines the daily diversion volume or flowrate limit to a given demand site from a given water source. When a given diversion is active, the *maximum flow volume* of the transmission link will define the allowed flow limit, often related to the paper water right limit (4.3.9). When a diversion is not active, often related to toggling the reservoir operations on or off in different scenarios as well as the irrigation season (4.3.4), the *maximum flow volume* may toggle off the given transmission link to inactivate it. In addition, the *supply preference* (4.3.10) of the transmission links defines that the reservoir water source is used first, when available, to supply the demand sites before the river or passthrough sources. Finally, the *maximum flow percent of demand* defines constraints for the flow rate as a function of the percentage of the total demand. It is only defined for the river and passthrough withdrawals to SPTIA, according to the percentage of the daily demand of Sequim Prairie, Eureka, or Independent district out of the total SPTIA demand.

The properties of each transmission link in the model are described in further detail in Table 4 below. These transmission links can be located on the WEAP schematic by identifying the demand site and withdrawal node locations in Figure 8 above.

Table 4. Model transmission links

Destination:	Source:	Description:	Active in reservoir active setting?	Active in no reservoir setting?	Maximum Flow Volume:	Supply Preference:
From Agnew Outtake	To Agnew ID	Transmission link represents direct diversion from river to Agnew Irrigation District.	Y	Y	Maximum irrigation diversion from the given source, set to the paper water right limit, stored in <i>Key\Demands\Paper water right limits CFS</i> (4.3.9) and is subject to the irrigation turn-down schedule stored under <i>Key\Operations\Irrigation turn down rules fraction of max withdrawal</i> (4.4.4) and the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4). Maximum flow volume is not restricted during the off-season stockwatering season outside of the irrigation season. Under a historical simulation (set under <i>Key\Historical Simulation</i> (4.1)), the maximum flow volume is unlimited to allow for the observed diversions.	River diversion supply preference
From CCD Outtake	To CCD	Transmission link represents direct diversion from the river to Clallam-Cline-Dungeness.	Y	Y	Maximum irrigation diversion from the given source, set to the paper water right limit, stored in <i>Key\Demands\Paper water right limits CFS</i> (4.3.9) and is subject to the irrigation turn-down schedule stored under <i>Key\Operations\Irrigation turn down fraction of max withdrawal</i> (4.4.4) and the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4). Maximum flow volume is not restricted during the off-season stockwatering season outside of the irrigation season. Under a historical simulation (set under <i>Key\Historical Simulation</i> (4.1)), the maximum flow volume is unlimited to allow for the observed diversions.	River diversion supply preference
From DID and SPTIA delivery from storage	To Dungeness ID	Transmission link represents diversion from off-channel reservoir storage to the Dungeness Irrigation District.	Y	N	Follows the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4). No restriction during active reservoir season (other than capacities of the H1 lateral and reservoir release). No diversions from reservoir allowed outside active season (4.3.5).	Reservoir diversion from storage supply preference
From Sequim Prairie Outtake	To Dungeness ID	Transmission link represents direct diversion from river to the Dungeness Irrigation District.	Y	Y	Maximum irrigation diversion from the given source, set to the paper water right limit, stored in <i>Key\Demands\Paper water right limits CFS</i> (4.3.9) and is subject to the irrigation turn-down schedule stored under <i>Key\Operations\Irrigation turn down fraction of max withdrawal</i> (4.4.4) and the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4). Maximum flow volume is not restricted during the off-season stockwatering season outside of the irrigation season. Under a historical simulation (set under <i>Key\Historical Simulation</i> (4.1)), the maximum flow volume is unlimited to allow for the observed diversions.	River diversion supply preference

To Highland ID DG (downgradient)	From HID delivery from passthrough	Transmission link represents reservoir passthrough supply (not diversion from storage) to the Highland Irrigation District portion which lies downgradient of the reservoir site.	Y	N	Only active in scenarios where the reservoir is active. If the reservoir is not active, water is withdrawn via the river instead. When this transmission link is active, the maximum flow volume is set to the paper water right limit, stored in <i>Key\Demands\Paper water right limits CFS</i> (4.3.9) and is subject to the irrigation turn-down schedule stored under <i>Key\Operations\Irrigation turn down rules fraction of max withdrawal</i> (4.4.4) and the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4). These values are multiplied by <i>Key\Demands\HID fraction downgradient of res</i> (4.3.2). Maximum flow volume is not restricted during the off-season stockwatering season outside of the irrigation season.	Passthrough diversion supply preference
To Highland ID DG	From HID delivery from storage	Transmission link represents diversion from off-channel reservoir storage to the Highland Irrigation District portion which lies downgradient of the reservoir site.	Y	N	Follows the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4). No restriction during active reservoir season (other than capacities of the H1 lateral and reservoir release). No diversions from reservoir allowed outside active season (4.3.5). These values are multiplied by <i>Key\Demands\HID fraction downgradient of res</i> (4.3.2).	Reservoir diversion from storage supply preference
To Highland ID DG	From Highland Outtake	Transmission link represents direct diversion from river to the Highland Irrigation District portion which lies downgradient of the reservoir site.	N	Y	Only active from the river in scenarios where the reservoir is not active. If the reservoir is active, direct diversion is withdrawn via the H1 lateral instead. When this transmission link is active, the max flow volume is set to the paper water right limit, stored in <i>Key\Demands\Paper water right limits CFS</i> (4.3.9) and is subject to the irrigation turn-down schedule stored under <i>Key\Operations\Irrigation turn down rules fraction of max withdrawal</i> (4.4.4) and the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4). These values are multiplied by <i>Key\Demands\HID fraction downgradient of res</i> (4.3.2). Maximum flow volume is not restricted during the off-season stockwatering season outside of the irrigation season. Under a historical simulation (set under <i>Key\Historical Simulation</i> (4.1)), the maximum flow volume is unlimited to allow for the observed diversions.	River diversion supply preference
To Highland ID UG (upgradient)	From Highland Outtake	Transmission link represents direct diversion from river to the Highland Irrigation District portion which lies upgradient of the reservoir site.	N	Y	Only active from the river in scenarios where the reservoir is not active. If the reservoir is active, direct diversion is withdrawn via the Main Canal instead. When this transmission link is active, the max flow volume is set to the paper water right limit, stored in <i>Key\Demands\Paper water right limits CFS</i> (4.3.9) and is subject to the irrigation turn-down schedule stored under <i>Key\Operations\Irrigation turn down rules fraction of max withdrawal</i> (4.4.4) and the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4).	River diversion supply preference
To Highland ID UG	From Highland UG delivery from Main Canal	Transmission link represents direct diversion (not diversion from storage) via the Main Canal to the Highland Irrigation District portion which lies upgradient of the reservoir site.	Y	N	Only active in scenarios where the reservoir is active. If the reservoir is not active, water is withdrawn via the river instead. When this transmission link is active, maximum flow volume is set to the paper water right limit, stored in <i>Key\Demands\Paper water right limits CFS</i> (4.3.9) and is subject to the <i>Key\Operations\Irrigation turn down rules fraction of max withdrawal</i> (4.4.4) and the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4). These values are multiplied by $(1 - \text{Key\Demands\HID fraction downgradient of res})$ (4.3.2). Maximum flow volume is not restricted during the off-season stockwatering season outside of the irrigation season.	River diversion supply preference

To SPTIA	From DID and SPTIA delivery from Storage	Transmission link represents diversion from off-channel reservoir storage to the SPTIA.	Y	N	Follows the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4). No restriction during active reservoir season (other than capacities of the H1 lateral and reservoir release). No diversions from reservoir allowed outside active season (4.3.5).	Reservoir diversion from storage supply preference
To SPTIA	From Eureka delivery from passthrough	Transmission link represents reservoir passthrough supply (not diversion from storage) to the Eureka portion of the SPTIA.	Y	N	Only active in scenarios where the reservoir is active. If the reservoir is not active, water is withdrawn via the river instead. When this transmission link is active, the maximum flow volume is set to the paper water right limit, stored in <i>Key\Demands\Paper water right limits CFS</i> (4.3.9) and is subject to the irrigation turn-down schedule stored under <i>Key\Operations\Irrigation turn down rules fraction of max withdrawal</i> (4.4.4) and the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4). Maximum flow volume is not restricted during the off-season stockwatering season outside of the irrigation season.	Passthrough diversion supply preference
To SPTIA	From Highland Outtake	Transmission link represents direct diversion from river to SPTIA using the Eureka water right.	N	Y	Only active from the river in scenarios where the reservoir is not active. If the reservoir is active, direct diversion is withdrawn via the H1 lateral instead. When this transmission link is active, the max flow volume is set to the paper water right limit, stored in <i>Key\Demands\Paper water right limits CFS</i> (4.3.9) and is subject to the irrigation turn-down schedule stored under <i>Key\Operations\Irrigation turn down rules fraction of max withdrawal</i> (4.4.4) and the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4).	River diversion supply preference
To SPTIA	From Independent Outtake	Transmission link represents direct diversion from river to SPTIA using the Independent water right.	Y	Y	Maximum irrigation diversion from the given source, set to the paper water right limit, stored in <i>Key\Demands\Paper water right limits CFS</i> (4.3.9) and is subject to the irrigation turn-down schedule stored under <i>Key\Operations\Irrigation turn down rules fraction of max withdrawal</i> (4.4.4) and the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4). Maximum flow volume is not restricted during the off-season stockwatering season outside of the irrigation season. Under a historical simulation (set under <i>Key\Historical Simulation</i> (4.1)), the maximum flow volume is unlimited to allow for the observed diversions.	River diversion supply preference
To SPTIA	From Sequim Prairie Outtake	Transmission link represents direct diversion from the river to SPTIA using the Sequim Prairie water right	Y	Y	Maximum irrigation diversion from the given source, set to the paper water right limit, stored in <i>Key\Demands\Paper water right limits CFS</i> (4.3.9) and is subject to the irrigation turn-down schedule stored under <i>Key\Operations\Irrigation turn down rules fraction of max withdrawal</i> (4.4.4) and the active irrigation season stored under <i>Key\Demands\Irrigation schedules</i> (4.3.4). Maximum flow volume is not restricted during the off-season stockwatering season outside of the irrigation season. Under a historical simulation (set under <i>Key\Historical Simulation</i> (4.1)), the maximum flow volume is unlimited to allow for the observed diversions.	River diversion supply preference

In addition to the information in this section, the transmission links reference many expressions related to the demand information under *Key\Demands* (4.3). Those transmission links delivering water from the reservoir storage and passthrough sources additionally reference expressions related to the reservoir operations under *Key\Operations* (4.4) and their delivery is related to the reservoir (3.3), and diversion (3.2) objects. The transmission links only deliver water up to the demand of the demand sites (3.4) and their allocation priority in relation to the reservoir and flow requirements (3.6) is defined by the demand priority (4.5) of the demand sites.

### 3.6. Flow requirements

In WEAP, flow requirement objects request a certain water flow volume, defined by the input parameter *minimum flow requirement*, to flow past their location. The water allocation is calculated in WEAP according to the *priority* input parameter (4.5) of these objects, which compete for water with the demand nodes (3.4) and reservoir storage (3.3). There are 4 flow requirement objects in the Dungeness model, shown as purple targets located along the river (3.1) and diversion (3.2) model objects as shown in Figure 9 below.

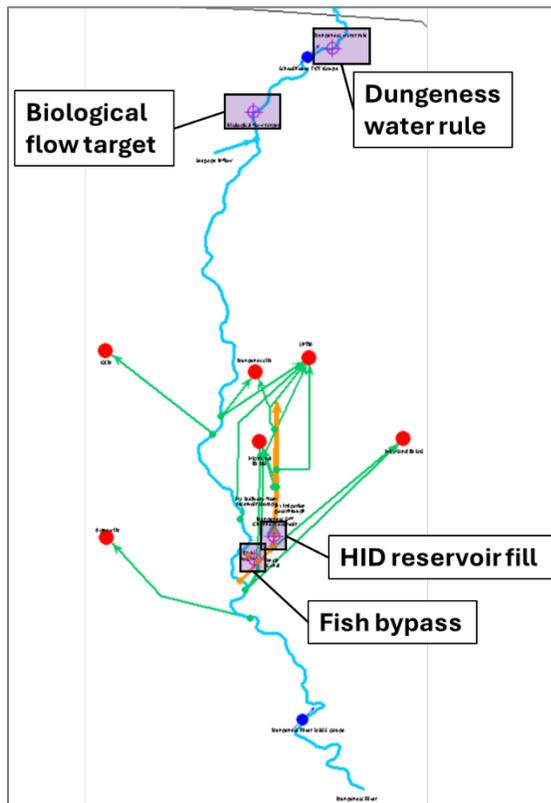


Figure 9. Flow requirement objects in schematic

The minimum flow objects are described individually below:

- *Dungeness water rule*
  - Represents the instream flow requirements of the Washington Department of Ecology at the Schoolhouse gauge on the Dungeness River.
  - *Minimum flow requirement* of 575 cfs from Nov-Mar, 475 cfs from Apr-Jul, and 180 cfs from Aug-Oct (all values in addition to a 10 cfs buffer described in 4.4.1). Monthly values

come from Table IIA: <https://apps.leg.wa.gov/WAC/default.aspx?cite=173-518&full=true#173-518-090> and shown in Table 5 below. Stored in Operations\Schoolhouse ECY flow req cfs.csv.

- The flow requirement adds on 10 cfs buffer based on recommendation from the reservoir workgroup, set under *Key\Operations\Dungeness water rule buffer* (4.4.1).
- Toggled active or off by the expression: *Key\Operations\Dungeness water rule toggle* (4.4.2).
- *Priority* (4.5) is junior to the demands and the HID reservoir fill, but senior to the MAW reservoir fill. This means that the reservoir may not fill using the MAW right when the water rule is not met, but that the demands and HID reservoir fill are unaffected.

Table 5. Dungeness Water Rule WAC 173-518-090.

Month	Dungeness Mainstem Requirement (cfs)
January	575
February	575
March	575
April	475
May	475
June	475
July	475
August	180
September	180
October	180
November	575
December	575

- *Biological flow target*
  - This object represents a biological flow target threshold of 105 cfs year-round, as a target flow for healthy fish habitat near river mile 4. The 105 cfs was a non-legally binding target considered by the Tribes per WWT.
  - Because this is a target not associated with a water right or policy, the *priority* (4.5) is set to the lowest in the model so that it does not affect the calculations.
- *Fish bypass requirement*
  - The fish bypass is designed to allow fish caught in main canal to safely return to stream. It is only active in scenarios (6) where the reservoir is active. Although the fish bypass is currently active in the stream in reality, it is not simulated in the model in scenarios without the reservoir, as it does not have a significant impact on the water allocation.
  - *Minimum flow requirement* of 2 cfs set according to *Key\Operations\Fish bypass flow cfs* (4.4.3), but set to 0 when the Main Canal does not allow flow.
  - *Priority* (4.5) is most senior, meaning that the fish bypass must have flow going through it if any water is to be diverted through the Main Canal.

- *HID reservoir fill*
  - Implements the reservoir fill from the unused portion of the HID water right. The available water to fill is taken from *Key\Operations\HID water available for reservoir fill cfs* (4.4.6). Is additionally limited to only divert up to the remaining unfilled reservoir storage.
  - *Priority* (4.5) is junior to the demands, meaning that the HID reservoir fill will only fill the reservoir once the demands are fulfilled. *Priority* is senior to the *Dungeness water rule*, meaning the Dungeness water rule doesn't need to be met before HID reservoir fill diverts to reservoir storage.

In addition to the information in this section, the flow requirement objects reference several expressions within *Key\Operations* (4.4), as referenced within this section. The water allocation across the flow requirement objects, reservoir fill, and demand sites (3.4) is further described within *Key\Priorities* (4.5). The *Fish bypass* and *HID reservoir fill* flow requirements are connected with the reservoir operations, described within the diversion (3.2) and reservoir (3.3) sections.

### 3.7. Streamflow gauges

The model schematic contains 2 streamflow gauges, which store observed historical flow data for comparisons of modeled and observed flows. The streamflow gauges are used for reference only, used to inform the calibration and validation (7), but do not affect the calculations in WEAP. As shown in Figure 10 below, the model contains streamflow gauge objects depicted as dark blue circles for the *Dungeness River USGS Gauge*, which reads in data from the upper gauge located above the diversion objects operated by the USGS under Hydrology\Dungeness USGS gauge observed cfs.csv from 1923-2023 and the *Schoolhouse ECY Gauge*, reading in data from the Schoolhouse gauge located on the lower part of the river near the outlet operated by Washington Department of Ecology under Hydrology\Schoolhouse ECY gauge observed cfs.csv from 1999-2022. The use of the observed data in the calibration and validation process is documented in section 7.

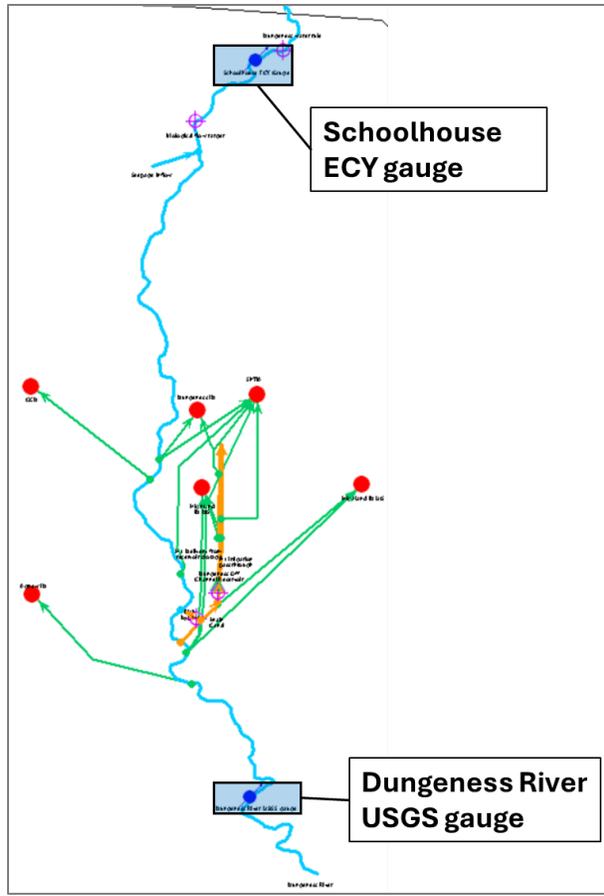


Figure 10. Streamflow gauge objects in schematic

## 4. Key assumptions

In WEAP, key assumptions are expressions found in the data tree which act as variables, storing information which may be accessed by the schematic objects described in section 3 above. This section describes the key assumptions used in the Dungeness WEAP model.

### 4.1. Key\Historical simulation

Toggles if the simulation is re-creating historical conditions. The toggle has been set to on only for calibration simulations to attempt to re-create the observed stream flows (for example, the historical observed streamflow from 2007 would be ran during the model simulation year of 2007).

0 = NOT historical simulation

1 = Historical simulation

### 4.2. Key\Hydrology climate scenario

Sets the climate projection to be used. Expression must begin with a semicolon, followed by the column name in the file `Hydrology\Streamflow_proj_USGS_cfs.csv`. Note that if historical is chosen, the model will loop the WY 2007-2022 data. The expression value varies according to the scenario set in section 6.

### 4.3. Key\Demands

#### 4.3.1. Demand method toggle

Toggles the method to calculate the irrigation demands.

0 = No demands

1 = Demands use permitted maximum demands

2 = Demands use representative observed demand year

3 = Demands use historical time-series of demands

Method 1, uses the permitted maximum demands of the paper water rights, from April 15 to September 15, adapted from *Key\Demands\Paper water right limits CFS* (4.3.9).

Method 2 uses a single representative year of WY 2020, from October 1, 2019 to September 30, 2022, (set under *Key\Demands\Representative demand year* (4.3.3)) from the historical observed data to represent the irrigation demands. The results in this report use this method 2, set to WY 2020.

Method 3 uses the historical time-series of demands, which are available from Oct 2013- Sep 2022.

#### 4.3.2. HID fraction downgradient of res

The fraction of HID located downgradient of the off-channel reservoir. Currently set to 0.21. Determines the proportion of HID that receives supply from the reservoir. The water demand and water right for HID is split according to this proportion as well. Proportion calculated according to Oct 2024 feedback from Ben Smith that generally 1.75 cfs goes to the upgradient portion and 6.5 cfs goes to the downgradient portion.

#### 4.3.3. Representative demand year

Sets the water year (Oct 1 of the preceding year to Sep 30) of demand data to use when the *Key\Demands\Demand method toggle* (4.3.1) is set to 2. Currently uses the WY 2020 demand data.

#### 4.3.4. Irrigation schedules\Irrigation season

Sets the irrigation season (default setting is April 15-September 15). This is the time period when the paper water right limits are enforced. The demand data is read differently between the irrigation and the off-season stockwatering season.

0 = Off-season

1 = Irrigation season

#### 4.3.5. Irrigation schedules\East side diversions from reservoir

Toggles the transmission link maximum flow volume to allow diversion or not. Reflects the water right season of allowed diversions from the reservoir for east side irrigators from August 15 to September 15 (when the reservoir is active).

0 = No diversion allowed

1 = Diversion allowed, up to maximum flow volume

#### 4.3.6. Irrigation schedules\East side diversions from river

Toggles the transmission link maximum flow volume to allow diversion or not. Reflects the water right season of allowed diversions from the river for east side irrigators from April 15 to September 15. Does not affect off-season stockwater diversions. See *Key\Priorities* (4.5) to see the supply preference of river, passthrough, and reservoir diversions.

0 = No diversion allowed (except off-season stockwatering)

1 = Diversion allowed, up to maximum flow volume

#### 4.3.7. Irrigation schedules\West side diversions from river

Toggles the transmission link maximum flow volume to allow diversion or not. Reflects the water right season of allowed diversions from the river for west side irrigators from April 15 to September 15. Does not affect off-season stockwater diversions.

0 = No diversion allowed (except off-season stockwatering)

1 = Diversion allowed, up to maximum flow volume

#### 4.3.8. Irrigation schedules\HID res fill season

Toggles the ability of the unused portion of the HID water right to fill the reservoir or not. Default setting is from April 15 to August 15.

0 = No reservoir fill using HID right allowed

1 = HID right can be used to fill reservoir

#### 4.3.9. Paper water right limits CFS

Maximum irrigation diversion, adapted from the max cfs of the file WUA - Low Flow - Withdrawal Spreadsheet -Non-Lease year.xlsx provided by the Washington Water Trust. The irrigation turn-down schedule stems from the 2012 Memorandum of Agreement Between the Washington State Department of Ecology and Members of the Dungeness River Agricultural Water Users Association. It is used to determine the *maximum flow volume* of the irrigation withdrawals of the transmission links (3.5) as well as is used to set the *daily demand* of the demand sites (3.4) when the *Key\Demands\Demand method toggle* (4.3.1) is set to a value of 1.

- Agnew = 24.5 cfs
- CCD = 23.3 cfs
- DID = 12.7 cfs
- Eureka = 2.2 cfs
- Highland = 14 cfs
- Independent = 9.3 cfs
- Sequim Prairie = 7.5 cfs

#### 4.3.10. Supply preference

The *supply preference* property of the transmission links (3.5) determines the order through which the demand sites (3.4) divert water through their different transmission link sources. The demand site will

attempt to supply its full demand through the transmission links with the highest supply preference. Only if a demand site cannot fulfill its entire demand through the transmission links with the highest supply preference will the demand site attempt to fulfill its demand through the transmission links with a lower supply preference. The supply preference of the transmission links are defined through the *Key\Demands\Supply Preference* designations listed below:

- Reservoir diversion from storage supply preference = 1
- River diversion supply preference = 2
- Passthrough diversion supply preference = 2

Supply preference is set to 1 for all reservoir storage diversions (not including the passthrough water going through the canal for SPTIA and HID), so that the diversion from the reservoir storage during the allowed period occurs before the river diversion. Supply preference is set to 2 for all river and passthrough diversions, so that the diversion from the reservoir storage occurs before the river and passthrough diversions, and that the priority of all river and passthrough diversions are equal to each other.

#### 4.4. Key\Operations

##### 4.4.1. Dungeness water rule buffer

A 10 cfs buffer added on to the *Dungeness water rule* flow requirement (3.6) which must be met in addition to the water rule before diversion of the MAW to the reservoir storage would occur. The buffer means that, if the Dungeness water rule is for 575 CFS, the MAW would not be diverted until the lower gauge reads 585 CFS. Added based on feedback from the reservoir workgroup.

##### 4.4.2. Dungeness water rule toggle

Toggles off or on the *Dungeness water rule* flow requirement (3.6) at the Washington Department of Ecology Schoolhouse gauge on the Dungeness River.

0 = Instream flows OFF

1 = Instream flows ACTIVE. Uses Table IIA monthly values (previously shown in Table 5 on page 24):  
<https://apps.leg.wa.gov/WAC/default.aspx?cite=173-518&full=true#173-518-090>

##### 4.4.3. Fish bypass flow cfs

The fish bypass flow sets the *minimum flow requirement* of the fish bypass flow requirement object (3.6) as well as the *maximum diversion* of the fish bypass diversion object (3.2), fixing the volume of water flowing through the diversion. The fish bypass is designed to allow fish caught in Main Canal to safely return to river. Per the WWT, the fish bypass flow is set to 2 cfs. The fish bypass flow only operates in scenarios where the reservoir is active. Although the fish bypass is currently active in the stream in reality, it is not simulated in the model in scenarios without the reservoir, as it does not have a significant impact on the water allocation.

##### 4.4.4. Irrigation turn down rule fraction of max withdrawal

Implements the fraction of the paper water right limit allowed to be diverted from the river, based on the streamflow at the upstream USGS gauge and the threshold set by the irrigation turn-down schedule and buffer contained in the WUA - Low Flow - Withdrawal Spreadsheet -Non-Lease year.xlsx provided by the WWT. Expression is incorporated in the *maximum flow volume* expressions of the transmission links

(3.5) and may be toggled off and on in *Key\Operations\Irrigation turn down rules toggle* (4.4.5). The irrigation turn-down schedule stems from the 2012 Memorandum of Agreement between the Washington State Department of Ecology and Members of the Dungeness River Agricultural Water Users Association. The turn-down rules begin curtailing the irrigation withdrawals from the river when the flow at the USGS gauge goes below 120 cfs. At 120 cfs, the turn-down rules only allow diversion up to 59% of the paper water right limit. The proportion of the water right limit able to be diverted decreases linearly with the streamflow, from 59% at 120 cfs down to 0 diversion at 63.5 cfs.

The values for this expression may range between 0 to 1. A value of 1 means there is no restriction to the river irrigation from the turn down rules, while a value of 0.5 means that only 50% of the max withdrawal is allowed, and 0 means no withdrawal is allowed.

#### 4.4.5. Irrigation turn down rules toggle

Toggles on or off the irrigation turn-down rules, implemented in *Key\Operations\Irrigation turn down rules fraction of max withdrawal* (4.4.4). Is active in all scenarios (6) except unimpaired.

0 = Irrigation turn down schedule OFF

1 = Irrigation turn-down schedule ACTIVE

#### 4.4.6. HID water available for reservoir fill

The flow rate of the unused portion of HID's water right available for reservoir fill. Set to the paper water right limit of HID (4.3.9) minus the irrigation demands (3.4) of the district for that day. Is additionally subject to the turn down rules extended to 158.5 cfs (beyond the 120 cfs threshold at which the *Key\Operations\Irrigation turn down rules fraction of max withdrawal* (4.4.4) first takes effect). The 158.5 cfs was calculated as the flow at which the 93.5 cfs total paper water right limits could be diverted and there would still remain the required 65 cfs left in the river. Is active from April 15 to August 15 as defined under *Key\Demands\HID res fill season* (4.3.8), when both the HID water right and the reservoir fill season are active.

#### 4.4.7. Main canal max capacity cfs

The flow capacity limit of the Main Canal (3.2). Set to 25 cfs + 2 cfs fish bypass (*Key\Operations\Fish bypass flow cfs in 4.4.3*) in the default, with an alternative scenario (6) for 35 cfs + 2 cfs fish bypass.

#### 4.4.8. Maximum Allocation Water cfs

Defines the allowed diversion to storage into the Dungeness Reservoir (3.3) using the water right for the MAW (WAC 173-518-090) Table VI Maximum Allocations on the Dungeness River Mainstem, which is the water legally available to withdraw. The rule allows for 25 cfs from November 16 to April 30, 35 cfs from May 1 to July 14, and 0 cfs from July 15 to November 15.

#### 4.4.9. Reservoir active toggle

Toggles the potential reservoir (3.3) and associated operations on or off in a given scenario (6). Is toggled on in the reservoir active scenarios, and off in the no reservoir and unimpaired scenarios.

0 = Reservoir OFF

1 = Reservoir ACTIVE

#### 4.4.10. Reservoir release capacity cfs

Maximum release limit of the reservoir of 25 cfs, provided by Anchor QEA. The sum of the delivery from reservoir storage and the reservoir passthrough water must be less than this limit. Is implemented within the *maximum hydraulic outflow* property of the reservoir object (3.3) as well as the *maximum diversion* of the *H1 Delivery from reservoir storage* and *H1 Irrigation passthrough* diversion objects (3.2). The combined constraint of 25 cfs through both the delivery plus passthrough flow of the H1 lateral is implemented through the *User Defined LP Constraints\Reservoir release capacity cfs* (5.4).

#### 4.4.11. Reservoir storage capacity AF

Storage capacity of the reservoir (3.3). Different storage capacities may be used to reflect the alternative designs provided by Anchor QEA.

Set to 959 AF in design E1 scenario (6) and to 1,610 AF in design E4 scenario.

#### 4.4.12. Peak river flow limit for reservoir diversion cfs

The streamflow threshold of 1700 cfs at the upper USGS gauge, above which no diversion through the Main Canal (3.2) would occur. Set according to Anchor QEA. Is based on avoiding sediment loads as well as preserving channel-forming flows in the river.

### 4.5. Key\Priorities

Sets the relative water allocation priority of each object, including the demands (3.4), reservoir fill (3.3), and flow requirements (3.6) in the model. The priority values are set below:

Priorities (1 = most senior, 100 = most junior):

- 1 = Fish bypass
- 2 = Demands
- 3 = HID reservoir fill
- 4 = Dungeness water rule
- 99 = Reservoir storage
- 100 = Biological flow target (not enforced)

The priorities are set so that any flows through the Main Canal must fulfill the fish bypass requirement, which has a priority value of 1. The demands, with a priority value of 2 are next most senior and are not subject to any instream flow rule restriction besides the turn-down schedule (4.4.4), which is implemented within the *maximum flow volume* of the transmission links (3.5). Next most senior is the *HID reservoir fill* flow requirement object with a priority value of 3, diverting only if the demands are met. Similar to the demand nodes, it is also not subject to any instream flow rule restriction, but subject to the turn-down schedule. The *Dungeness water rule* flow requirement object has a priority value of 4, which means that the demands of HID reservoir fill (4.4.6) are not subject to the flow rule, but that reservoir filling through the MAW (4.4.8) is subject to the flow rule. The reservoir object has priority value of 99, meaning the reservoir can only fill through the MAW right after the demands and Dungeness water rule have both been met. The *biological flow target* flow requirement is the most junior, with a priority value of 100, meaning that it is not enforced and the target does not affect the calculations.

## 5. Other assumptions

Other assumptions in WEAP perform the same function as the Key assumptions, acting as variables referenced by other objects in the model. In the Dungeness WEAP model, the Other assumptions are organized to represent those expressions which are utilized to calculate the results in section 8, but otherwise not used in the model allocation calculations or referenced by the model schematic objects (with the exception of the unit conversion factor stored in *Other\cfs to AFd*). This section is split between those expressions directly referenced within the results, stored under *Other\Results* (5.2), and those expressions within *Other\Intermediate variables* (5.3) which act as intermediate calculations used to help calculate the *Other\Results* expressions, but not directly used in the results.

### 5.1. *Other\cfs\_to\_AFd*

Conversion factor for cubic feet per second to acre-feet per day.

### 5.2. *Other\Results*

The expressions under *Other\Results* are calculations which are used to produce the results shown in section 8. They are used to display outputs only, but otherwise do not affect the inputs or the allocation calculations of the model.

#### 5.2.1. Available cumulative water in excess of reservoir capacity AF

Calculates the cumulative excess fill, updated as of the previous timestep and reset to 0 on September 18 at the end of each water year. The excess fill is defined as fill that the reservoir is capable of diverting to storage based on its water rights, but is volume in excess of the reservoir capacity, as the reservoir is already full at that time. Because this value is cumulative, it represents the total excess fill diverted so far during the current WY. Calculated based on the daily value of *Other\Results\Available water in excess of reservoir capacity cfs* (5.2.2). Shown in the results in section 8.4.

#### 5.2.2. Available water in excess of reservoir capacity cfs

Calculates the excess fill available in the previous timestep. Calculated according to the following conditions:

1. Excess fill limited by the Main Canal capacity remaining after meeting demands (calculated in *Other\Intermediate variables\Remaining Main Canal capacity cfs* in 5.3.5)
2. Excess fill is calculated as 0 under conditions where diversion to the reservoir would not be allowed (calculated in *Other\Intermediate variables\Possible reservoir diversion conditions* in 5.3.3)
3. Excess fill is calculated as the available MAW water (calculated in *Other\Intermediate variables\Available MAW water for fill cfs* in 5.3.1) plus the available HID water (calculated in *Other\Intermediate variables\Available HID water for fill cfs* in 5.3.2) minus the remaining volume needed to fill the reservoir to full capacity, considering evaporation and groundwater loss (calculated in *Other\Intermediate variables\Remaining reservoir fill needed cfs* in 5.3.6).

Expression is used to calculate *Other\Results\Available cumulative water in excess of reservoir capacity AF* (5.2.1), *Other\Results\HID excess water available daily* (5.2.7) and *Other\Results\MAW excess water available daily* (5.2.9).

### 5.2.3. Date of reservoir fill

Reports the day when the reservoir reaches storage capacity. Value is updated one timestep after the reservoir is filled, and resets to 0 on September 17 at the end of each water year. The value is reported as the number of days after Oct 1 of each water year. I.e., Oct 2 would have a value of 1.

### 5.2.4. HID excess water available cumulative AF

Calculates the cumulative excess fill attributed to the unused portion of the HID right, updated as of the previous timestep and reset to 0 on September 18 (the reset timing is different than *Other\Results\Date of reservoir fill* because this expression is calculated based on the previous timestep) at the end of each WY. Calculated based on the daily value of *Other\Results\HID excess water available daily cfs* (5.2.5).

### 5.2.5. HID excess water available daily cfs

Calculates the excess fill using the unused portion of the HID right in the previous timestep. Assumes that the reservoir is filled first using the MAW right first, when available, and then only uses the HID water right for fill when the MAW right is either already fully utilized for diversion to storage, or the MAW water is not able to be diverted. Calculated by subtracting *Other\Results\MAW excess water available daily cfs* (5.2.9) from *Other\Results\Available water in excess of reservoir capacity cfs* (5.2.2).

### 5.2.6. HID reservoir fill cumulative AF

Calculates the cumulative reservoir fill attributed to the unused portion of the HID right, updated as of the previous timestep and reset to 0 on September 18 at the end of each water year. Calculated based on the daily value of *Other\Results\HID reservoir fill daily cfs* (5.2.5). The cumulative fill may be larger than the storage capacity because of additional filling required to offset evaporation and groundwater losses.

### 5.2.7. HID reservoir fill daily cfs

Calculates the reservoir fill using the unused portion of the HID right in the previous timestep. Calculated by subtracting the *Other\Results\MAW reservoir fill daily cfs* (5.2.11) from the modeled reservoir fill. Assumes that the reservoir is filled first using the MAW right first, when available, and then only uses the HID water right for fill when the MAW right is either already fully utilized for diversion to storage, or the MAW water is not able to be diverted.

### 5.2.8. MAW excess water available cumulative AF

Calculates the cumulative excess fill attributed to the MAW right, updated as of the previous timestep and reset to 0 on September 18 at the end of each water year. Calculated based on the daily value of *Other\Results\MAW excess water available daily cfs* (5.2.9).

### 5.2.9. MAW excess water available daily cfs

Calculates the excess fill using the MAW right in the previous timestep. Outside of the irrigation season, all excess fill (calculated in *Other\Results\Available water in excess of reservoir capacity cfs* (5.2.2)) is attributed to the MAW right. During the irrigation season, the excess reservoir fill is attributed to MAW up to the limit of *Other\Intermediate variables\Available MAW water for fill cfs* (5.3.1), with any remaining fill attributed to the HID right.

Expression is also used to calculate *Other\Results\HID excess water available daily* (5.2.5) and *Other\Results\MAW excess fill cumulative AF* (5.2.8).

#### 5.2.10. MAW reservoir fill cumulative AF

Calculates the cumulative reservoir fill attributed to the MAW right, updated as of the previous timestep and reset to 0 on September 18 at the end of each water year. Calculated based on the daily value of *Other\Results\MAW reservoir fill daily cfs* (5.2.11). The cumulative fill may be larger than the storage capacity because of additional filling required to offset evaporation and groundwater losses.

#### 5.2.11. MAW reservoir fill daily cfs

Calculates the reservoir fill using the MAW right in the previous timestep. Calculates that the reservoir is filled first using the MAW right first, when available, and then only uses the HID water right for fill when the MAW right is either already fully utilized for diversion to storage, or the MAW water is not able to be diverted. Outside of the irrigation season, all reservoir fill is attributed to the MAW right. During the irrigation season, the reservoir fill is attributed up to the limit of *Other\Intermediate variables\Available MAW water for fill cfs* (5.3.1), with any remaining fill attributed to the HID right.

Expression is also used to calculate *Other\Results\HID daily reservoir fill daily cfs* (5.2.7) and *Other\Results\MAW reservoir fill cumulative AF* (5.2.10).

#### 5.2.12. Stored volume in excess of irrigation needs AF

Tracks the stored volume captured in the reservoir which exceeded the irrigation needs for the season. Is calculated by recording the volume remaining in the reservoir on September 15 of each year. In the model, the remaining volume on September 16 disappears from the model.

### 5.3. Other\Intermediate variables

The expressions under *Other\Intermediate variables* are not used directly within the results, but rather are intermediate variables which are used to help calculate the values within *Other\Results*.

#### 5.3.1. Available MAW water for fill cfs

Calculates the flow of the MAW available to fill the reservoir in the previous timestep. Expression contains the following conditions to calculate:

1. Available MAW water is limited by the MAW water right flowrate limit (4.4.8).
2. Available MAW water may only be diverted if the Schoolhouse lower gauge flow exceeds the Dungeness water rule (3.6) after irrigation demands are diverted.

Expression is used to calculate *Other\Results\Available water in excess of reservoir capacity cfs* (5.2.2), *Other\Results\MAW reservoir fill daily cfs* (5.2.11), and *Other\Results\MAW excess water available daily cfs* (5.2.9).

#### 5.3.2. Available HID water for fill cfs

Takes the *HID Key\Operations\HID water available for reservoir fill cfs* (4.4.6) value for the previous timestep, representing the cfs from the HID unused portion available to fill the reservoir. It was useful to calculate the value from 4.4.6 in the previous timestep as a separate expression in order to make the calculations for 5.2.2 clearer.

Expression is used to calculate *Other\Results\Available water in excess of reservoir capacity cfs* (5.2.2).

### 5.3.3. Possible reservoir diversion conditions

Calculates if reservoir diversion would have been possible in the previous timestep. Returns a value of 0 if not possible and a value of 1 if possible. The expression considers the following conditions, all of which must be met in order for possible reservoir diversion.

1. Is there MAW or HID water available?
2. Are there no unmet demands not from paper water right limits (calculated under *Other\Intermediate variables\Unmet demand not from paper limit cfs* in 5.3.8)?
3. Is the inflow less than the peak river flow limit for reservoir diversion (4.4.12)?

Expression is used to calculate *Other\Results\Available water in excess of reservoir capacity cfs* (5.2.2).

### 5.3.4. Previous day storage cfs

Reports the reservoir storage volume in the previous day timestep.

Is used to calculate *Other\Intermediate variables\Remaining reservoir fill needed cfs* (5.3.6), which is ultimately used to calculate the excess fill results.

### 5.3.5. Remaining Main Canal capacity cfs

Calculates the Main Canal capacity that would remain to be available for excess fill in the previous timestep. The expression takes the Main Canal physical conveyance capacity (4.4.7) and subtracts out the fish bypass flow (4.4.3), the passthrough demand, and the remaining volume needed to fill the reservoir to full capacity.

Expression is used to calculate *Other\Results\Available water in excess of reservoir capacity cfs* (5.2.2).

### 5.3.6. Remaining reservoir fill needed cfs

Calculates the cfs for one day that would be needed to fill the reservoir to full capacity, calculated for the previous timestep. The expression takes the reservoir storage capacity plus the evaporation loss plus the groundwater loss and subtracts the previous day storage volume.

Expression is used to calculate *Other\Intermediate variables\Remaining Main Canal capacity cfs* (5.3.5) and *Other\Results\Available water in excess of reservoir capacity cfs* (5.2.2).

### 5.3.7. Unmet demand due to paper limit cfs

Calculates the unmet demand (that is the volume of water demand unable to be supplied in the model) in the previous timestep due to a district's cfs input demand being larger than its paper water right limit. The expression takes the sum of the value for each irrigation district of the flowrate of the demand minus the paper water right, or 0 if the paper water right is larger than the demand.

Is used to calculate *Other\Intermediate variables\Unmet demand not from paper limit cfs* (5.3.8), which is ultimately used to calculate the excess fill results.

### 5.3.8. Unmet demand not from paper limit cfs

Calculates the unmet demand in the previous timestep which is not due to *Other\Intermediate variables\Unmet demand due to paper limit CFS* (5.3.7) and is due to low flows instead. The expression takes the sum of the unmet demands and subtracts out the *Unmet demand not from paper limit CFS*.

Is used to calculate *Other\Intermediate variables\Possible reservoir diversion conditions* (5.3.3), which is ultimately used to calculate the excess fill results.

#### 5.4. User Defined LP Constraints\Reservoir release capacity cfs

In WEAP, a user defined LP constraint will be implemented within the model’s calculations performed by the LP solver. This variable implements the reservoir release capacity (set under *Key\Operations\Reservoir release capacity* 4.4.10) so that the sum of the H1 Delivery from reservoir storage plus the H1 Irrigation passthrough can't exceed this limit.

## 6. Scenarios

The Dungeness WEAP model can be run according to many different scenario simulations. Table 6 below shows the settings of the model scenarios presented in December 2024. The model is easily modifiable to include additional scenarios. Highlighted values in the table show expressions which are either turned off (cyan), or deviate from the baseline values (yellow).

Table 6. Model scenarios

Operation scenarios	Reservoir Size	Irrigation Demands	Reservoir fill rules	Main canal cfs limit	Climate Projections
No reservoir	Off	2020 water year demands	Off	N/A	Each operation scenario is run across 10 future climate projections (2030-2080) and a historical climate (2007-2022).
Reservoir design E1 (959 AF)	959 AF	2020 water year demands	Maximum Allocation Water + HID right	25 cfs + fish bypass (2 cfs)	
Reservoir design E4 (1,610 AF)	1,610 AF	2020 water year demands	Maximum Allocation Water + HID right	25 cfs + fish bypass (2 cfs)	
E4, 35 cfs conveyance	1,610 AF	2020 water year demands	Maximum Allocation Water + HID right	35 cfs + fish bypass (2 cfs)	
Unimpaired	Off	Off	Off	Off	

Each of the operation scenarios is ran across the 10 different future climate projections described in 3.1 from 2030-2060. The results in section 8 aggregate the results for all 10 climate projections for each

operation scenario and then divide the results into 2030-2060 and 2050-2080 timesteps. An additional set of results is run for each of the operation scenarios for the historical inflows from 2007-2022.

## 7. Calibration and validation

The seepage inflow, described in section 3.1, was set according to a calibration process and the model results were validated by comparing the modeled versus observed streamflow at the lower Schoolhouse gauge (3.7).

The input flow data contained the streamflow of the Dungeness River at the USGS gauge, upstream of the agriculture diversions. However, the reservoir filling depends on the fulfillment of the Dungeness water rule (3.6), which is enforced based on the streamflow at the lower Schoolhouse gauge. Additionally, stakeholders were interested in calculating accurate streamflow results at the lower Schoolhouse gauge. For these reasons, it was important to calculate the seepage inflow and outflow between the USGS and lower Schoolhouse gauges.

Evidence of significant seepage flows can be assumed based on tributary streams present in aerial imagery as well as quantified seepage measurements in the USGS paper, Surface Water-Ground Water Interactions Along the Lower Dungeness River and Vertical Hydraulic Conductivity of Streambed Sediments, Clallam County, Washington, September 1999-July 2001 by William Simonds and Kirk Sinclair. However, the only seepage readings in the Simonds and Sinclair paper are on April 11, 2000, October 4, 2000, and April 12, 2001. Because the snapshots in this paper are so limited and are from a period before the complete record of irrigation withdrawals beginning October 2013, they were not able to be used to inform the calibration of the seepage flows.

The calibration process used to set the seepage inflows made a simplified assumption that the lower Schoolhouse gauge observed flow minus observed agriculture withdrawals minus observed USGS observed inflow equals seepage flow, shown below in Equation 1.

*Equation 1. Seepage inflow calculation*

$$\text{Seepage flow} = \text{Lower Schoolhouse gauge observed flow} - \text{observed agriculture withdrawals} - \text{USGS observed inflow}$$

The period of record for the agriculture withdrawals was WY 2014-2022. The even years within this period were taken as the calibration period, while the odd years were used as the validation period. Four initial methods used to predict the seepage inflow were tested: (1) Monthly fixed seepage values, (2) Monthly seepage values as a fixed % of USGS inflow (3) Monthly seepage values set as a function of USGS inflow, and (4) Monthly seepage values as a % of USGS inflow set as a function of USGS inflow. These methods were used to calculate the seepage inflow during the calibration period, with the top 20<sup>th</sup> percentile of USGS flows removed for each month to isolate the effects of background seepage, rather than precipitation runoff. This decision was also influenced by the motivation to prioritize accurate flows during lower baseflow periods rather than periods of high flow during precipitation events. This 20<sup>th</sup> percentile was selected as the lowest threshold where the trends between the USGS flow and calculated seepage flow became more clearly correlated based on a combination of visual inspection and R<sup>2</sup> values. The methods #2 and #4 were first eliminated because of their irregular trends based on visual inspection and lowest R<sup>2</sup> values of the methods. Next, method #3 was selected over #1 because the visual inspection and R<sup>2</sup> values did reveal significant trends between USGS inflow and seepage flow.

Once method #3 was selected, the method was modified to create one function throughout the year rather than functions for individual months. This was because the observed historical monthly flow pattern differed significantly from the future projected monthly flow patterns, which had different timing for peak snowmelt. The monthly patterns in the future projections were not seen in any of the historical records. In testing, one linear function used for the whole year across all flows (Figure 11), did not produce a satisfying correlation from a visual or  $R^2$  value standpoint. From here, visual inspection revealed thresholds between certain flows where the average seepage started to significantly change. The seepage flows were then sorted into stepwise points of upper and lower bounds of USGS flow. Upon experimentation, bound ranges of 50 CFS produced the smoothest trends that visually matched the overall pattern of the complete set of data points. The median observed seepage CFS is shown as a function of the midpoint of the bound set of the USGS observed flow is shown below in Figure 12.

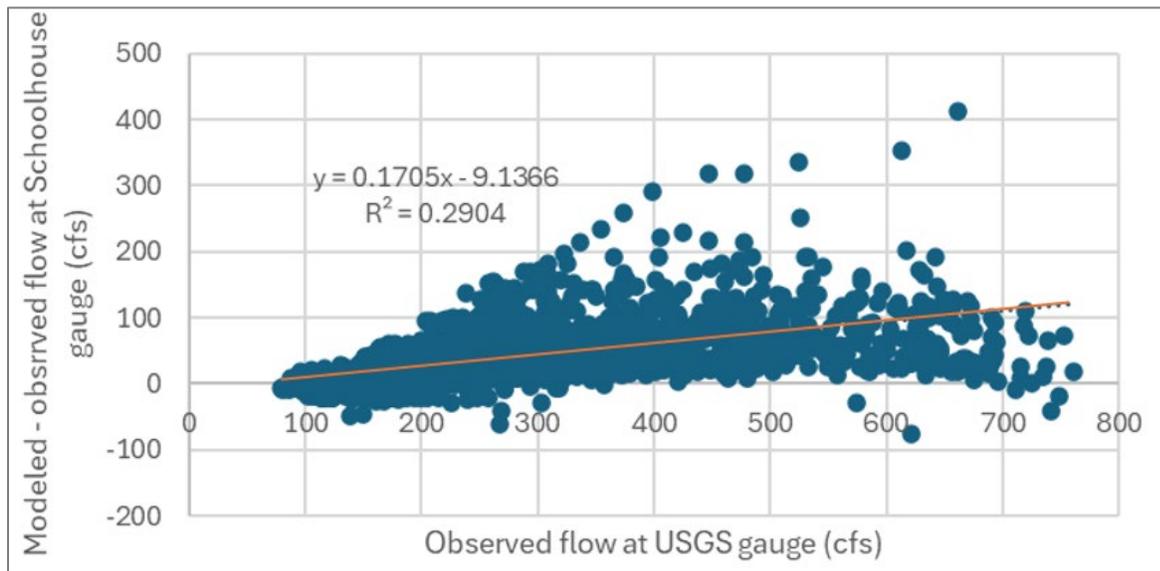


Figure 11. Unused preliminary calibration method of one linear function to predict seepage across all flows. Trendline shown in orange.

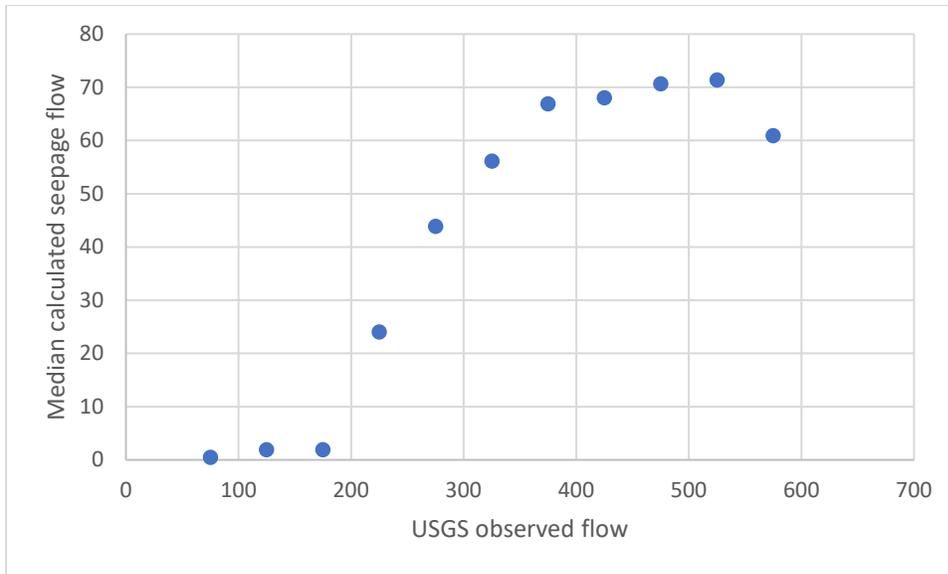


Figure 12. Median calculated seepage flow vs. USGS observed flow

Visual inspection of Figure 12 revealed that the seepage values showed a clear increase as USGS flows increased between 200 to 350 cfs. Above 350 cfs, there is no longer a clear changing trend, and the seepage values look to remain roughly constant around 68 cfs. Below 200 cfs, the seepage values similarly do not show a clear changing trend and look to remain roughly constant at a seepage value around 1.5 cfs. Based on these thresholds, a stepwise function was produced based on the median values for seepage calculated below 200 cfs, above 350 cfs, and for 50 cfs intervals between 200 and 350 cfs. The stepwise function uses linear interpolation between the following values in Table 7 below, previously shown in Table 2 on page 12. These values are the final calibration values ultimately used as the seepage inflow in the model.

Table 7. Seepage inflow stepwise function values

Headflow at USGS gauge (cfs)	Seepage inflow (cfs)
=<200	1.5
225	24
275	43.9
325	56.2
>=350	68

The seepage values produced by this stepwise function are compared to the seepage values produced from Equation 1 for the range of observed flows at the USGS gauge in Figure 13. A visual comparison of Figure 13 demonstrates that there lie calculated seepage values significantly above and below those produced by the stepwise function. However, the stepwise function appears to generally match the overall pattern of the seepage values. Further investigation at a monthly scale revealed that certain months produce different trends of differences between the two sets of values, likely an effect of the background wet or dry soil during the course of the season. However, because analysis revealed that the future projections would have significantly different monthly trends never before observed in the

historical record, the stepwise function was not able to adapt to these monthly trends. This stepwise function generally matched the overall trend of predicted seepage and its simplified manner was appropriate based on the limited data available. Because of this, this calibrated stepwise function for the seepage inflow was advanced on to the validation phase to test its performance.

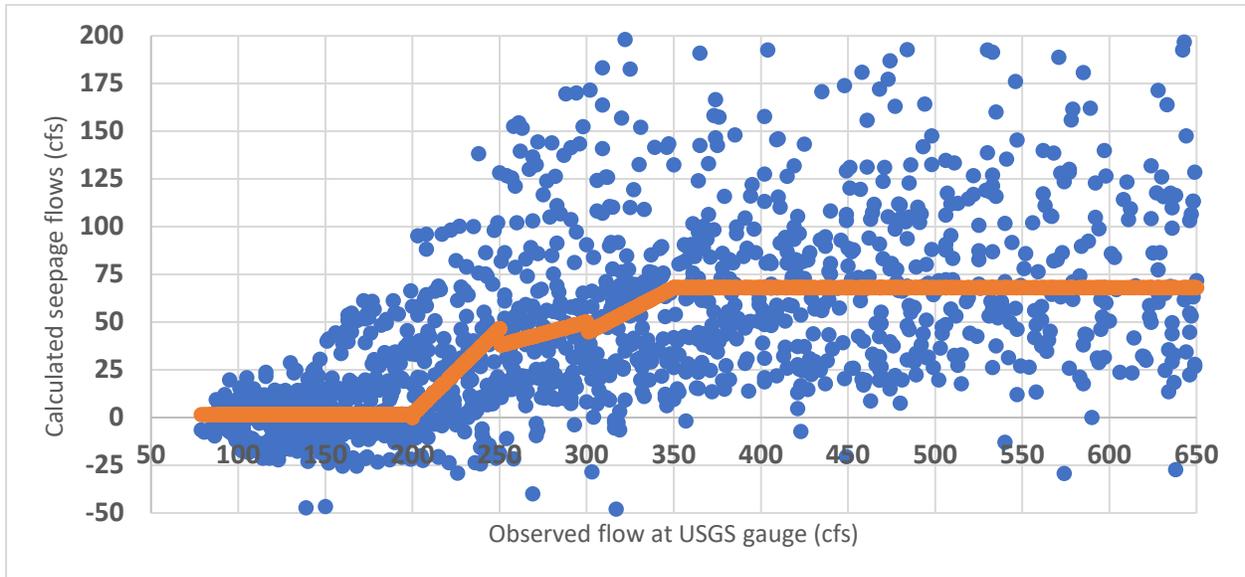


Figure 13. Observed flow at USGS gauge vs. calculated seepage flows (calibration period). Calculated daily seepage values in blue, stepwise function shown in orange.

Beyond the visual inspection described above, the stepwise function was quantitatively validated for the odd years in WY 2014-2022 to confirm the reproduction of satisfactory results. The comparison of modeled to observed values during the validation period is shown below in Figure 14. The validation performance evaluation results are shown below in Table 8, developed based on the performance criteria for watershed models involving both hydrology and systems operation from [Moriasi et al., 2015](#) shown in Table 9 below. Figure 14 shows a visually strong match between the observed and modeled streamflow values while Table 8 shows performance criteria for  $R^2$ , Nash Sutcliffe Efficiency (NSE), and percent bias (PBIAS) all falling within the best performance category of “Very good” within Table 9. Thus, the validation confirmed strong model performance and the seepage validation was accepted into use for the model simulations.

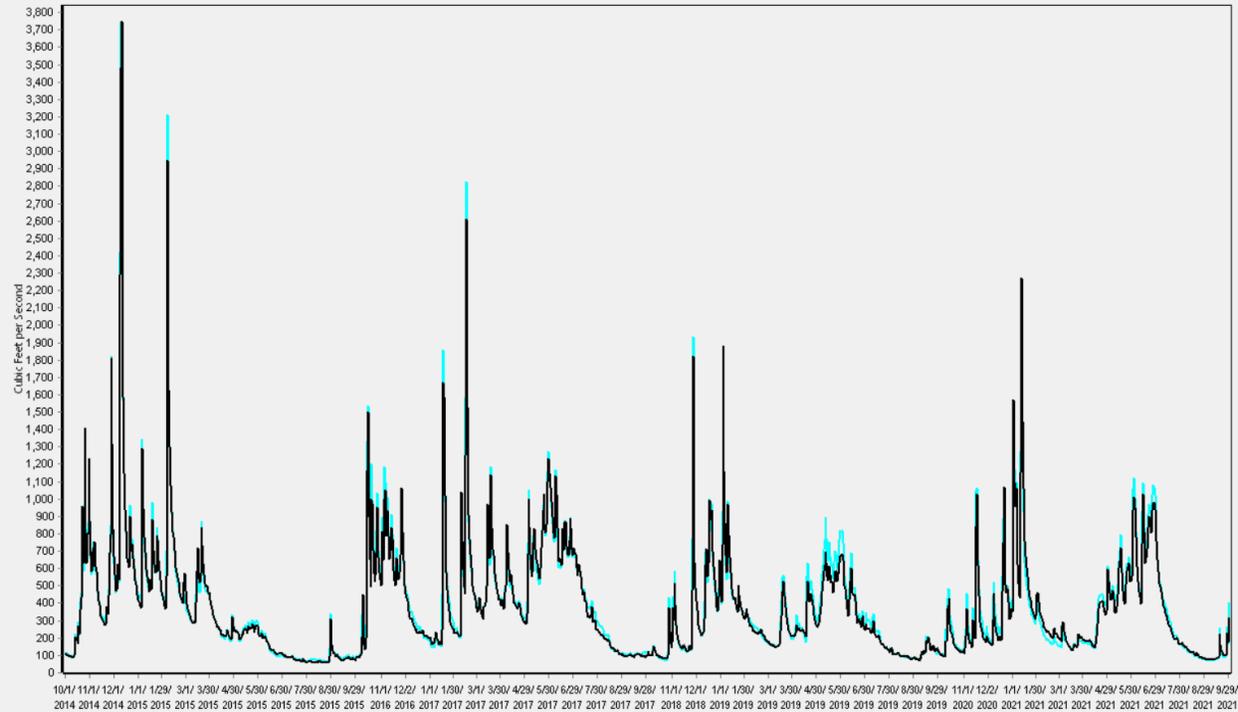


Figure 14. Modeled (cyan) vs. observed (black) streamflow values at Schoolhouse gauge for validation time period.

Table 8. Validation performance evaluation results

Parameter	Validation value	Performance evaluation criteria
R <sup>2</sup>	0.98	Very good
NSE	0.98	Very good
PBIAS	3.1%	Very good

Table 9. Performance evaluation criteria for watershed models, from [Moriassi et al., 2015](#).

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

## 8. Results

The results in this section are updated as of December 2024. They present the four scenarios described in section 6, as well as the unimpaired scenario results for the streamflow. These same results have been presented to stakeholders in October and December 2024.

The results are divided into the different timesteps of 2030-2060 future climate projections (ran across the 10 rcp8.5 climate projections described in 3.1), 2050-2080 future climate projections, and the 2007-2022 historical observed inflow. These future time periods were selected by the Dungeness Reservoir Workgroup. The 2030-2080 overall period was selected to represent the potential first 50 years of the lifecycle of the potential reservoir. The division of the future timesteps into 2 periods and the inclusion of the 2007-2022 period was meant to illustrate the predicted changes in hydrology trends and results over time. The selection of 30-year future bands was based on a recommendation from the Point No Point Treaty Council to use 30-year future periods to fully represent the climate cycles tied to the Pacific Ocean.

## 8.1. Results summary

The results within this section are summarized below:

- Future inflows (8.2):
  - Higher future inflows from December to May than historical inflows
  - Lower future inflows from June to October than historical inflows
- Reservoir fill (8.3)
  - Reservoir completely fills under 100% of annual simulations
  - Higher future inflows during reservoir fill period fill reservoir faster in future
- Excess fill (8.4)
  - Mean annual excess fill from 2,500-3,100 AF across scenarios
  - Higher future inflows during reservoir fill period drive greater excess fill volume in future
- 8.5: Maximum Allocation Water vs. HID fill
  - Mean MAW fill accounts for 87-94% of reservoir fill across scenarios, with the remaining 6-13% from the HID right.
  - Mean MAW fill accounts for 71-80% of excess fill across scenarios, with the remaining 20-29% from the HID right.
  - Higher priority and later season of HID fill has greater impact in simulations with lower inflow after April 15.
- 8.6: Irrigation supply
  - Mean August 15 to September 15 supply to irrigation each reservoir release season increases across scenarios from 110-240 AF without reservoir in future and 930 AF in historical without reservoir to 940-1,040 AF with reservoir.

In absence of reservoir, lower future inflows and increased frequency of turn-down rule curtailment drive decrease in proportion of demand able to be supplied from August 15-September 15, from 89% from 2007-2022 to 23% in 2030-2060, to 11% in 2050-2080.
- 8.7: Turn-down rules
  - Lower future inflows from June to September drive increased frequency of partial and complete turn-down rule curtailment.
  - The increased future turn-down rule curtailment frequency drives lower supply to irrigation and lower flow benefits.

- 8.8: Downstream flow and flow benefit
  - Lower future inflows from June to October drive future mean flows beneath 105 cfs biological flow target in summer and fall.
  - Flow benefit of reservoir from August 15 to September 15 ranges from 0-17 cfs, with the maximum flow benefit equal to the full demand of the districts connected to the reservoir supply.
  - 50<sup>th</sup> percentile flow benefits of reservoir from August 15 to September 15 range from 0-9 cfs from 2030-2060, 0-1 cfs from 2050-2080, and 13-17 cfs from 2007-2022. Decreased future flow benefits driven by increased turn-down rule curtailment frequency.

## 8.2. Future inflows

### Conclusions summary:

- **Higher future inflows from December to May**
- **Lower future inflows from June to October**

The future inflows are largely a model input, rather than a result variable, as they are defined by the Point No Point Treaty Council flow projections documented in 3.1, and are otherwise not modified within WEAP. Regardless, they are documented in this section, as they provide a useful insight behind the rest of the results, which are additionally summarized in this section

Figure 15 shows the daily mean of the inflows for each of the time periods. Note that the inflows are not only averaged across all of the years, but also each of the ten climate projections for the future periods. Therefore, this graph shows the aggregated differences in flow between the time periods, but does not describe the variability across individual years and climate projections. These inflows are a major driver behind the results in the rest of this section, as well as the motivation behind the proposed reservoir project.

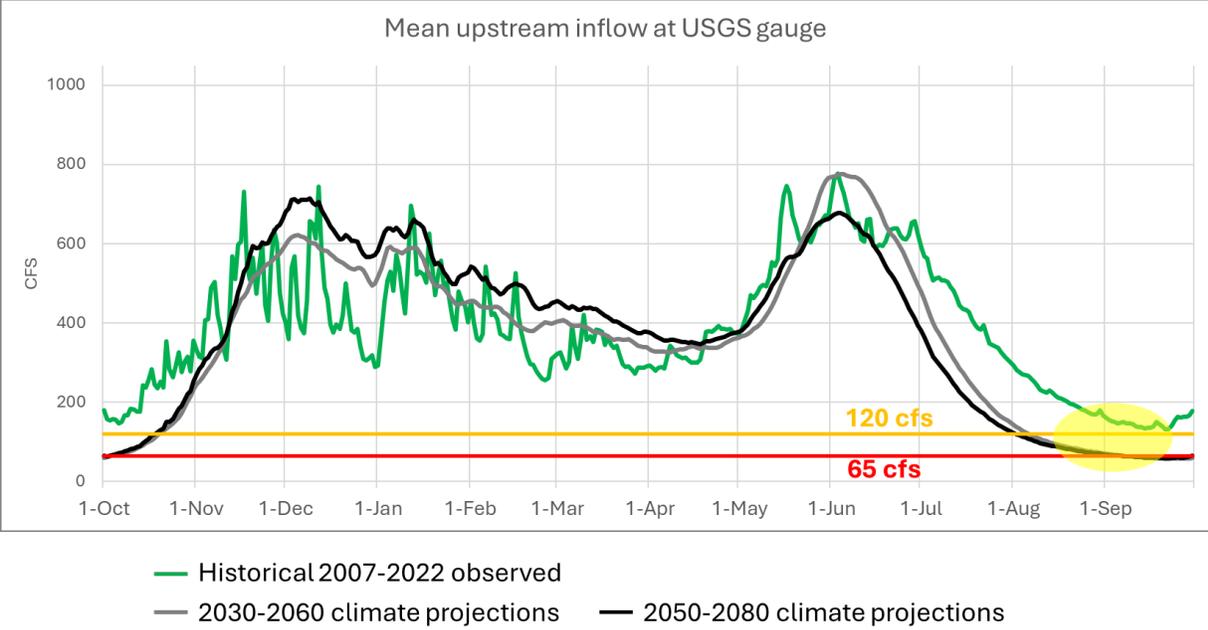


Figure 15. Future inflows

The 2030-2060 climate projections show relatively higher inflows from December to May. While the specific causes of this difference are not explored within this project, some possible explanations may include winter precipitation falling as rain instead of snow, earlier snowmelt, or larger winter storms. In addition, the 2030-2060 climate projections show lower inflows from June to October, which may be caused by earlier snowmelt, lower summer precipitation, or a drying of the landscape due to increased evaporation from higher summertime temperatures. These patterns are further exaggerated in the 2050-2080 inflows, which overall show even higher inflows from December to May and even lower inflows from June to October. The orange line in Figure 15 highlights 120 cfs, the threshold at which the irrigation turn-down rules (documented in 4.4.4) come online and begin to curtail the irrigation supply from the river and passthrough diversions. The red line highlights 65 cfs, the threshold at which the irrigation turn-down rules completely curtail the river and passthrough diversions. The mean historical inflows stay above these thresholds, while the mean future inflows are below 120 cfs from early August until mid-October and are below 65 cfs from mid-September to early October. The yellow oval highlights the reservoir release period from August 15 to September 15. The lower predicted future flows during this period are one of the major motivations behind the proposed reservoir project.

### 8.3. Reservoir fill

#### Conclusions summary:

- **Reservoir completely fills under 100% of annual simulations.**
- **Higher future inflows during reservoir fill period fill reservoir faster in future.**

The reservoir fill results describe the ability of the reservoir to fill during its allowed season from November 15 to August 15 using the MAW and HID water rights. The filling operations of the reservoir are described in section 3.3. The reservoir fill results are summarized below in Table 10.

Table 10. Reservoir fill results

	2030-2060			2050-2080			2007-2022		
	Reservoir design E1	Reservoir design E4	E4 35 cfs conveyance	Reservoir design E1	Reservoir design E4	E4 35 cfs conveyance	Reservoir design E1	Reservoir design E4	E4 35 cfs conveyance
Median date of full fill	Jan 5	Feb 17	Feb 14	Dec 28	Jan 28	Jan 25	Feb 3	Apr 26	Apr 21
% of years with full fill	100%	100%	100%	100%	100%	100%	100%	100%	100%

Notably, the reservoir completely fills under 100% of annual simulations across all scenarios. The results show the median date when the reservoir reaches full capacity for 2030-2060 as Jan 5 for E1 scenario (959 AF), Feb 17 for the E4 scenario (1,610 AF), and Feb 14 for the E4 35 cfs scenario. The E4 scenario takes longer to fill because the storage volume is larger. The 35 cfs conveyance fills the reservoir a median 3 days sooner from 2030-2060. This difference is limited by the fact that the MAW is only 25 cfs until April 15, meaning the only benefit of the 35 cfs conveyance capacity would be the ability for the Main Canal to convey both the full 25 cfs diversion to storage in addition to passthrough demand. The 25 cfs conveyance would only be able to store up to the 25 cfs MAW right minus the passthrough demand. The excess fill results in 8.4 show that the more significant benefits of the 35 cfs conveyance capacity show up after April 15, when the filling right goes up to 25 cfs MAW plus 5-10 cfs of the unused HID right. Because the inflows are generally increasingly higher during the reservoir fill season further into the future, the 2050-2080 scenarios show faster filling compared to 2030-2060, with median fill dates of Dec 28 for E1, Jan 28 for E4, and Jan 25 for E4 35 cfs. The 2007-2022 scenarios show slower filling compared to 2030-2060, with median fill dates of Feb 3 for E1, Apr 26 for E4, and Apr 21 for E4 35 cfs conveyance.

The below figures show more detailed reservoir fill results for each scenario. Figure 16, Figure 18, and Figure 20 show the median daily reservoir storage volume for the 3 timesteps. They show the median reservoir storage volume achieved for each day of the year across all climate projections and years for each scenario. While the fill timing varies across each year and climate projection, these median fill patterns depict a representative general fill pattern. Half of the yearly simulations will have a lower storage volume than that on the graph on each day, while half will have higher. The reservoir begins filling in November, and the median simulation reaches full capacity between December to April. Figure 17, Figure 19, and Figure 21 show the frequency of the full reservoir fill by date, describing the resilience

of the reservoir fill across the full set of years and climate projections. These graphs show the frequency of the total simulations which have achieved full reservoir fill by each date. They illustrate the results of Table 10, showing that the reservoir reaches full capacity in all simulations. The first simulations reach full capacity beginning in December and all the simulations reach full capacity by the end of June.

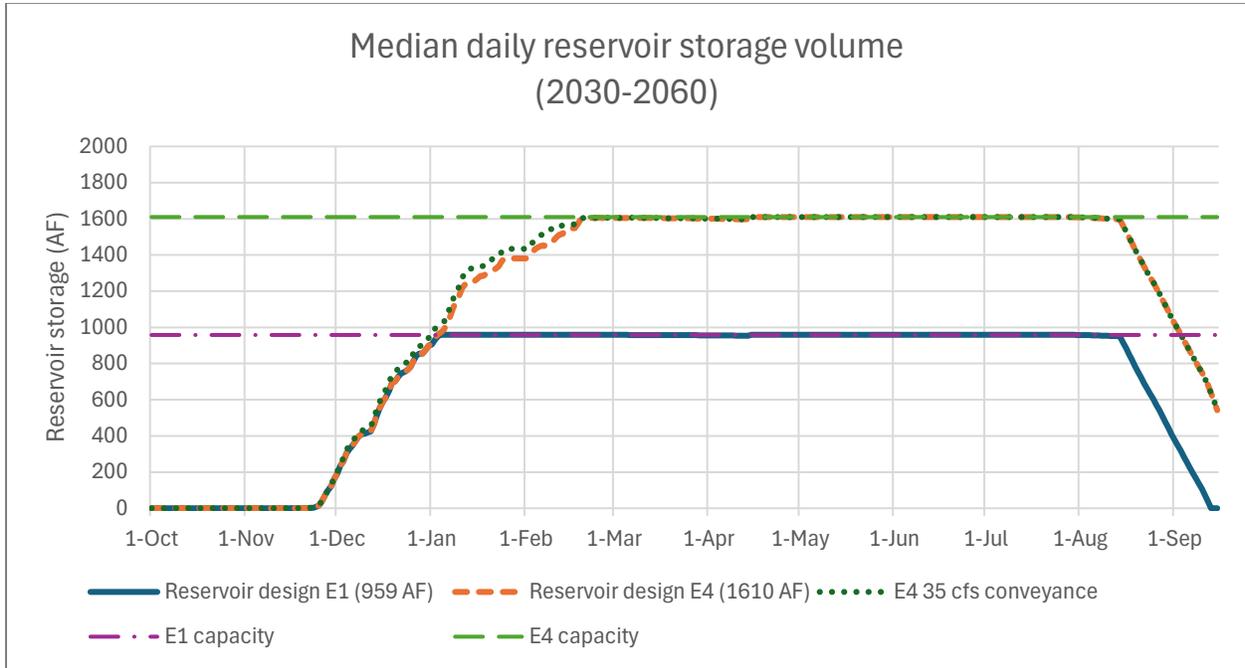


Figure 16. Reservoir fill volume results (2030-2060)

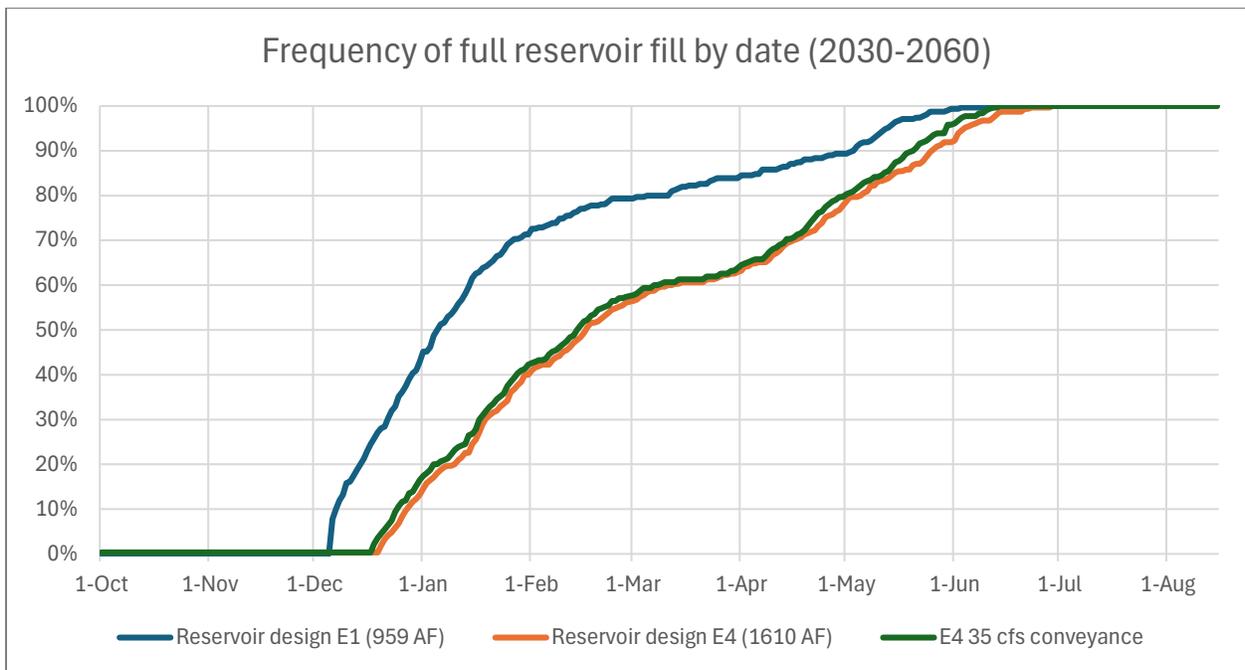


Figure 17. Reservoir fill frequency results (2030-2060)

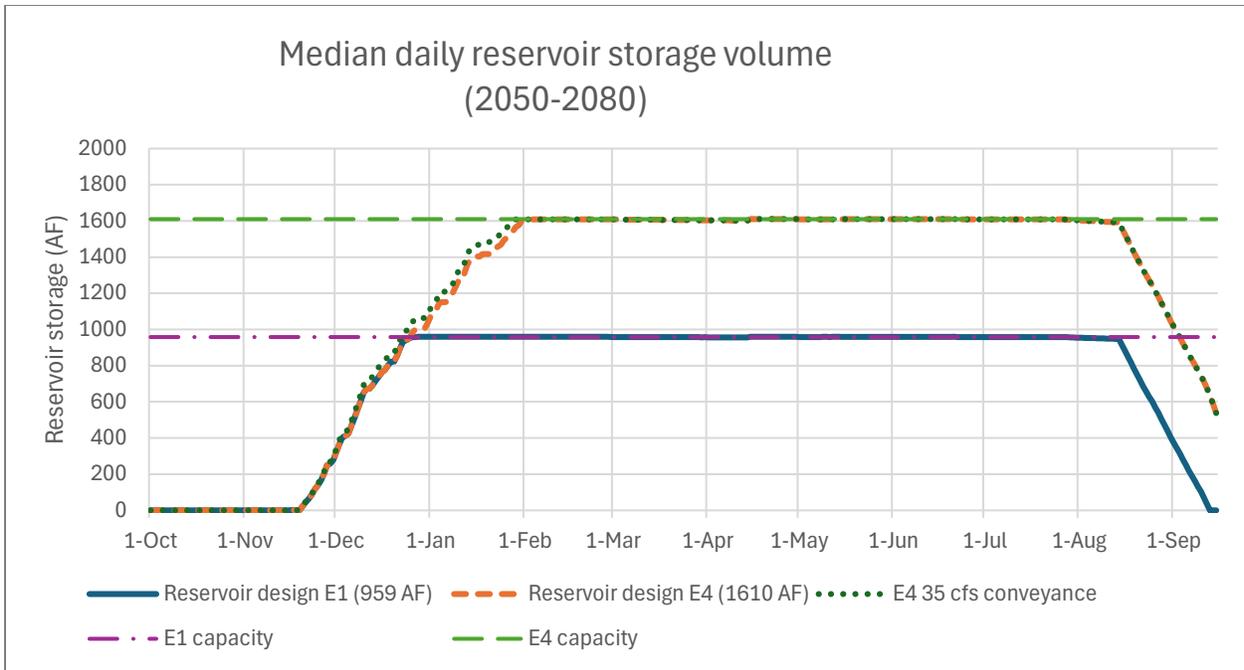


Figure 18. Reservoir fill volume results (2050-2080)

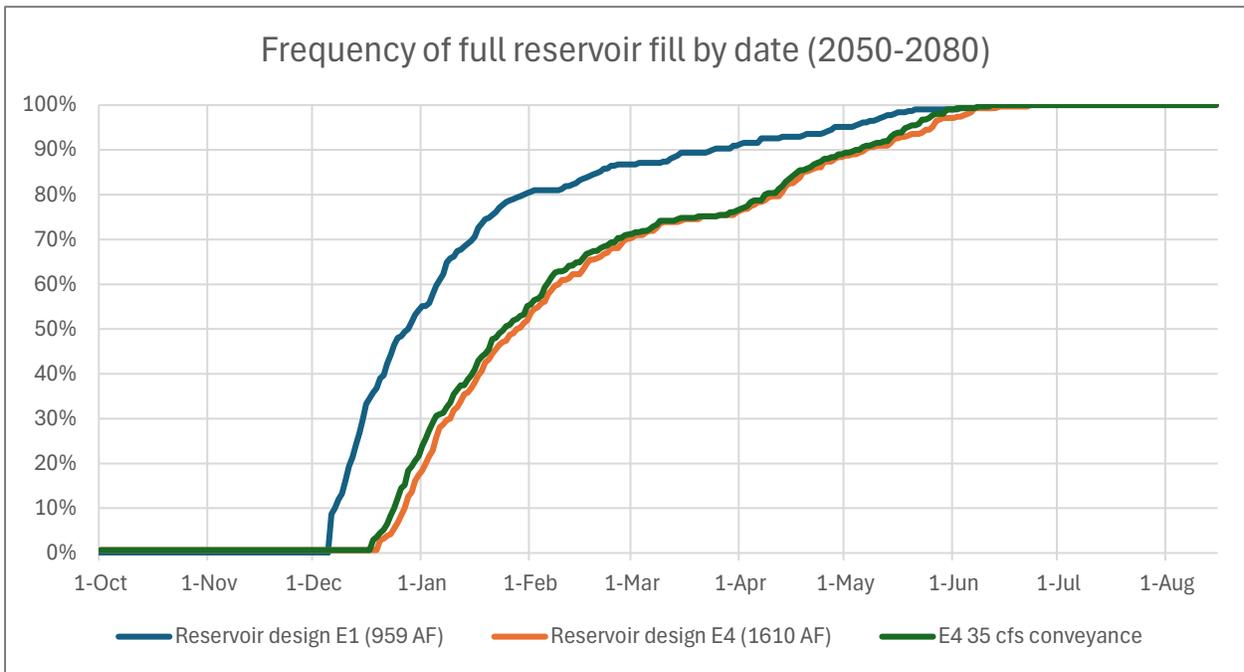


Figure 19. Reservoir fill frequency results (2050-2080)

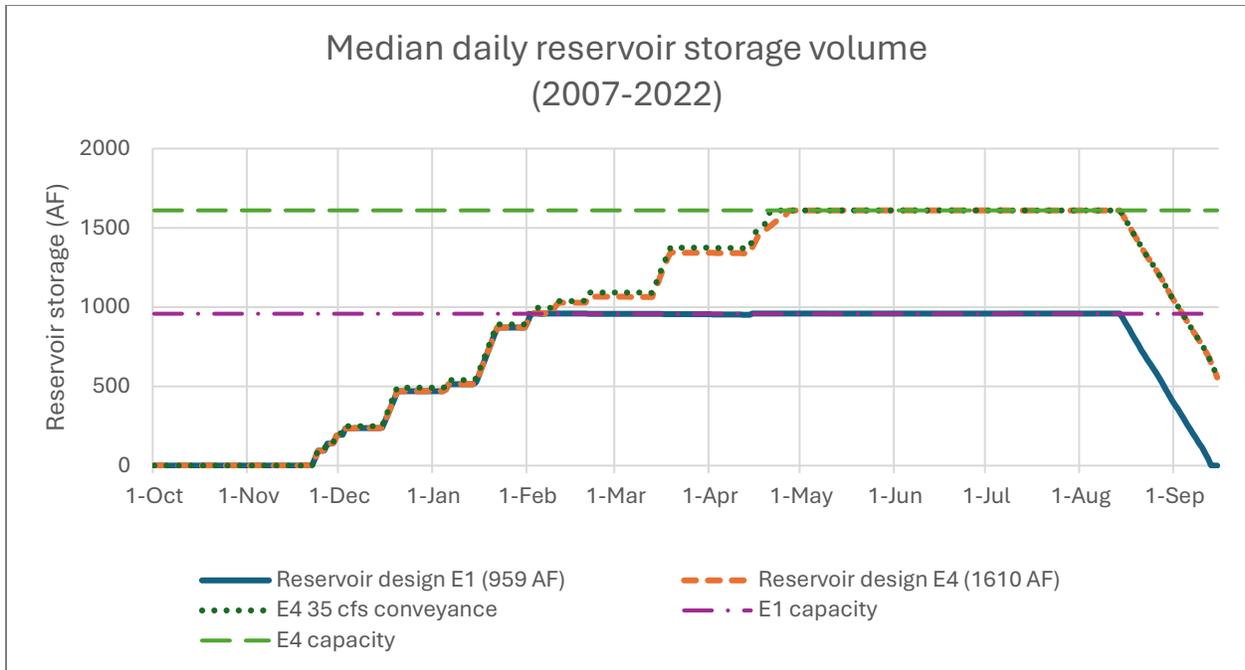


Figure 20. Reservoir fill volume results (2007-2022)

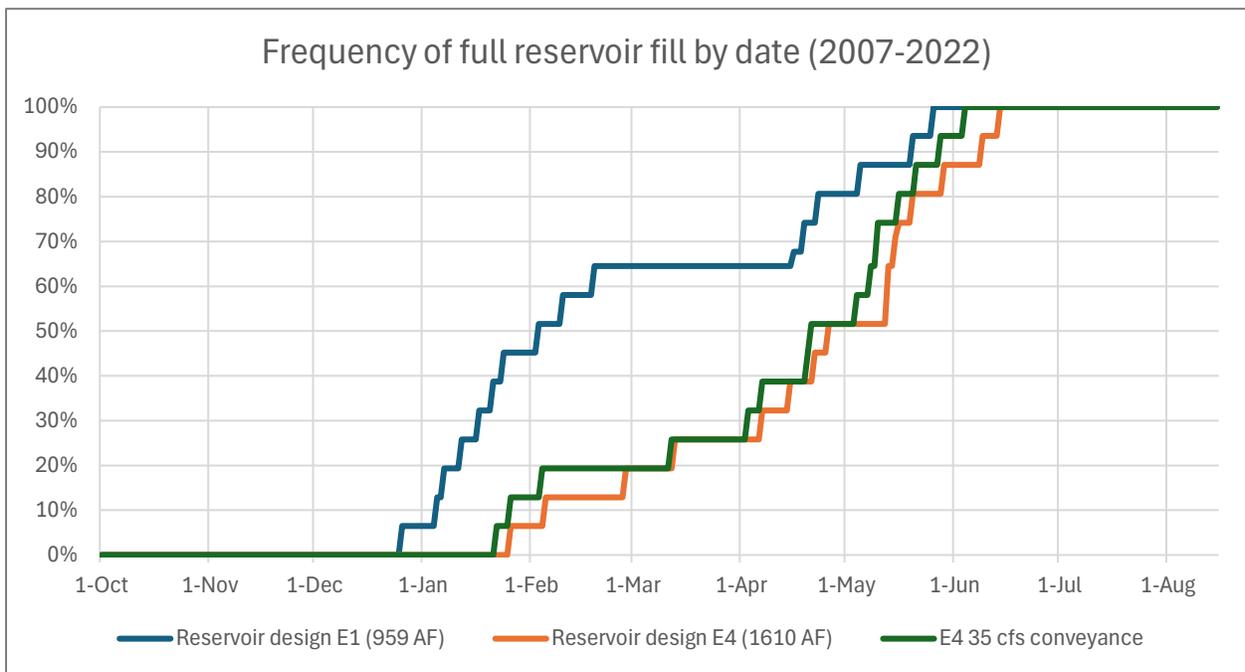


Figure 21. Reservoir fill frequency results (2007-2022)

#### 8.4. Excess fill

##### Conclusions summary:

- Mean annual excess fill from 2,500-3,100 AF across scenarios.
- Higher future inflows during reservoir fill period drive greater excess fill volume in future.

The excess fill results describe the volume that the reservoir would be able to divert using its fill water rights after already achieving maximum storage volume. These results were requested by the Dungeness Reservoir Workgroup to illustrate potential flexibility in the reservoir operation. The excess fill results are summarized below in Table 11.

Table 11. Excess fill results

	2030-2060			2050-2080			2007-2022		
	Reservoir design E1	Reservoir design E4	E4 35 cfs conveyance	Reservoir design E1	Reservoir design E4	E4 35 cfs conveyance	Reservoir design E1	Reservoir design E4	E4 35 cfs conveyance
Mean annual available water in excess of reservoir capacity (AF)	3,500	2,800	3,700	3,800	3,100	3,900	3,200	2,500	3,600
Mean annual stored volume in excess of irrigation needs (AF)	0	540	540	0	540	540	0	540	540

The results show the mean volume of excess fill possible at the end of each fill season across each year and climate projection. While excess fill volumes vary by year and climate projection, these mean results are meant to depict a general magnitude of the excess fill volume available. The mean excess fill volume, labeled as mean annual available water in excess of reservoir capacity, across all years and climate projections from 2030-2060 for each scenario is 3,500 AF for E1, 2,800 AF for E4, and 3,700 AF for the 35 cfs conveyance. The excess fill volume is always 700 AF greater under E1 than E4 simply because the reservoir capacity is approximately 700 AF less. The excess fill volume is 800-1,100 AF greater with the 35 cfs conveyance compared to 25 cfs conveyance under E4, highlighting the primary benefit shown of the 35 cfs conveyance. The 35 cfs conveyance is able to provide greater excess fill because it is able to divert to storage a greater portion of the 25 cfs MAW right plus 5-10 cfs HID right starting April 15, and the 35 cfs MAW right plus 5-10 cfs HID right starting May 1. There is generally increasingly greater inflow available during the reservoir fill season the further into the future. As a result, the 2050-2080 results show mean greater excess fill volumes of 3,800 AF for E1, 3,100 AF for E4, and 3,900 AF for 35 cfs conveyance. The 2007-2022 results show lower excess fill volumes of 3,200 AF for E1, 2,500 AF for E4, and 3,600 AF for 35 cfs conveyance.

Table 11 also shows results for mean annual stored volume in excess of irrigation needs, which is the volume of water leftover in the reservoir at the end of the irrigation season. Because the reservoir fills to full capacity in all simulations and the same demands are used, this result is the same any simulations using the same reservoir size. The E1 scenario has 0 storage volume leftover after the irrigation season. The irrigation supply results in section 8.6 show that the E1 storage is fully depleted beginning September 13, running out 2 days before the end of the irrigation season. The E4 scenario shows 540 AF leftover at the end of the irrigation season.

Figure 22, Figure 23, and Figure 24 below show the mean cumulative excess fill volume achieved by each day of the season for each scenario and timestep. They depict a representative excess fill pattern over

the course of a season. The excess fill begins as early as December, and shows benefits of greater excess fill with the 35 cfs conveyance most significantly beginning April 15.

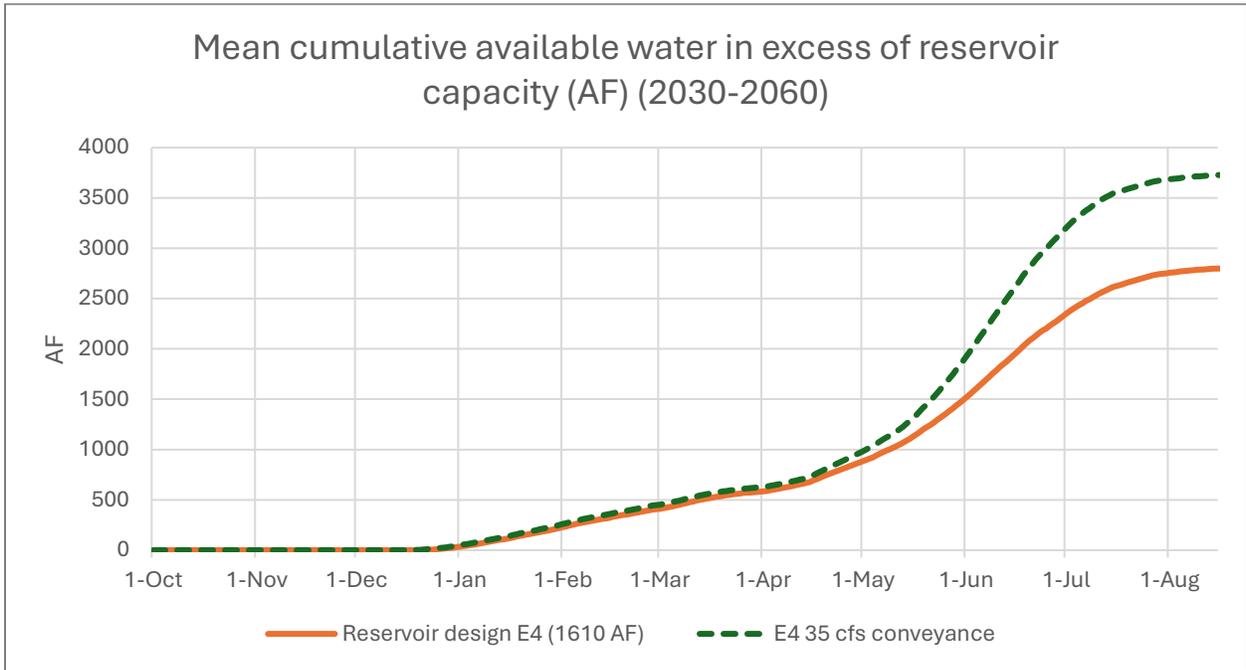


Figure 22. Daily excess fill results (2030-2060)

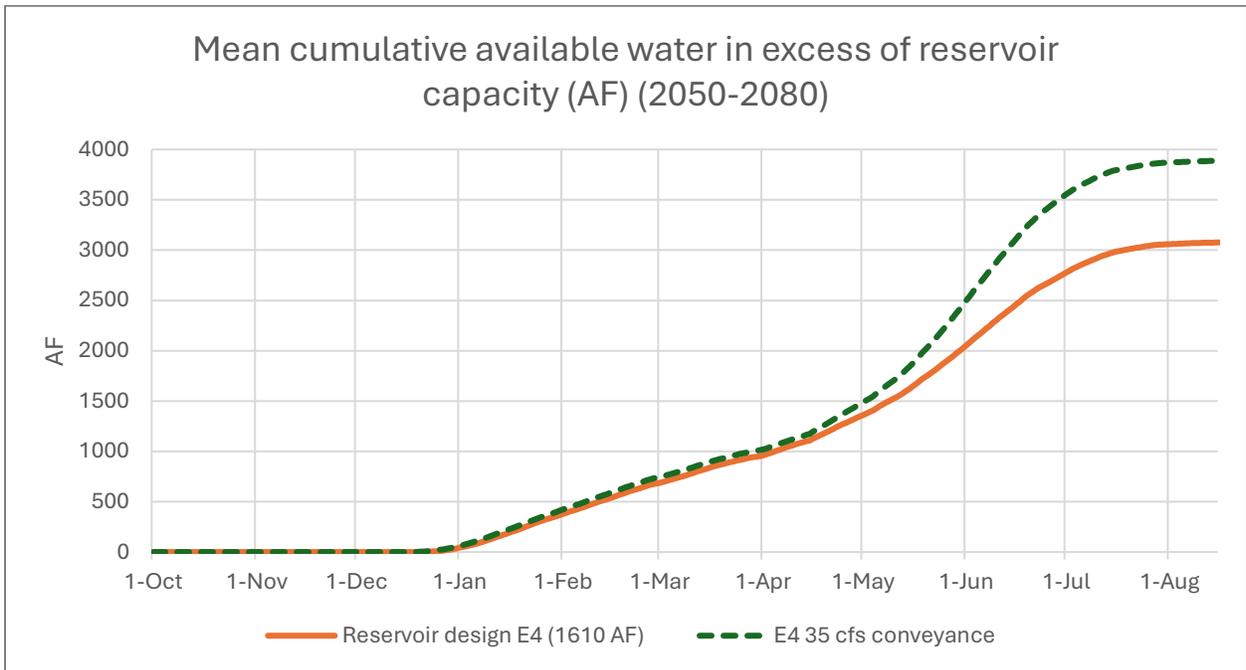


Figure 23. Daily excess fill results (2050-2080)

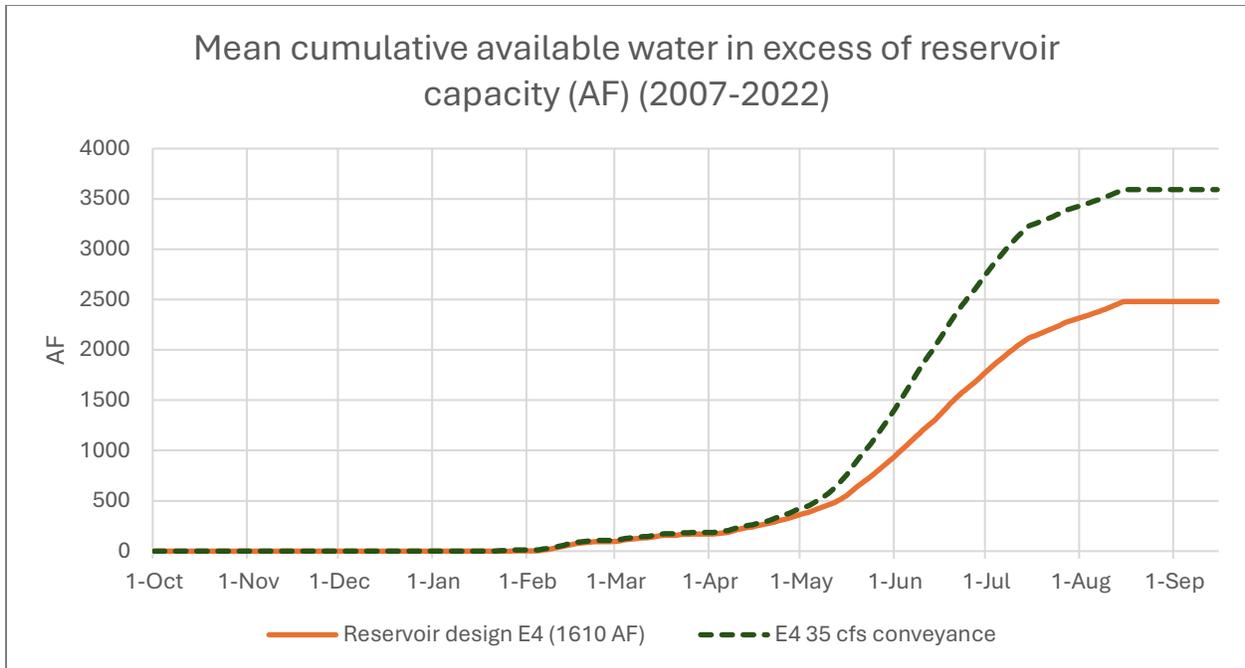


Figure 24. Daily excess fill results (2007-2022)

### 8.5. Maximum Allocation Water vs. HID fill

#### Conclusions summary:

- Mean MAW fill accounts for 87-94% of reservoir fill across scenarios, with the remaining 6-13% from the HID right.
- Mean MAW fill accounts for 71-80% of excess fill across scenarios, with the remaining 20-29% from the HID right.
- Higher priority and later season of HID fill has greater impact in simulations with lower inflow after April 15.

This section describes the contributions to the reservoir fill and excess fill made up by the two water rights used to fill the reservoir, the MAW and HID rights, described in sections 3.3 and 4.4. The results describe the volume and timing of the fill achieved by each right, used to infer the relative contribution and importance of each.

Table 12 and Table 13 below show the mean reservoir fill volume and excess fill volume across all years and climate projections achieved each season using the MAW and HID rights. The calculations, documented in section 5, designate the fill volume as MAW, up to the full volume that would have been achieved by the presence of the MAW right alone. When the fill volume exceeds the MAW right limit, or the fill volume would only have been able to be diverted through HID and not MAW due to the more junior priority of MAW compared to the Dungeness water rule (3.6), the fill volume is designated as HID instead. The total fill volume exceeds the reservoir capacity because the reservoir must keep filling to offset losses from evaporation and groundwater seepage.

Table 12. Mean reservoir fill of MAW and HID rights

Mean reservoir fill (AF)	2030-2060			2050-2080			2007-2022		
	Reservoir design E1	Reservoir design E4	E4 35 cfs conveyance	Reservoir design E1	Reservoir design E4	E4 35 cfs conveyance	Reservoir design E1	Reservoir design E4	E4 35 cfs conveyance
MAW	960	1,570	1,580	980	1,610	1,610	930	1,520	1,520
HID	80	160	160	60	120	110	130	220	220

Table 13. Mean excess fill of MAW and HID rights

Mean excess fill (AF)	2030-2060			2050-2080			2007-2022		
	Reservoir design E1	Reservoir design E4	E4 35 cfs conveyance	Reservoir design E1	Reservoir design E4	E4 35 cfs conveyance	Reservoir design E1	Reservoir design E4	E4 35 cfs conveyance
MAW	2,680	2,080	2,970	2,970	2,340	3,120	2,360	1,770	2,850
HID	820	720	760	810	740	770	820	710	740

The results show that the mean reservoir fill is comprised from 87-94% by MAW, with only the remaining 6-13% by the HID right. However, it is important to note that these results only show the mean values. The results in section 8.3 highlight that most of the simulations completely fill the reservoir prior to April 15 when the HID right first comes online. However, during simulations with lower flow, the HID right would have more importance. Starting April 15, the HID right can fill the reservoir using the full 5-10 cfs available in the unused portion during times when inflows in the river go down to 158.5 cfs, when the turn-down rules begin restricting the diversion volume. On the other hand, the MAW right can only fill when the inflow at the USGS gauge is above the 495 cfs of the Dungeness water rule plus the buffer from April 15 to July 31. This means that only the HID right can be used to divert to storage from April 15 to July 31 when the inflow is between 495 to 158.5 cfs. Thus, the results can be interpreted that, while the MAW provides the large majority of the fill volume, the HID right provides security and resilience, bolstering the reservoir fill during dry simulations when the full fill still hasn't been achieved by the spring and there are low inflow conditions below 495 cfs in the spring. Because the excess fill results show the potential filling past April 15 during all years, they show a greater proportion than the reservoir fill results achieved by the HID right, with 71-80% of the excess fill achieved by the MAW with the remaining 20-29% achieved by the HID right.

Figure 25, Figure 27, and Figure 29 show the mean cumulative reservoir fill volume contribution of the MAW and HID rights across all years and climate projections achieved by each day of the season for each scenario and timestep. They depict a representative reservoir fill pattern of the MAW and HID rights over the course of a season. The MAW rights fill between November and August, while the HID rights have a lower volume of fill, achieved between April and August. Figure 26, Figure 28, and Figure 30 show the mean cumulative excess fill volume contribution of the MAW and HID rights, depicting a representative excess fill pattern of the two rights. The MAW rights achieve excess fill from December to August while the HID rights achieve a lower volume of excess fill, between April and August.

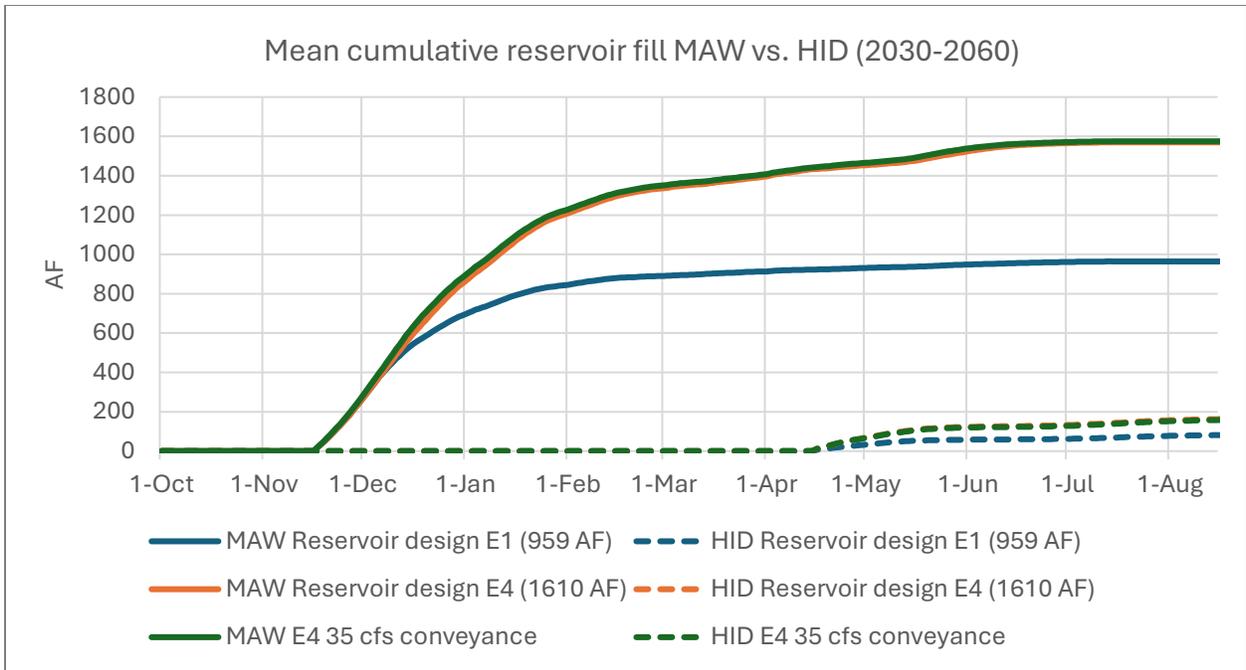


Figure 25. MAW vs. HID reservoir fill (2030-2060)

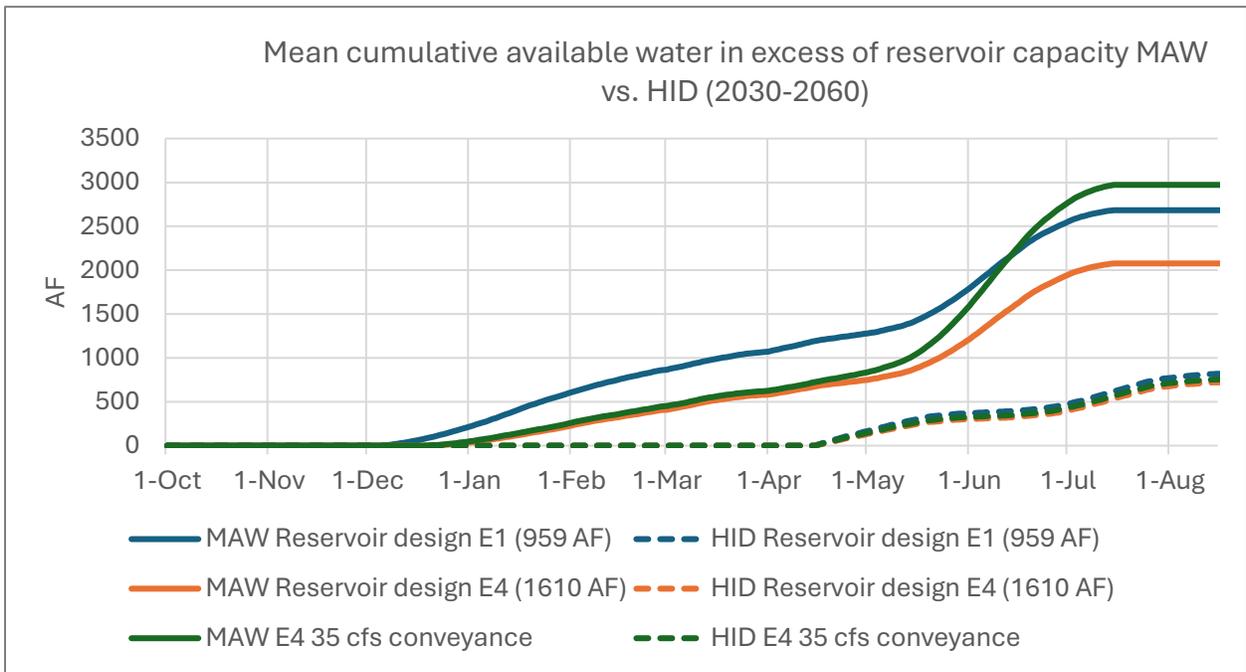


Figure 26. MAW vs. HID excess fill (2030-2060)

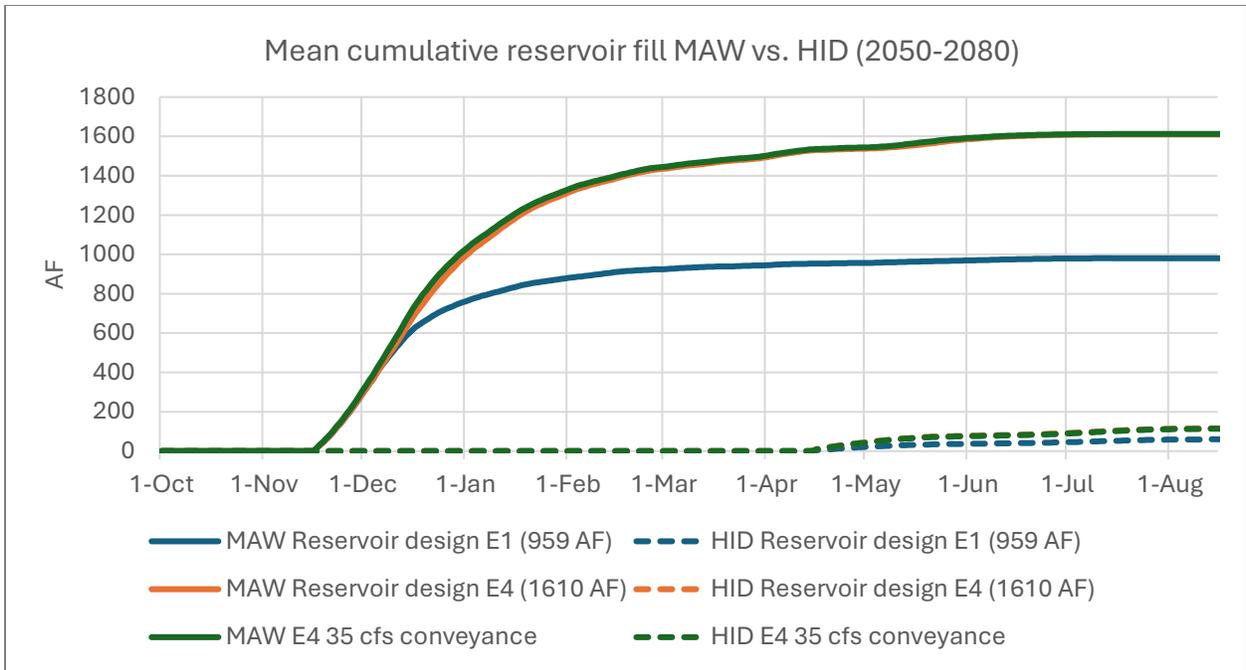


Figure 27. MAW vs. HID reservoir fill (2050-2080)

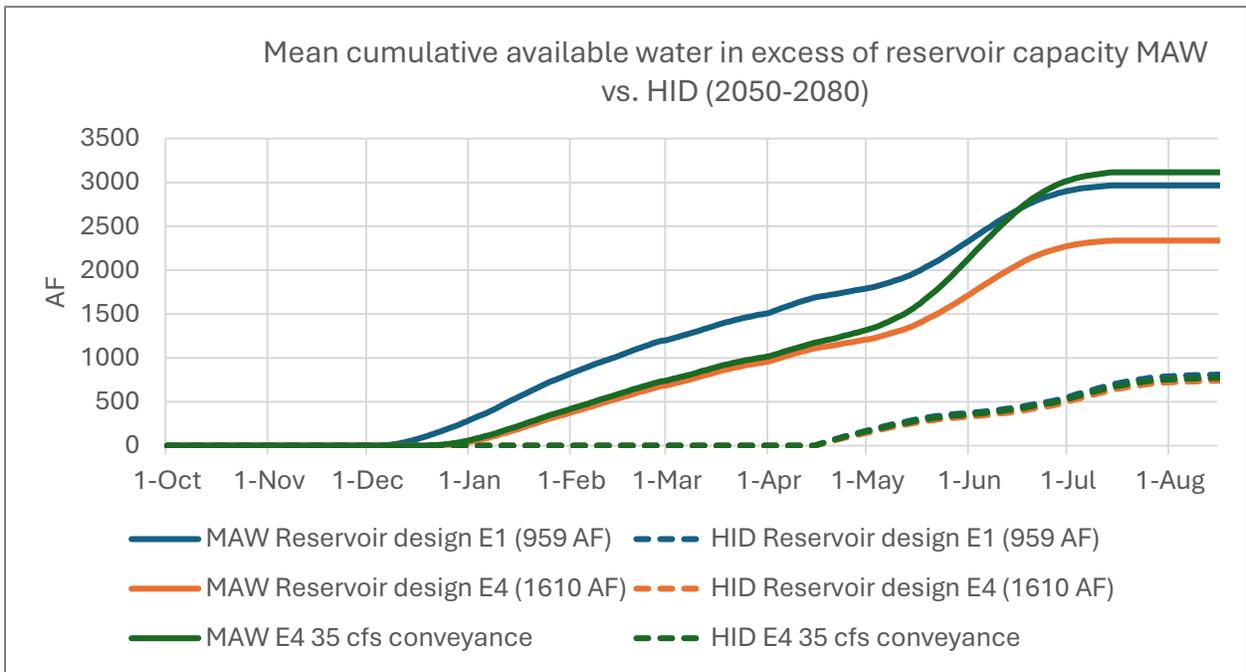


Figure 28. MAW vs. HID excess fill (2050-2080)

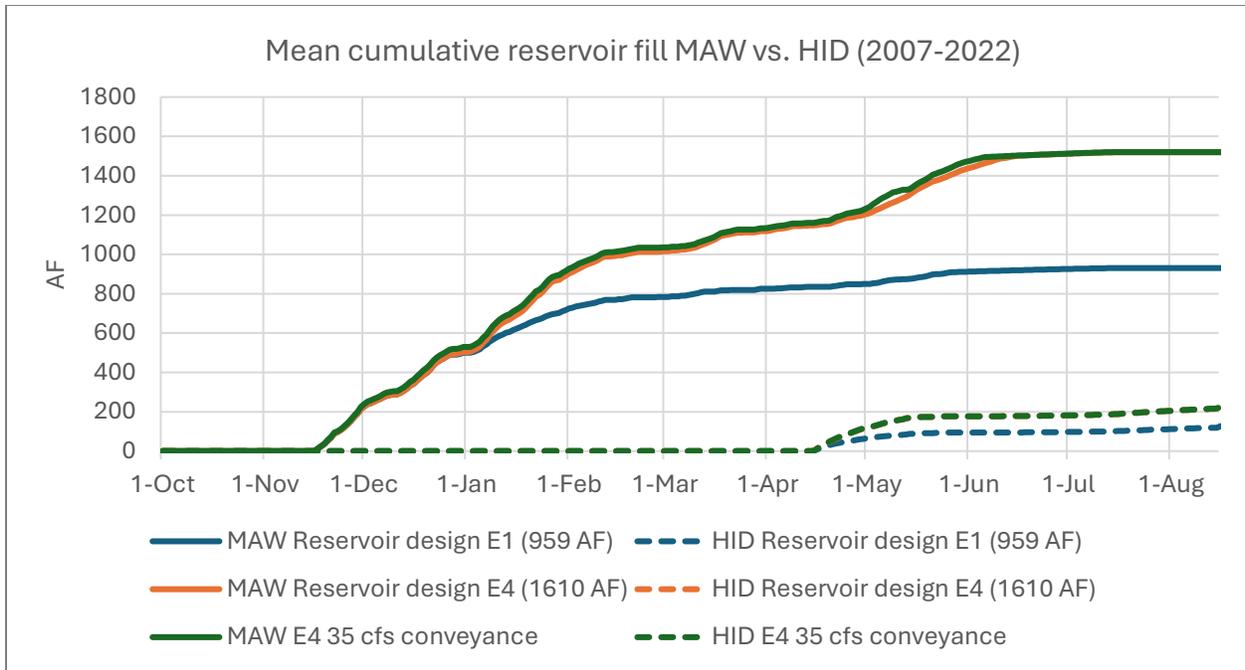


Figure 29. MAW vs. HID reservoir fill (2007-2022)

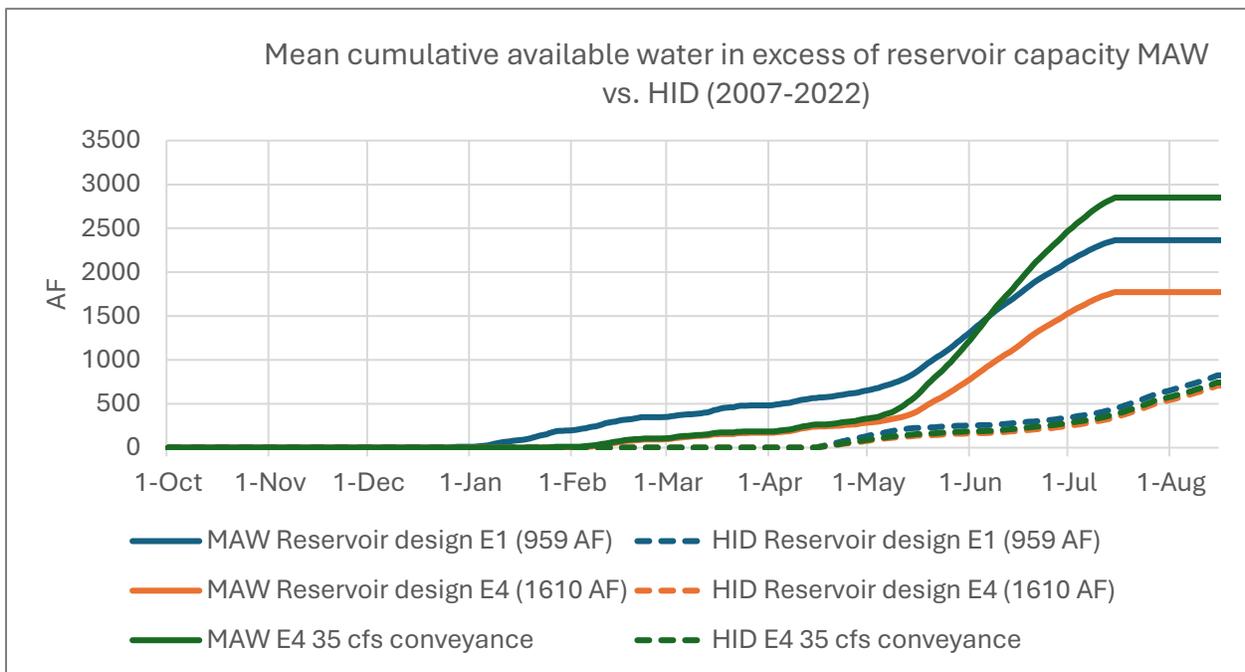


Figure 30. MAW vs. HID excess fill (2007-2022)

## 8.6. Irrigation supply

### Conclusions summary:

- Mean August 15 to September 15 supply to irrigation each reservoir release season increases across scenarios from 110-240 AF in future, 930 AF in historical without reservoir to 940-1,040 AF with reservoir.

- **In absence of reservoir, lower future inflows and increased frequency of turn-down rule curtailment drive decrease in proportion of demand able to be supplied from August 15-September 15, from 89% from 2007-2022 to 23% in 2030-2060, to 11% in 2050-2080.**

This section describes the water supply to irrigation possible under the various operations scenarios and climate simulations. The agriculture demands are described under section 3.4 while the operations are described across sections 3.2, 3.3, 3.5, and 3.6. The irrigation supply results are summarized below in Table 14.

Table 14. Irrigation supply results

	2020 demand	2030-2060			2050-2080			2007-2022		
		No reservoir	Reservoir design E1	Reservoir design E4	No reservoir	Reservoir design E1	Reservoir design E4	No reservoir	Reservoir design E1	Reservoir design E4
Mean annual supply to all districts (AF)	13,100	10,800	11,500	11,600	9,900	10,700	10,800	12,970	13,040	13,070
Mean Aug 15-Sep 15 supply to reservoir districts (AF)	1,040	240	950	1,040	110	940	1,040	930	1,000	1,040
Mean Aug 15-Sep 15 supply to unconnected districts	1,500	440	440	440	200	200	200	1,460	1,460	1,460

Table 14 shows the mean water supply volume to irrigation across all climate projections and years of all irrigation districts across the entire year as well as the supply volume during the reservoir release season from August 15 to September 15, broken out by those districts which are connected to the reservoir supply versus those unconnected. As of report writing, as described in section 3.4, the irrigation districts east of the river and downstream of the reservoir are connected to the reservoir supply, including DID, SPTIA, and 21% of HID (the breakdown of HID described in section 4.3.2). The irrigation districts west of the river, CCD and Agnew, as well as the 79% of HID located upstream of the reservoir are unconnected. The values represent the water volume diverted and do not account for transmission losses before reaching the irrigation fields. The values for the E4 35 cfs conveyance scenario are not shown separately because they are identical to the values for the E4 scenario.

The results in Table 14 show the input demand from the 2020 water year, which is the volume of water the model attempts to divert and supply. The total annual demand across all districts is 13,100 AF. From August 15 to September 15, the total demand of the reservoir districts is 1,040 AF (41% of Aug 15-Sep 15 total) while the total demand of the unconnected districts is 1,500 AF (59% of Aug 15-Sep 15 total). The mean annual supply volume for all districts is 10,800 AF from 2030-2060 for the no reservoir scenario. Because the inflows during the summer when irrigation demands peak generally decrease over time, causing increased curtailment frequency due to the turn-down rules (see results in 8.7), the supply volume is lower from 2050-2080 at 9,900 AF and higher from 2007-2022 at 12,970 AF. The supply to the unconnected districts is not affected by reservoir operations and therefore does not change across the operation scenarios, showing mean seasonal August 15 to September 15 supply of 440 AF for 2030-2060, 200 AF for 2050-2080, and 1,460 AF for 2007-2022 for all operations scenarios. The addition of the E1 reservoir allows the connected districts to divert from reservoir storage even during low flow

summer periods when turn-down rules prevent diversion from the river. Therefore, the mean seasonal August 15 to September 15 supply to the connected districts increases from the no reservoir to the E1 scenario from 240 to 950 AF for 2030-2060, from 110 to 940 AF for 2050-2080, and from 930 to 1,000 AF for 2007-2022. The daily results, shown in the figures at the bottom of this section, show that the reservoir storage in the E1 scenario fully depletes on September 13, just before the end of the irrigation season on September 15. The E4 scenario storage lasts through the entire irrigation season and it is this additional delivery from September 13-15 that creates the modest increases in supply results for the connected districts, showing that the entire August 15 to September 15 demand of 1,040 AF is met for all the timesteps.

One notable outcome of these results is that during the late irrigation season from August 15 to September 15, there is a significant decrease in the supply able to be delivered from the river, but that the operation of the reservoir significantly increases the supply during this period to the connected districts. The supply to connected districts in the no reservoir scenario decreases from 930 AF (89% of demand) in 2007-2022 to 240 AF (23% of demand) in 2030-2060 and to 110 AF (11% of demand) in 2050-2080. This difference is due to the increased frequency of turn-down rule curtailment during low flow periods. This result highlights the importance of reservoir supply for achieving reliability of irrigation supply by the late season. However, with the addition of the E1 and E4 reservoirs, the mean supply to the connected districts from August 15 to September 15 increases by about 300% higher compared to the no reservoir scenario from 240 AF (no reservoir) to 950 (E1) and 1,040 AF (E4) from 2030-2060, increases by about 800% from 110 AF to 940 and 1,040 AF from 2050-2080, but only increases by about 10% from 930 AF to 1,000 and 1,040 AF from 2007-2022. This result indicates the ability of the reservoir to maintain the supply to the connected districts during the reservoir release season, even as turn-down rule curtailment restricts river diversions during low-flow periods.

The below figures show more detailed daily irrigation supply results for each scenario. Figure 31, Figure 34, and Figure 37 show the irrigation supply to all districts. Figure 32, Figure 35, and Figure 38 show the irrigation supply from August 15-September 15 for the reservoir districts. Figure 33, Figure 36, and Figure 39 show the irrigation supply from August 15 to September 15 for the unconnected districts. The figures show the demand pattern throughout the year, with lower stockwatering demands during the off-season and higher irrigation demands from March 15 to September 15. In addition, the figures show decreased supply to irrigation during later parts of the summer, the ability of the reservoir to increase the supply to the reservoir districts from August 15 to September 15, and the supply benefits of the E1 scenario depleted from September 13-15 due to depleted storage, while the supply benefits remain elevated for E4 due to remaining storage.

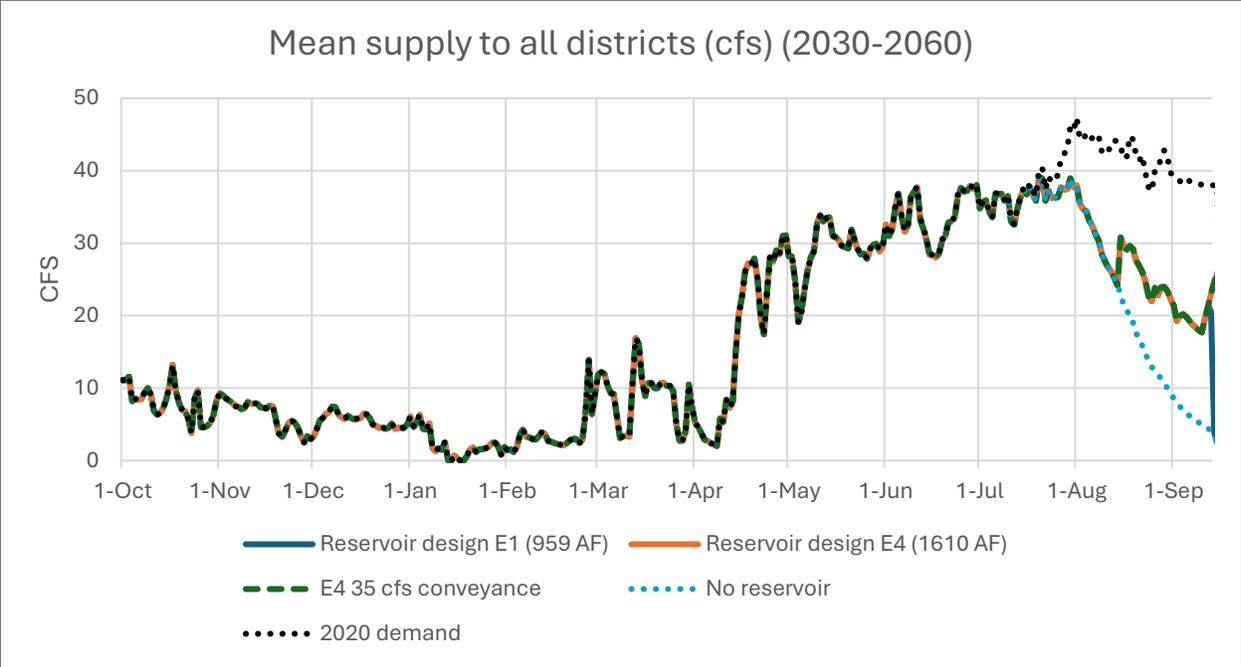


Figure 31. Irrigation supply to all districts (2030-2060)

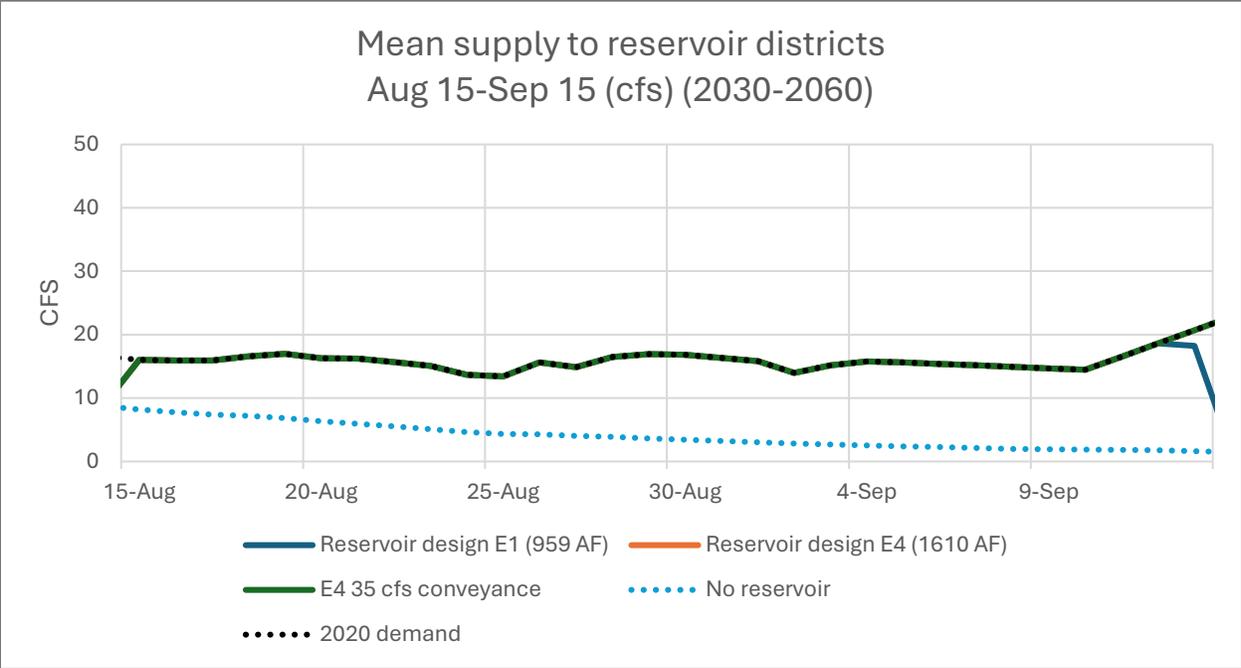


Figure 32. Irrigation supply to reservoir districts (2030-2060)

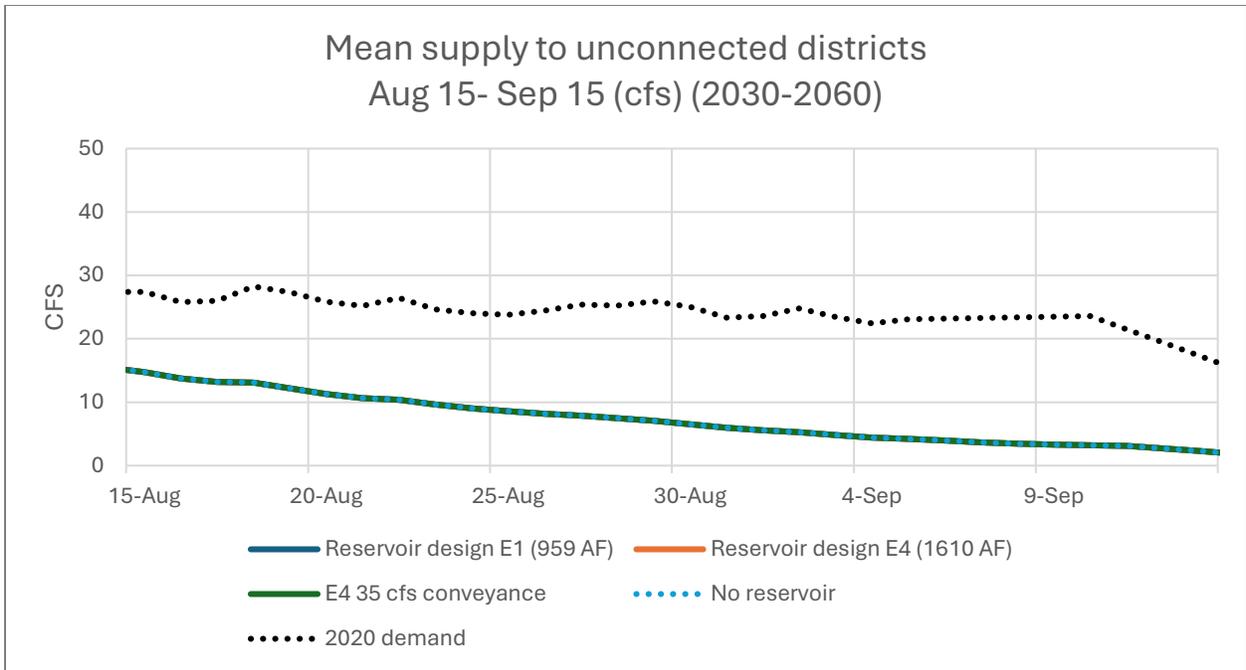


Figure 33. Irrigation supply to unconnected districts (2030-2060)

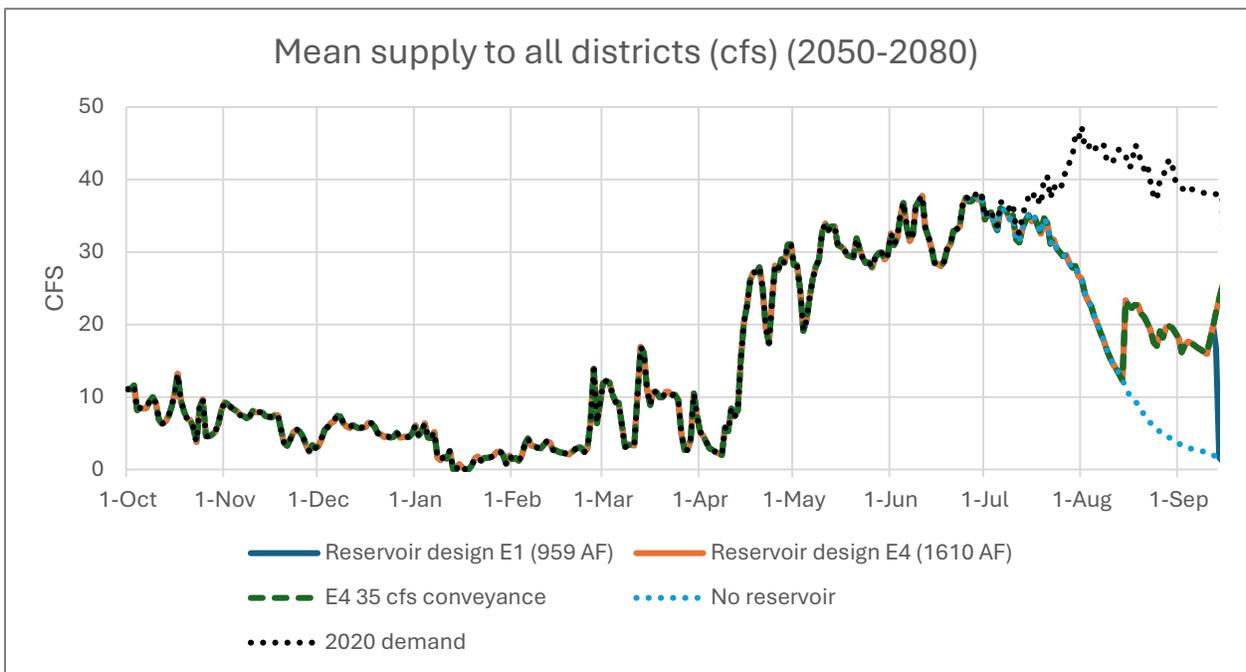


Figure 34. Irrigation supply to all districts (2050-2080)

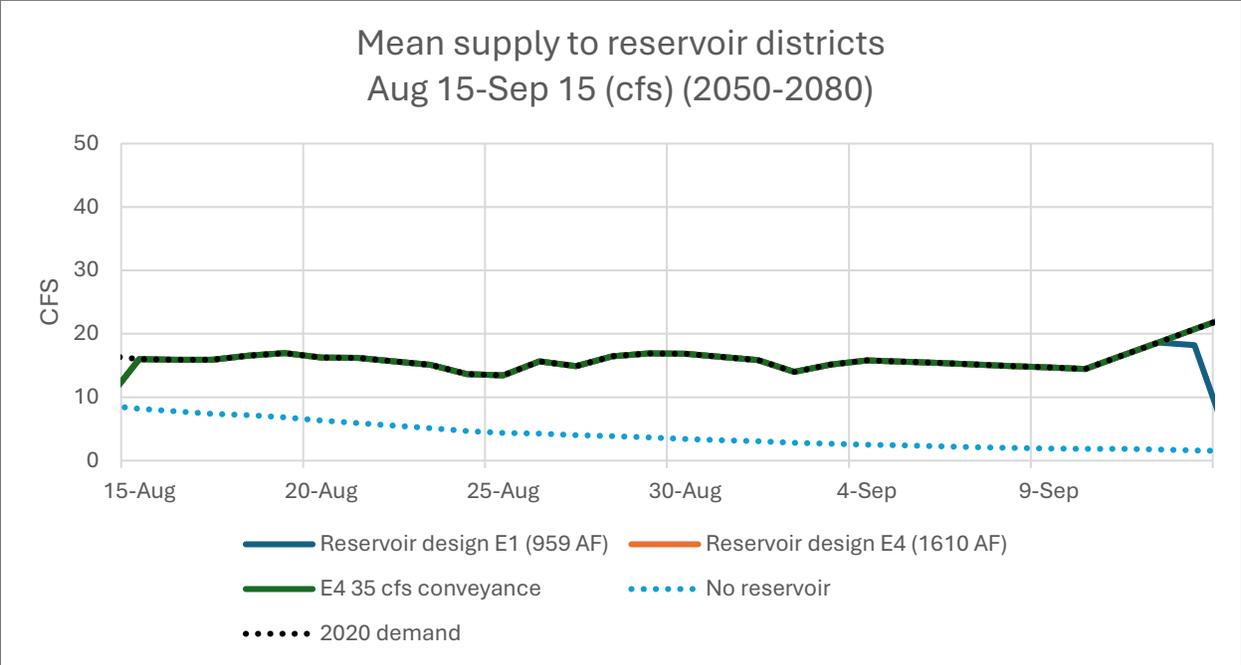


Figure 35. Irrigation supply to reservoir districts (2050-2080)

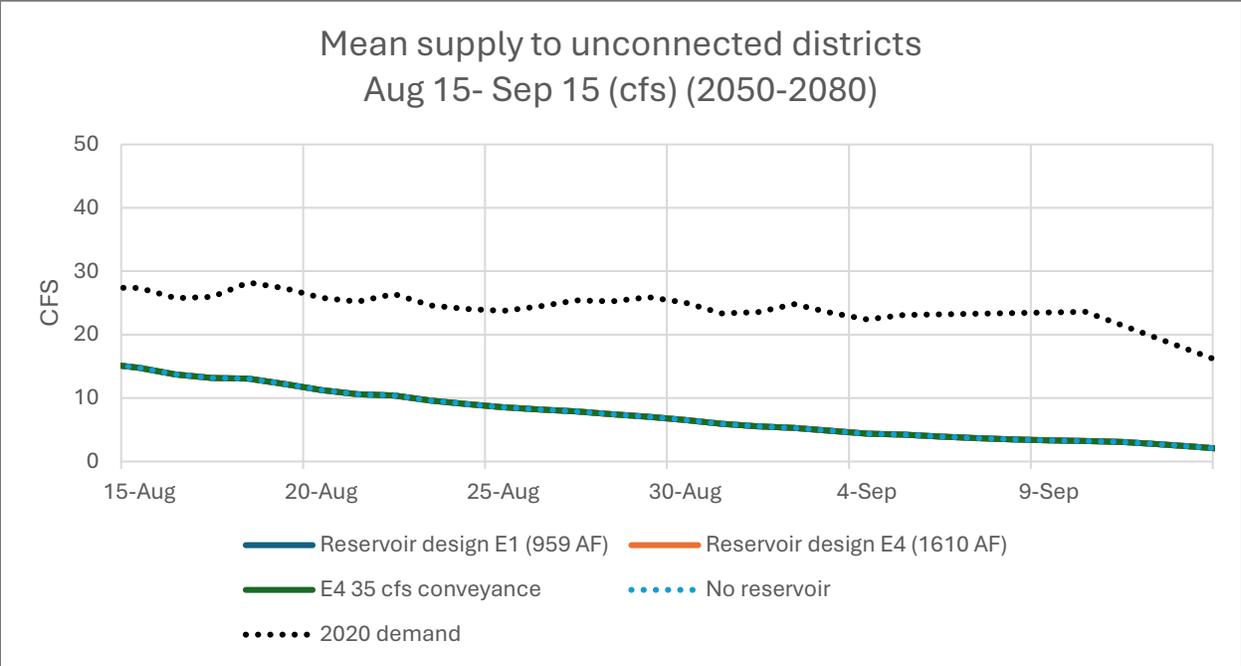


Figure 36. Irrigation supply to unconnected districts (2050-2080)

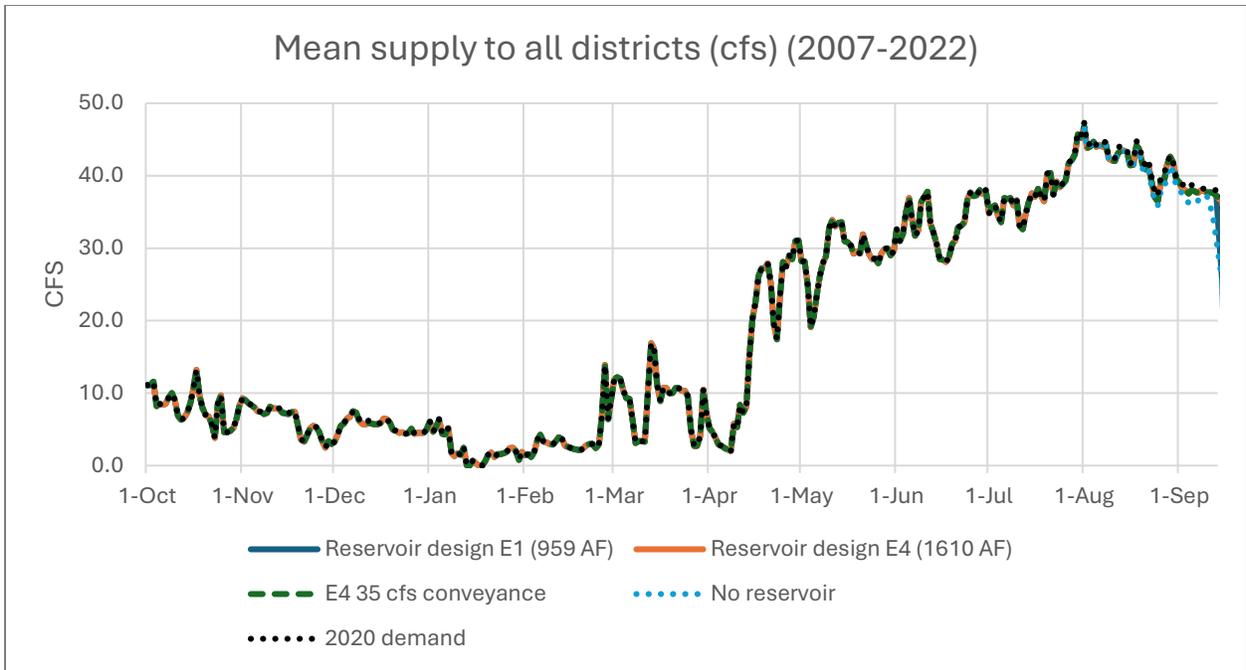


Figure 37. Irrigation supply to all districts (2007-2022)

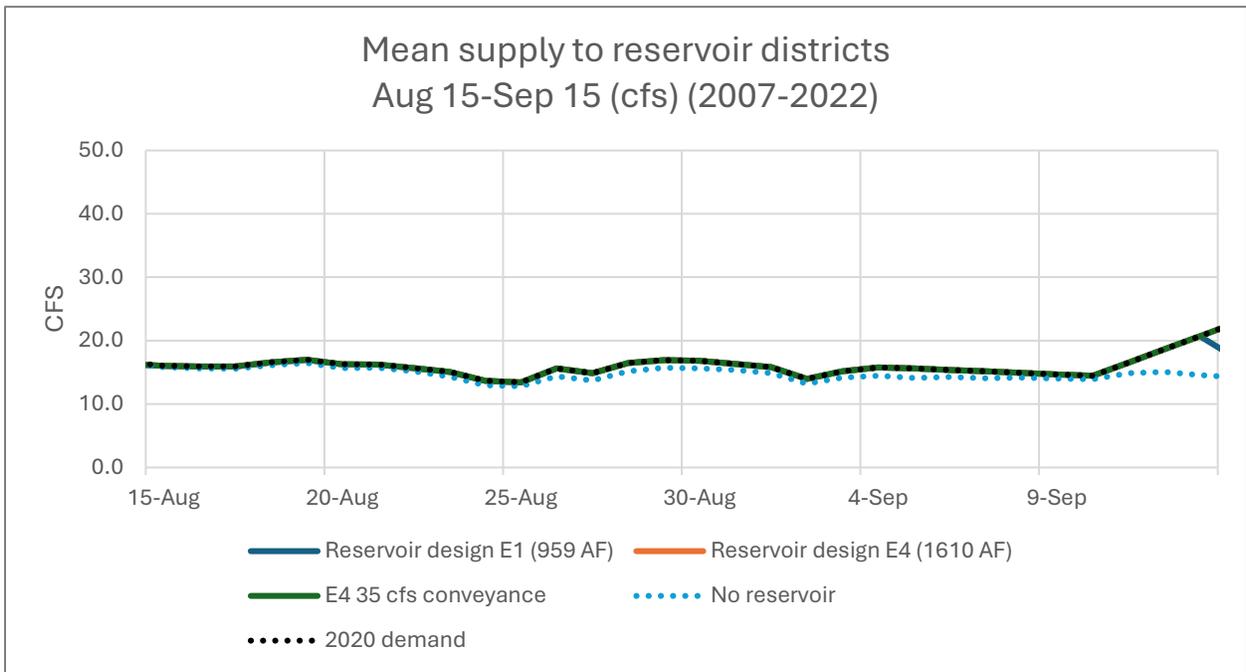


Figure 38. Irrigation supply to reservoir districts (2007-2022)

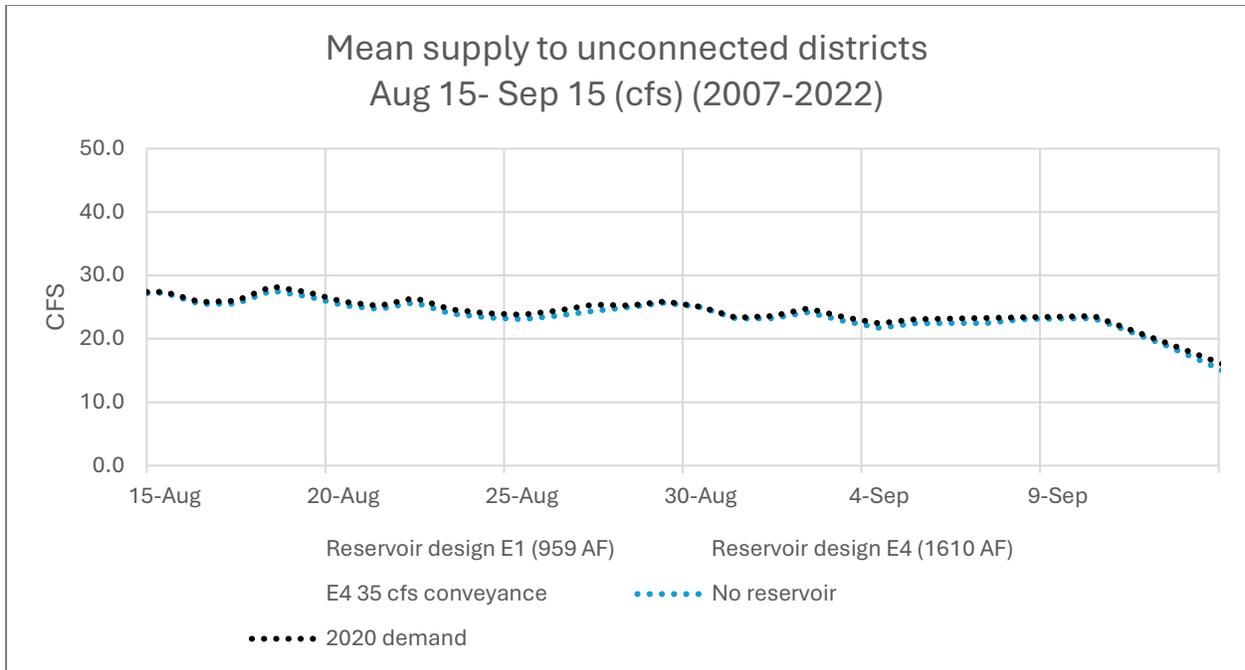


Figure 39. Irrigation supply to unconnected districts (2007-2022)

### 8.7. Turn-down rules

#### Conclusions summary:

- **Lower future inflows from June to September drive increased frequency of partial and complete turn-down rule curtailment.**
- **The increased future turn-down rule curtailment frequency drives lower supply to irrigation and lower flow benefits.**

As described in section 4.4.4, the irrigation turn-down rules curtail irrigation diversion from the river beginning when the inflow at the USGS gauge goes below 120 cfs, fully curtailing all irrigation diversion from the river below flows of 65 cfs. As illustrated in section 8.2, summer flows are projected to generally decrease into the future, causing increased frequency of low flow periods when the turn-down rules are active. This section describes the frequency of the curtailment from the turn-down rules in the modeling periods, shown below in Figure 40 and Figure 41. The turn-down rules are the driver behind the decrease in future timesteps of the irrigation supply results in section 8.6 and the streamflow benefits of the reservoir in section 8.8.

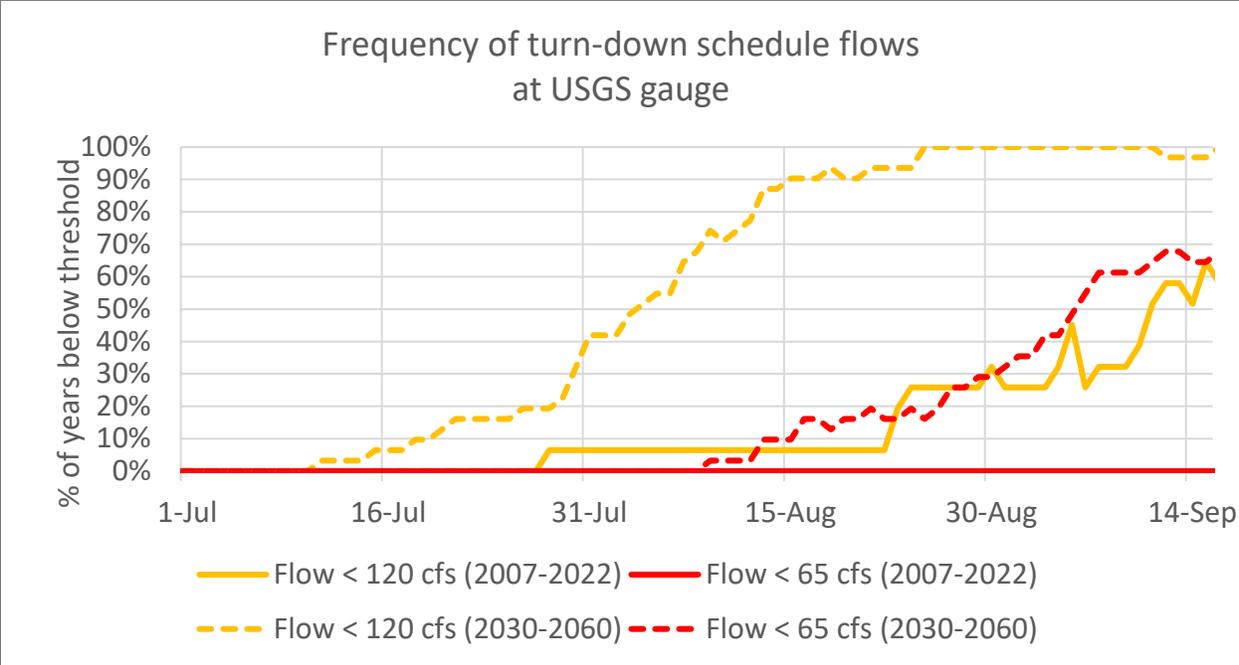


Figure 40. Turn-down schedule flows (2030-2060)

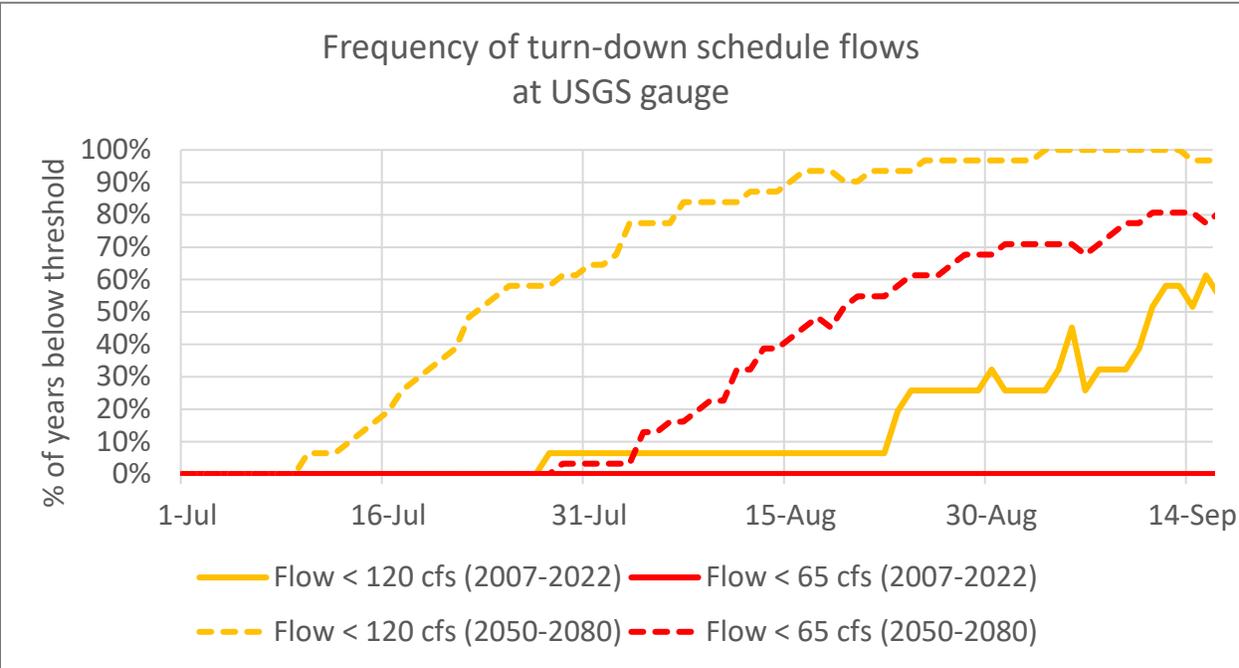


Figure 41. Turn-down schedule flows (2050-2080)

Both of the above figures compare the frequency, expressed in %, of the number of years and climate projections in each timestep where the daily streamflow at the USGS gauge falls below the 120 cfs threshold where the turn-down schedule at least partially curtails river diversion, and the 65 cfs threshold where the turn-down schedule fully curtails river diversion. Figure 40 compares the frequencies from 2030-2060 to those from the historical 2007-2022 data, while Figure 41 compares

2050-2080 to the historical. The figures show a significant increase in the frequency that the turn-down rules become active during the irrigation season. In the historical time period, the flows remain above 120 cfs in all simulations through near the end of July, and go below 120 cfs in only 6% (one year) of the simulations through August 22<sup>nd</sup>. After August 22<sup>nd</sup>, the frequency of going below 120 cfs increases with time, up to 60% by the end of the irrigation season by September 15. The flows always remain above 65 cfs in the historical timestep. From 2030-2060, the flows first go below 120 cfs several weeks earlier, as soon as July 11. During 2030-2060, the frequency below 120 cfs reaches 60%, the maximum of the historical period, more than a full month earlier than the historical period, and proceeds to reach a frequency of nearly 100% from August 27 onwards, indicating that a partial curtailment would nearly always present for the last weeks of the irrigation season. From 2030-2060, the flow goes below the 65 threshold, which was never seen in the historical period, as early as August 9, with frequency increasing over time until a maximum near 70% by the end of the irrigation season by September 15. This means that by the end of the irrigation season, zero diversion would be allowed from the river in a projected 70% of years. The curtailment frequency further increases in the 2050-2080 timestep. From 2050-2080, the frequency below 120 cfs begins in mid-July and reaches nearly 100% by late August, similar to 2030-2060, albeit with higher frequencies from mid-July to mid-August. During 2050-2080, the streamflow first goes below the 65 cfs threshold about two weeks earlier than during 2030-2060, beginning on July 29. During 2050-2080, the frequency below 65 cfs reaches a higher peak of around 80% by the end of the irrigation season.

This increased frequency in turn-down rule curtailment restricts river diversion to agriculture, resulting in the lower irrigation supply results in future timesteps in section 8.6. If agriculture is not able to divert water from the river due to curtailment, then the source switching of the connected districts in drawing from the reservoir supply instead would not change the streamflow with the addition of the reservoir. Therefore, the flow benefit results in section 8.8 show streamflow benefits of the reservoir decreasing into the future.

### 8.8. Downstream flow and flow benefit

Part of the motivation of the proposed reservoir is to increase streamflow in the lower part of the river during the low flow late summer period to protect salmonid aquatic habitat for passage during a critical spawning period. The operations would require the connected irrigation districts to divert from reservoir storage, if available, from Aug 15 to Sep 15, as described in section 3.4. These districts would only be allowed to divert from the river if the reservoir storage is depleted. As a result, less water would be diverted from the river, leaving higher instream flow. This increased potential flow as a result of the proposed reservoir operations is referred to as the flow benefit. This section describes the modeled streamflow and flow benefit results at the downstream Schoolhouse Ecology gauge, located downstream of all the diversions and the seepage inflow, as seen in the model schematic in Figure 1.

It is important to note that the 2007-2022 flow results are not the historical observed flows. These are modeled flows which use the historical inflows at the USGS gauge, but use the input operations and demands which would have differed from the actual operations and demands in the past. While a precise estimated range of uncertainty was not calculated, the magnitude of the difference in flow due to difference in operations scenarios, including the flow benefit, should be considered more accurate than the magnitude of the streamflow itself. The streamflow result has the additional source of uncertainty of the seepage inflow, which was calculated using a simplified correlation rather than a

more precise rainfall-runoff hydrology model. The future streamflow conditions during the summer contain flows lower than any flows in the historical record, which creates uncertainty around the accuracy of the seepage inflow under these conditions. The results of the WEAP model will be used to inform project decisions and design operations.

The streamflow results are shown for the entire year in the below Figure 42, Figure 45, and Figure 48. The streamflow results are isolated to the reservoir release period from August 15 to September 15 to more clearly illustrate the impact of the proposed reservoir operations in the below Figure 43, Figure 46, and Figure 49. Finally, the ranges and frequencies of the flow benefits achieved from August 15 to September 15 are shown in the below Figure 44, Figure 47, and Figure 50.

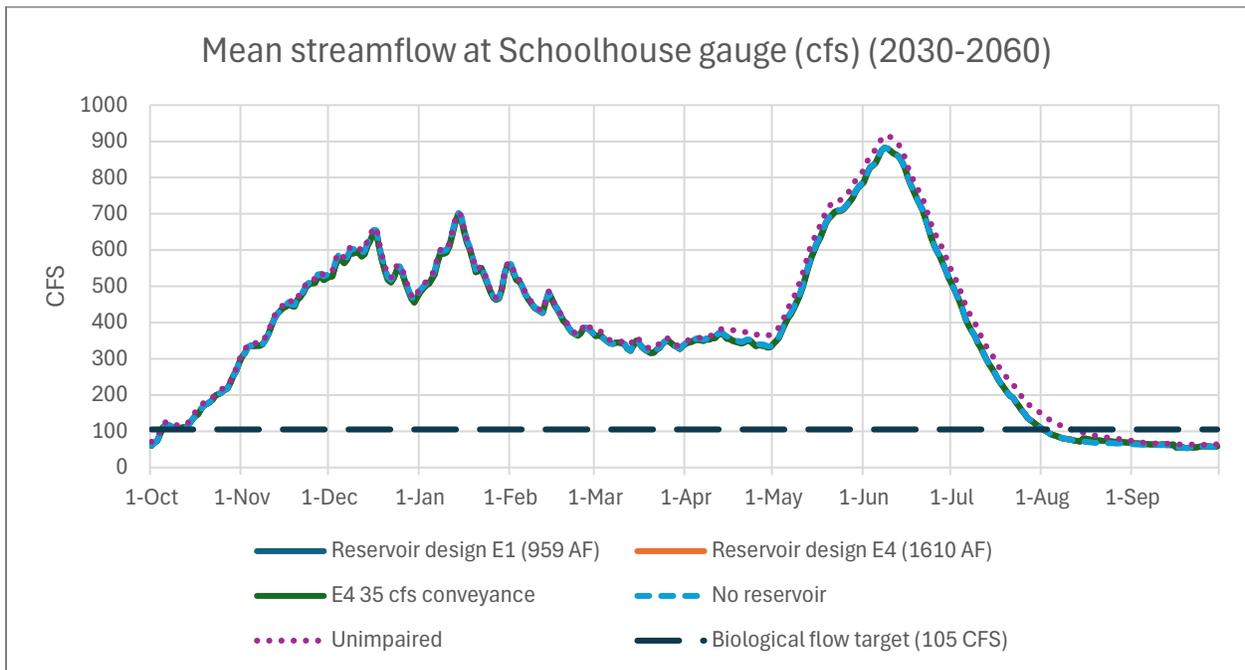


Figure 42. Streamflow results (2030-2060)

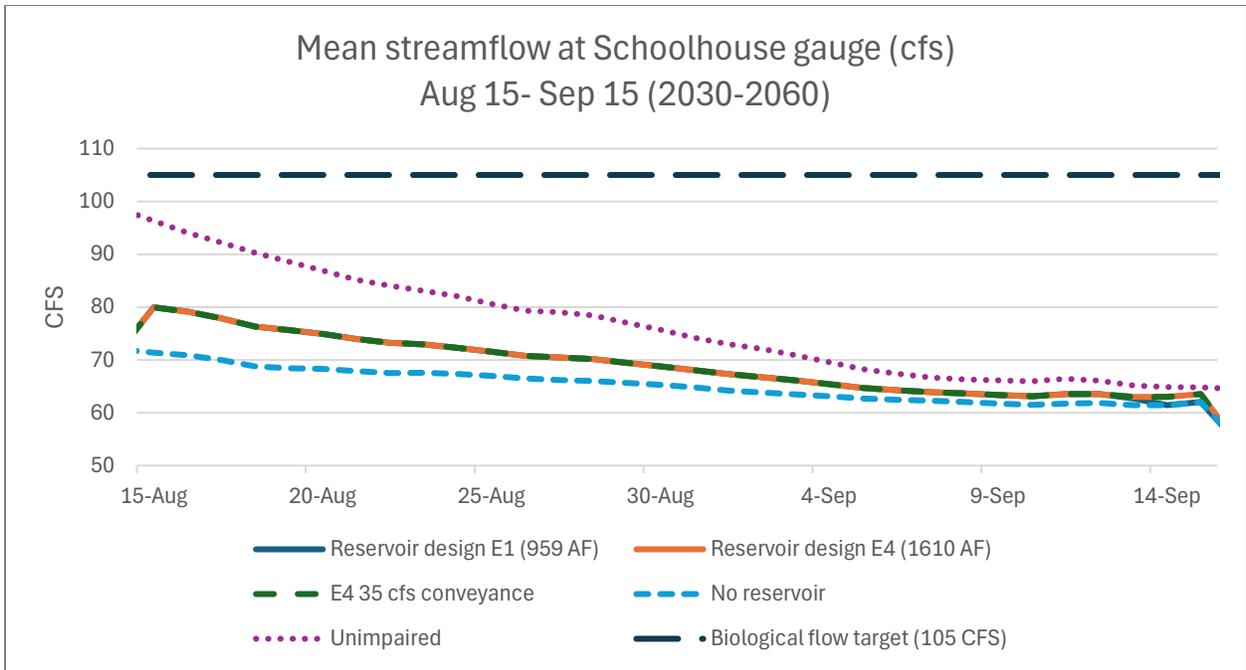


Figure 43. Streamflow results Aug 15-Sep 15 (2030-2060)

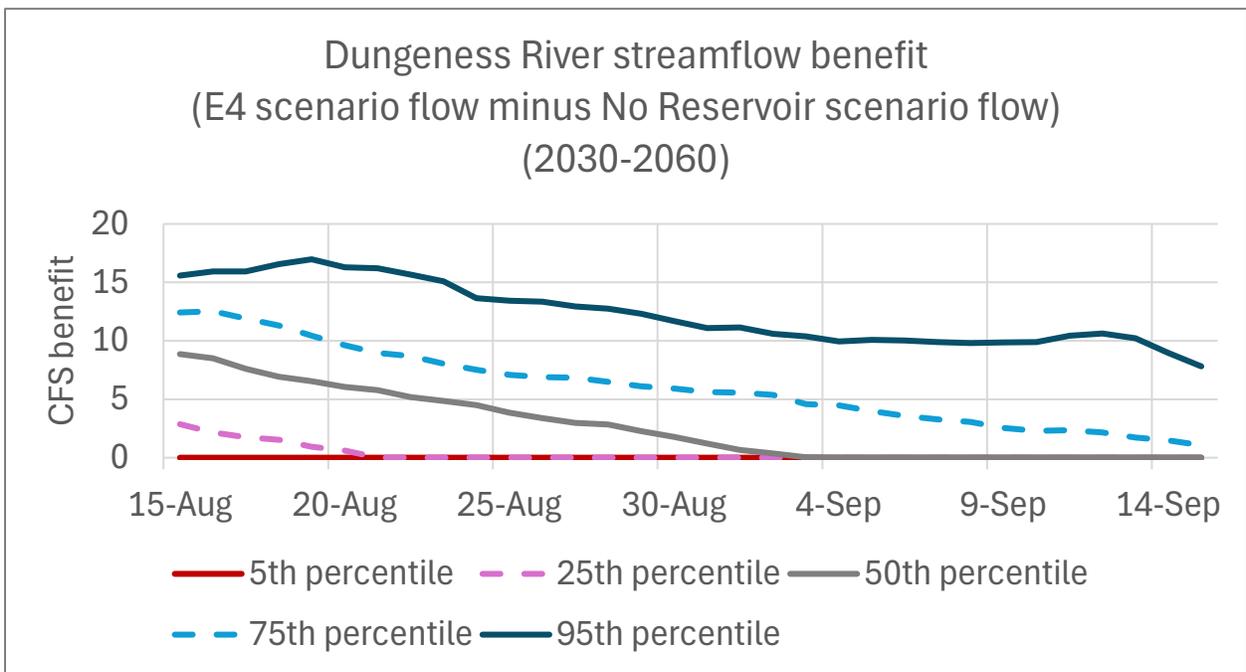


Figure 44. Streamflow benefit results (2030-2060)

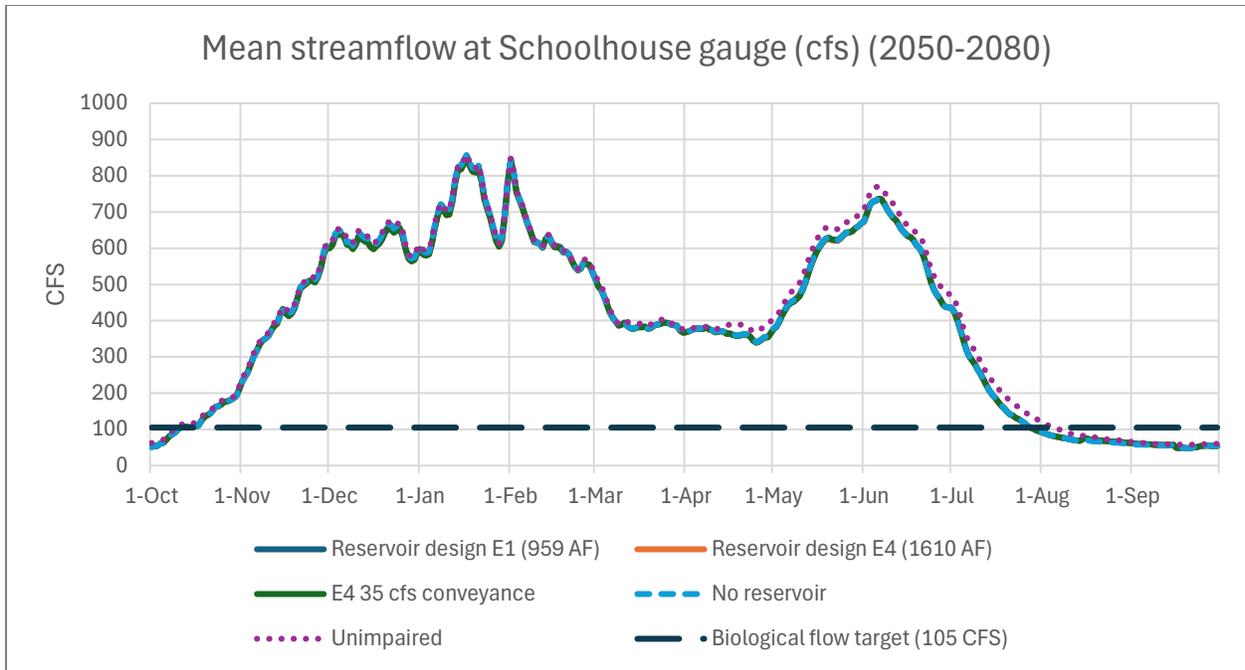


Figure 45. Streamflow results (2050-2080)

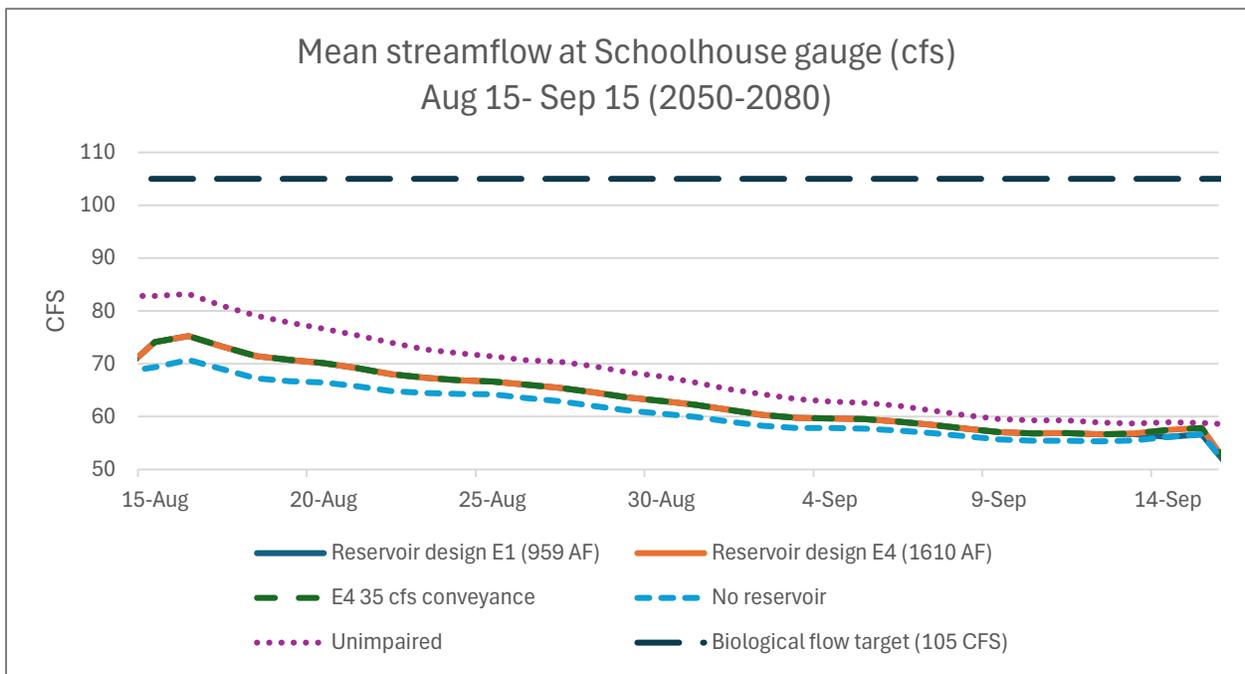


Figure 46. Streamflow results Aug 15-Sep 15 (2050-2080)

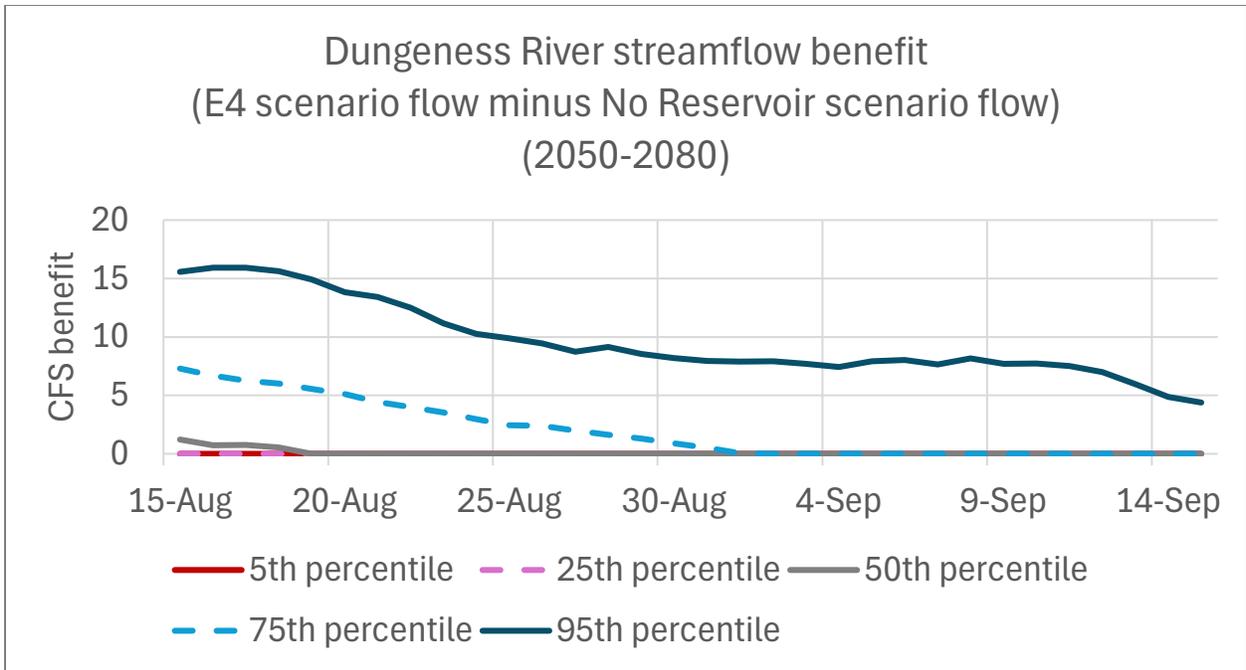


Figure 47. Streamflow benefit results (2050-2080)

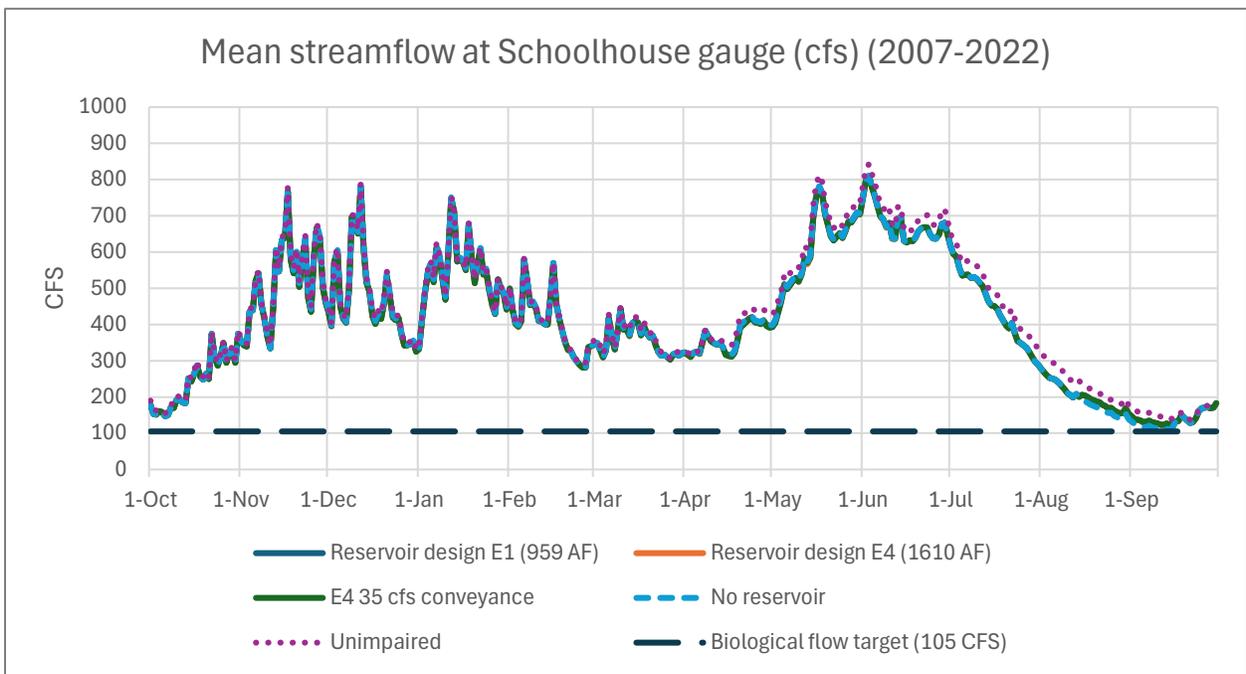


Figure 48. Streamflow results (2007-2022)

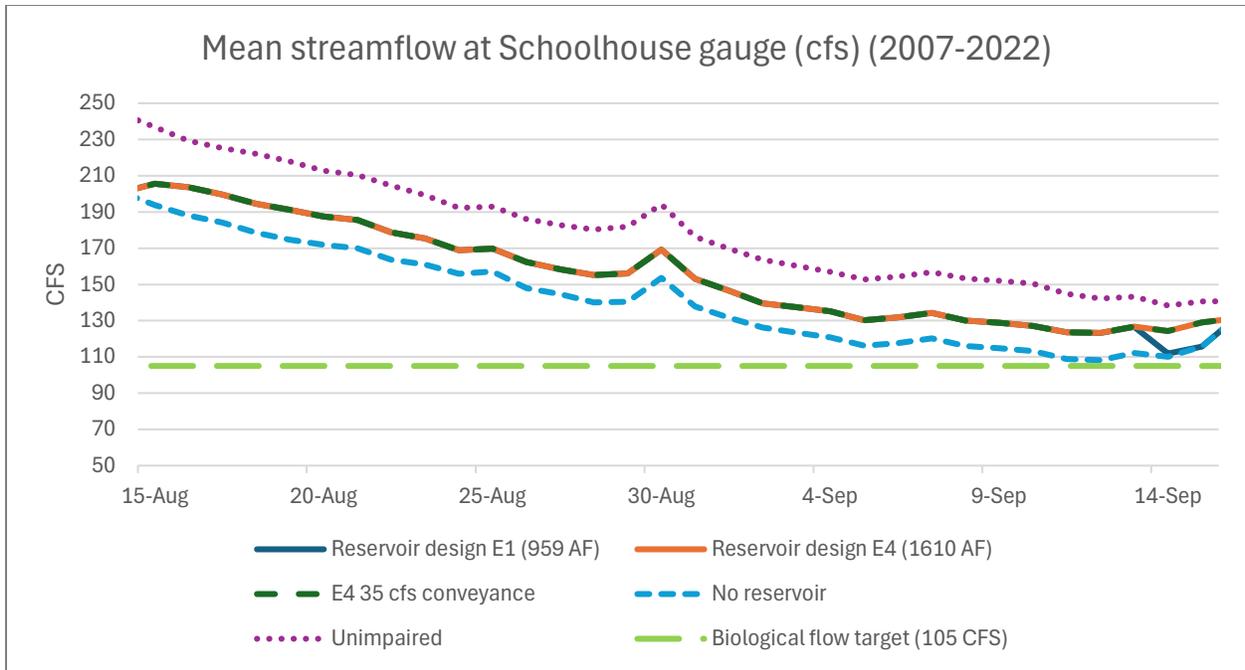


Figure 49. Streamflow results Aug 15-Sep 15 (2007-2022)

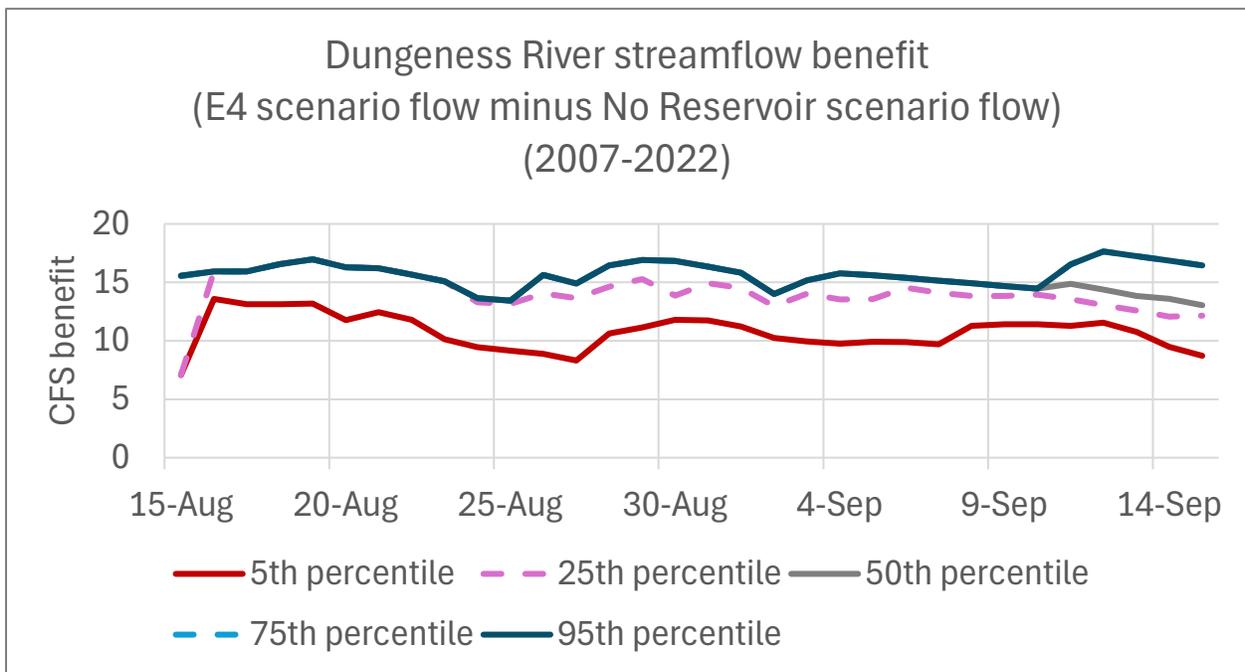


Figure 50. Streamflow benefit results (2007-2022)

These results include the streamflow under the unimpaired scenario, which removes all diversions and reservoir operations as described in section 6. Note that the inflows are not only averaged across all of the years, but also each of the ten climate projections (for the future periods). Therefore, this graph shows the aggregate differences in flow between the time periods, but does not describe the variability across individual years and climate projections. While the inflow results in section 8.2 are the upstream

flows at the USGS gauge location used as input data, the results in this section show the downstream results at the Schoolhouse gauge location, after the diversions to reservoir storage and irrigation have been removed from the river and the modeled seepage flow has been added.

The results show the modeled streamflow against the biological flow target of 105 cfs, described in section 3.6. From 2030-2060 and 2050-2080, the mean flows go below the 105 cfs target from late July to mid-October, remaining above for the rest of the year. In the modeled? historical 2007-2022, the mean flows remain above 105 cfs throughout the year.

The mean annual results do not show visually significant effects of river diversions outside of the irrigation season from September 16 to March 14. As noted in the annual operations in Table 1, during this period, the stockwatering demands are generally under 10 cfs, and the reservoir diversions, which may only occur starting November 15 when the inflow is above 585 cfs during this time, are limited to 25 cfs. For an inflow of 585 cfs, a combined maximum human diversion of around 35 cfs represents 6% of the total river flow.

In the spring, the irrigation demand increases rapidly from April 8-17 from below 10 cfs up to around 30 cfs. The irrigation demand fluctuates around 30 cfs, until mid-July, when it increases to a peak of 47 cfs on August 1, then generally decreases down to 38 cfs by the end of the irrigation season on September 15. The increase in irrigation demand creates a more significant difference in the streamflow relative to the unimpaired after mid-April. Starting August 15 is when the effects of the reservoir on the streamflow begin. The streamflow results shown in the above figures are additionally shown below in Table 15 and described here. The mean unimpaired flow decreases from 96 cfs on August 15 to 65 cfs on September 15 for 2030-2060, from 83 to 59 cfs for 2050-2080, and from 237 to 141 cfs for 2007-2022. When the flow decreases below 120 cfs, the turn-down rules curtail more of the river diversion and there becomes less difference between the unimpaired and no reservoir scenario, as well as between the no reservoir scenario and the reservoir scenarios. The mean no reservoir scenario flow ranges decreases from 71 to 62 cfs from August 15 to September 15 in 2030-2060 (3-25 cfs lower than unimpaired), from 69 to 57 cfs in 2050-2080 (2-14 cfs lower than unimpaired), and from 194 to 116 cfs (25-43 cfs lower than unimpaired). The mean E4 reservoir scenario flow decreases from 80 to 64 cfs in 2030-2060 (1-16 cfs lower than unimpaired, 2-9 cfs higher than no reservoir), from 74 to 58 cfs in 2050-2080 (1-9 cfs lower than unimpaired, 1-5 cfs higher than no reservoir) in 2050-2080, and from 206 to 129 cfs in 2007-2022 (12-31 cfs lower than unimpaired, 12-13 cfs higher than no reservoir).

Table 15. Mean streamflow results

Scenario	Mean Aug 15 ECY gauge flow(cfs)			Mean Sep 15 ECY gauge flow (cfs)		
	E4 reservoir	No reservoir	Unimpaired	E4 reservoir	No reservoir	Unimpaired
2007-2022	206	194	237	129	116	141
2030-2060	80	71	96	64	62	65
2050-2080	74	69	83	58	57	59

The differences in the flow between the no reservoir and the E4 reservoir scenario mentioned above are referred to as the flow benefit of the reservoir, that is, the additional flow left instream as a result of

diversion from the reservoir storage rather than the river. The flow benefits decrease with the inflow at the USGS gauge as it goes below 120 cfs due to the turn-down rules preventing any diversion from the river, and therefore, decreasing any effect of the reservoir on the streamflow. The flow benefits may range up to a maximum of 13-17 cfs, equal to the full demand of the connected districts shown previously in Figure 32 when inflow is greater than 120 cfs, down to 0 cfs if the inflow is less than 65 cfs. The flow benefits decrease in the future timesteps and generally decrease towards the end of the irrigation season in the future timesteps. The flow benefit results from the above figures are shown below in Table 16 and described here. The 50<sup>th</sup> percentile flow benefits, where half of the simulations had flow benefits lesser and half greater, range from 9 cfs on August 15 to 0 cfs starting September 3<sup>rd</sup> from 2030-2060, from 1.2 cfs on August 15 to 0 cfs starting August 19 from 2050-2080, and from 16 cfs on August 15 to 13 cfs on September 15 from 2007-2022. The 75<sup>th</sup> percentile flow benefits, where 75% of the simulations had flow benefits lesser and 25% greater, range from 12 cfs on August 15 to 1.1 cfs on September 15th from 2030-2060, from 7.3 cfs on August 15 to 0 cfs starting September 2nd from 2050-2080, and from 16 cfs on August 15 to 17 cfs on September 15 from 2007-2022. The 25<sup>th</sup> percentile flow benefits, where 25% of the simulations had flow benefits lesser and 75% greater, range from 2.9 cfs on August 15 to 0 cfs starting August 21st from 2030-2060, 0 cfs the entire month from 2050-2080, and from 7.1 cfs on August 15 to 12.1 cfs on September 15 from 2007-2022. The 95<sup>th</sup> percentile flow benefits, where 95% of the simulations had flow benefits lesser and 5% greater, went from 16 cfs on August 15 to 7.8 cfs on September 15th from 2030-2060, from 16 cfs on August 15<sup>th</sup> to 4.4 cfs on September 15<sup>th</sup> from 2050-2080, and from 16 cfs on August 15<sup>th</sup> to 17 cfs on September 15<sup>th</sup> from 2007-2022. The 5<sup>th</sup> percentile flow benefits, where 5% of the simulations had flow benefits lesser and 95% greater, were 0 cfs the entire month from 2030-2060 and 2050-2080, and went from 7.1 cfs on August 15<sup>th</sup> to 8.7 cfs on September 15<sup>th</sup> from 2007-2022.

Table 16. Flow benefit results

Scenario	Aug 15 flow benefit (cfs)					Sep 15 flow benefit (cfs)				
	5 <sup>th</sup> percentile	25 <sup>th</sup> percentile	50 <sup>th</sup> percentile	75 <sup>th</sup> percentile	95 <sup>th</sup> percentile	5 <sup>th</sup> percentile	25 <sup>th</sup> percentile	50 <sup>th</sup> percentile	75 <sup>th</sup> percentile	95 <sup>th</sup> percentile
2007-2022	7.1	7.1	15.5	15.6	15.6	8.7	12.1	13.0	16.5	16.5
2030-2060	0.0	2.9	8.9	12.4	15.6	0.0	0.0	0.0	1.1	7.8
2050-2080	0.0	0.0	1.2	7.3	15.6	0.0	0.0	0.0	0.0	4.4

Attachment 1



# Point No Point Treaty Council

Port Gamble S'Klallam • Jamestown S'Klallam

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.*

*For more information, please contact:  
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(360) 710-4288*

### **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 PNPTC 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 1<sup>st</sup>, 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.