WDFW Hatchery Climate Change Vulnerability Assessment Project

Hatchery Climate Change Vulnerability Assessment

FINAL
Revision No. 1

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Revision Log

Revision No.	Date	Revision Description
0	6/19/2023	DRAFT report
1	7/17/2023	FINAL report

1.0 Executive Summary

McMillen Inc. (McMillen) was retained by the client, Washington Department of Fish and Wildlife (WDFW), to provide an assessment of four WDFW fish hatcheries (Marblemount, Kendall Creek, Samish, and Goldendale) in the context of their vulnerability to the effects of climate change. Climate and hydrologic modeling were performed by Northwest Hydraulic Consultants (NHC), and these results have been incorporated into the analysis for each facility.

All facilities in this report have outstanding projects specified in WDFW's capital improvements plan (CIP) for the 2021-2023 biennial. These must be addressed in addition to other issues identified in this report. The following summarizes the findings from the evaluations and the proposed improvements to each facility.

Marblemount has aging infrastructure that will need extensive refurbishment or replacement soon, some of which is addressed in the most recent Capital Project Request (lack of a pollution abatement system, deterioration above and below ground infrastructure, degraded rearing areas, and inadequate broodstock handling infrastructure). McMillen has also identified a severe deficit of suitable rearing space for the early life stages of Chinook and Chum salmon programs; it will be critical to address this as Chum Salmon production continues to increase towards its release goals in the Hatchery Genetic Management Plant (HGMP). The Cascade River, which already reaches temperatures of 58°F, is the main water source, with some supplementation from Jordan and Clark creeks. These creeks run dry during summer months, and issues of decreasing flows and increasing temperatures will continue to be exacerbated by climate change. Marblemount is forecasted to transition from a snow dominated region to rain dominated region that will lead to higher peak flow events (i.e., more severe flooding) and an earlier onset and duration of low-flow periods as the available snowpack that currently feeds the rivers and streams disappears. These issues will limit the viability of Jordan and Clark creeks' water sources, as well as impact the quality of water received from the Cascade River. This situation is especially bleak considering the current well production is only half of the full water right due to an aging well and pump infrastructure.

Kendall Creek also has several infrastructure issues that limit fish production in the current facility. McMillen has determined there is a lack of available rearing space for early life stages of fish, particularly when production of several species overlaps in March. There is also not enough rearing infrastructure to maintain target densities for Coho Salmon specified in the HGMP without potentially decreasing production of other species. A major hurdle for consistent fish production is the lack of productive wells. Existing wells are currently producing only a small fraction of their original design, and it is critical that new pumping equipment and well refurbishment is completed soon. Past changes to the facility resulted in two wells that are not routed through an aeration tower. Well water aeration is a necessity to off-gas nitrogen and provide a safe environment for fish. Unproductive wells result in more reliance on Kendall Creek, which is reported to rise and fall rapidly during flooding events that will become more common as climate change worsens. Using surface water will become an issue as low-flow periods increase in frequency during the late winter and early spring, particularly in March when facility water demands peak. Kendall Creek will also experience significantly increased average temperatures and decreased flows in August, which will negatively impact the spring Chinook egg-take effort.

The Samish hatchery is in a similar position to Marblemount—with aging infrastructure and a lack of sufficient rearing space. McMillen has determined that an additional 69,000 ft^3 of rearing space and 12 cfs of water supply is required to meet the programmatic production and density goals set forth in the HGMP. Additionally, the hatchery's only water source is untreated surface water, preventing Samish hatchery from providing high-quality water for sensitive life stages including eggs, fry, and spawning adults. Other major issues facing the facility are the intake and fish passage structures on Friday Creek being out of compliance with WDFW and NOAA standards. This infrastructure is currently at a high risk of further damage because the intake is becoming exposed. In the event of an emergency, repairs may be difficult or impossible to perform safely because the road leading to the infrastructure is eroding. These issues will only deteriorate in the future due to climate change because Friday Creek is expected to have lower flows during periods when Samish has its highest density of fish on-site.

Goldendale is unlike the other facilities analyzed in this report due to its natural spring water source. Because of a lack of available information specific to this spring, only the direction of change for the aquifer was projected and is expected to increase on average, which would ensure a reliable water source in the future. Unfortunately, current water demand at the facility exceeds the total allowable use specified in the water right. Water savings and reuse measures must be incorporated into the facility to bring operations within compliance. The proposed improvements for each facility that will support WDFW in maintaining or improving production are summarized in Table 1-1.

Table 1-1. Proposed Facility Upgrades

Proposed Upgrade	Marblemount	Kendall Creek	Samish	Goldendale
Raceway Partial Recirculating Aquaculture (PRAS)		Various options available depending on flexibility required	Two modules with four raceways each	Three modules: one for broodstock (two raceways) and two for production (5 raceways each)
Circular Tank PRAS	3 new systems for early rearing spring Chinook, yearling Chinook, and yearling Coho	Early rearing winter steelhead (24 4 ft-diameter tanks)	Install 52 16 ft-diameter tanks using space in ponds 9-13.	
New Hatchery Building	35 ft x 85 ft for fry/fingerling spring Chinook	45 ft x 30 ft for fry/fingerling winter steelhead		
Well rehabilitation	For 5 existing wells	For 5 existing wells, additional aeration and pump equipment		
New well development			Develop new wells to provide 336 gpm of clean, cold water for egg incubation.	
Intake improvements	Cascade River intake replacement	Kendall Creek intake replacement	Friday Creek intake replacement and improved road access. Upgrade Samish River intake to resolve mechanical issues.	Seal leaks in cistern, replace dam boards, perform regular maintenance on the transit pipe supplying head box.
Effluent improvements	Installation of two abatement ponds			
General recommendation for all facilities	Additional shade covers for outdoor rearing areas and refurbishment of concrete rearing surfaces. Evaluate electrical power availability for the addition of new PRAS technologies (pumps, chillers, UV, etc.). Transition to full stack style incubators and add recirculation			

Proposed Upgrade	Marblemount	Kendall Creek	Samish	Goldendale
	capabilities to reduce water use. Install instrumentation and controls to minimize unnecessary water use.			

High level cost estimates were developed for each hatchery and the proposed improvements. These estimates have a 25% contingency and are in 2023 dollars. These costs will need to be escalated to the anticipated year of construction to meet the needs of the facilities. Escalation has been highly variable over the last 4 years. McMillen's construction division has seen increases of up to 40% for aquaculture equipment from 2019. Table 1-2 summarizes the estimated costs for the improvements and includes soft costs such as design, permitting, and construction support.

Table 1-2. Summary of Costs for Proposed Modifications

Description	Marblemount	Kendall Creek	Samish	Goldendale
Base Construction Costs	**$10,999,000**	**$3,773,000**	**$10,467,000**	**$2,227,000**
Contingency (Const Cost 25%)	$2,750,000	$944,000	$2,617,000	$557,000
Overhead (7%)	$962,000	$330,000	$916,000	$195,000
Profit (8%)	$1,100,000	$377,000	$1,047,000	$223,000
Bond Rate (Approximate 1%)	$137,000	$47,000	$131,000	$28,000
Total Base Construction Price	**$15,948,000**	**$5,471,000**	**$15,178,000**	**$3,230,000**
Design, Permitting, Construction Assistance	$2,392,000	$821,000	$2,277,000	$485,000
Total Project Cost - Base Bid	**$18,340,000**	**$6,292,000**	**$17,455,000**	**$3,715,000**
Accuracy Range -30%	$12,838,000	$4,404,000	$12,219,000	$2,601,000
+50%	$27,510,000	$9,438,000	$26,183,000	$5,573,000

For WDFW to maintain its commitment to the conservation and recreational fishery goals, it must invest in these facilities to ensure consistent, resilient operations as climate change continues to alter the landscape. Climate change will undoubtedly result in worsening conditions for fish that will lead to more stress and higher prevalence of diseases. It is critical that WDFW approach hatchery improvement projects with this in mind. Future projects should not solely focus on repairing existing infrastructure to the original specifications, but include water treatment, reuse, and increased rearing capacity to ensure production goals can be met.

2.0 Introduction

This section presents a summary of the overall project including authorization, purpose, and project understanding, as well as the Draft Hatchery Climate Change Vulnerability Assessment (HCCVA) report organization.

2.1 Authorization

McMillen, Inc. (McMillen) was retained by the Washington Department of Fish and Wildlife (WDFW) to provide a climate change evaluation of four WDFW hatcheries. The contract was authorized on February 17, 2023, under Contract No. 23-21733.

2.2 Purpose

This report documents the climate change evaluation of four WDFW hatcheries: Marblemount, Kendall Creek, Samish, and Goldendale. Ultimately, the evaluation will provide WDFW with the information needed to increase the resiliency of WDFW hatchery facilities to the impacts of climate change, including proposed facility improvements and management actions, and the potential capital costs associated with these changes.

2.3 Project Understanding

Climate change will exacerbate existing challenges to fish hatchery management across Washington state. Hatchery operations are challenged by (1) warming stream temperatures and associated increasing prevalence of disease, (2) declines in summer streamflow, and (3) increases in peak streamflow. New hatchery processes are needed to improve water quality and increase fish survival during warm periods and low summer flows. Global warming has had an impact worldwide and implementing developing technologies and methods is critical to WDFW’s long-term goal to improve water quality and increase fish survival at their hatcheries.

The project approach is based on achieving the following project objectives stated in the Request for Proposal (RFP).

Objective 1: Provide a qualitative assessment of climate change vulnerability for the following four WDFW hatcheries: Marblemount, Kendall Creek, Samish, and Goldendale.

Objective 2: Provide a quantitative assessment for the four hatcheries on how projected changes in climate (e.g., changing water availability, surface flows, supply/recharge, water temperature) will affect the “business as usual” paradigm for WDFW’s existing fish culture schedules and production targets.

Objective 3: Provide a fish health assessment for the four hatcheries.

The hatchery qualitative assessment will include an evaluation of the climate stressors for each of the hatcheries, followed by development of management actions to mitigate the impact of those stressors. As noted in the RFP, the stressors to be evaluated include (but are not limited to) the following:

- Surface water and groundwater quality, quantity, and temperature
- Air temperature extremes
- Snowpack declines
- Heavy precipitation events
- Landslides, erosion, and sediment transport
- Flood events/drought events

Each of the four hatcheries will be evaluated for upgrades, modifications, or complete reconstruction to meet existing and future production requirements based on the climate change evaluation. This will include developing management actions. The following actions would be considered:

- Water reuse systems such as recirculating aquaculture systems (RAS) or partial recirculating aquaculture systems (PRAS), airlifts, serial reuse with oxygen, etc.
- Production water treatment/conditioning systems
- Temperature control
- Controls development to minimize water usage such as supervisory control and data acquisition (SCADA), programmable logic controller (PLC), and pumps with variable frequency drives (VFDs), etc.
- Enclosure of the production rearing vessels
- Power consumption minimization (photovoltaic systems, energy efficient systems, etc.)
- Water distribution systems
- Promotion of effective passive effluent systems and return of clean water to receiving water
- Minimization of the overall impacts to the natural systems

2.4 Report Organization

The report organization is summarized in Table 2-1.

Table 2-1. Hatchery Climate Change Vulnerability Assessment Outline and Purpose

Section	Description	Purpose
1	Executive Summary	Briefly summarizes the report findings applicable to hatchery operations in the context of climate change impacts.
2	Introduction	Summarizes of the project authorization, purpose, project understanding, and report organization.
3	Design Criteria	Presents the development of biological, civil, geotechnical, architectural, structural, mechanical, and instrumentation and controls design criteria.
4	Existing Facility Descriptions	Presents a description of each facility (Marblemount, Kendall Creek, Samish, and Goldendale) that includes location, infrastructure, fish health history, and a bioprogram review.
5	Climate Impacts Evaluation	Describes potential climate stressors, climate evaluation methods, and results.
6	Future Facility Impacts	Applies the results from the climate evaluation and outlines impacts to climate stressors, fish health, and bioprogramming at each facility.
7	Alternatives Development (Technologies)	Outlines the approach to developing the concept alternatives including oxygenation, tempering, water reuse systems, and pathogen treatments.
8	Management Actions (Adaptive Management)	Provides general and hatchery-specific recommendations.
9	Opinion of Probable Construction Costs	Presents an opinion of construction cost for advancement at each hatchery.
10	Conclusions and Recommendations	Reports conclusions and final recommendations.
11	References	Lists the references used in developing the conceptual design.

Section	Description	Purpose
Appendices		
A	Interview Documentation	Presents the drawings illustrating the concept alternative modifications/upgrades for each facility.
B	Bioprogramming	Provides the information used for the climate evaluation and any calculations as required.
C	Climate Evaluation Modeling Results	Provides all information used for the climate evaluation and any calculations as required to evaluate the proposed management actions.
D	Hatchery Figures (Management Actions)	Presents the drawings illustrating the concept alternative modifications/upgrades for each facility.
E	Cost Estimates	Summarizes the cost estimates prepared for the evaluation.

3.0 Design Criteria

For this assessment, the design criteria developed here are the general standards required for the State of Washington. These are the typical codes and guidelines for each major engineering discipline that will need to be followed as design advances. These general criteria were utilized during the evaluation of the project.

3.1 Biological

3.1.1 Water Temperature

Water temperature is the primary determining factor for fish development and growth rates. Daily average temperatures are important metrics for forecasting fish growth and development, whereas peak maximum temperatures are important when evaluating fish health in terms of each species' critical threshold. Any temperature increases outside the ideal or desired temperature range for a species will result in increased stress that can affect fish growth rates, post-release survival, and susceptibility to disease. The hatcheries evaluated in this report use a combination of surface and groundwater sources. The impacts of climate change on these water sources are discussed in detail in Section 5.0.

3.1.2 Growth and Development Rates

Growth rates may be expressed as length or weight over time but should incorporate water temperature. This is done by using temperature units (TU), which is the degrees-over-freezing of the water temperature in a given period. For example, if the average daily temperature is 50°F, the daily temperature unit (DTU) would be 18 (50°F - 32°F = 18°F over freezing). DTUs can then be used to track egg development and time to hatch, while monthly temperature units (MTU) can be used to track growth over longer periods or compare growth cycles from year to year.

As water temperatures increase due to climate change, fish respiration and growth will also increase, so long as food is available and water temperatures do not exceed the maximum threshold for a species. Targeted growth rates will depend on a hatchery's production goals, available rearing space, and release schedule. Increased temperatures in the future will likely alter expected development and rearing schedules.

3.1.3 Density Index

Density index (DI) describes the relationship of fish weight, or total biomass, and length to rearing volume (Piper et al. 1982). This is used by fish culturists as a "rule of thumb" to guide stocking densities. Maintaining a low DI is important to ensure that fish remain in good health and condition throughout the production cycle. It is important to note that DI does not account for flow rate and a low DI may not be enough to maintain fish health. See Section 3.1.4 for more information on how flow rate can impact carrying capacity. Piper et al. (1982) suggested that DI should be below 0.5 for trout, and the Northwest Indian Fisheries Commission (NWIFC) recommends a DI of 0.25 or less for Pacific salmon (Stewart et al., 2006). Useful calculations and equations adapted from Piper et al. (1982) are shown in Table 3-1.

Table 3-1. Key DI Calculations: W = weight (lbs.), D = density index, V = volume (ft^3), L = length (in.)

Design Question	Equation
What is the Density Index (DI)?	$D = \frac{W}{(L \times V)}$
What is the allowable weight of fish?	$W = D \times V \times L$
What is the required volume?	$V = \frac{W}{(D \times L)}$

3.1.4 Flow Index

Flow index (FI) is the relationship of fish weight and length to total incoming flow (Piper et al. 1982). The ideal FI also considers site elevation, water temperature, and dissolved oxygen capacity of the water. It is important to note that the equation itself (Table 3-2) does not take these parameters into account.

Table 3-2. Key FI Calculation

Design Question	Equation*
What is the Flow Index (FI)?	$F = \frac{W}{(L \times I)}$
What is the allowable weight of fish?	$W = F \times L \times I$
What is the required flow rate?	$I = \frac{W}{(F \times L)}$

*W = weight (lbs.), F = flow index, L = length (in.), I = inflow (gpm)

In Piper et al. (1982), there are suggested indices based on water temperature and elevation. An adapted table showing recommended indices for each hatchery at various temperatures is shown below (Table 3-3). As water temperature increases, the recommended flow index decreases for each hatchery. A maximum FI of 1.2 has been suggested for Pacific salmon (Stewart et al., 2006). This is a conservative approach that allows for variability in water temperature, dissolved oxygen, and rearing unit types, all of which can impact actual carrying capacity.

Table 3-3. Approximate Recommended FI at Various Water Temperatures for each Hatchery Based on Elevation*

Water Temperature (°F)	Marblemount[1] (330 ft)	Kendall Creek[2] (400ft)	Goldendale[3] (1,640 ft)	Samish [4] (105 ft)
50	1.80	1.80	1.68	1.80
55	1.50	1.50	1.40	1.50
60	1.29	1.29	1.20	1.29
64	1.15	1.15	1.08	1.15

*Based on Piper et al. (1982)

3.1.5 Life Stages

Life stage refers to the specific phase of life that a fish passes through during a normal production cycle (i.e., egg, fry, fingerling, yearling, adult). Different life stages have different water quality, quantity, and temperature tolerances; each stage also requires distinct types and sizes of rearing units. Eggs and small fry require clean and cool water for successful hatching rates since they are especially susceptible to pathogens. Juvenile fingerlings require a lower DI relative to yearlings because they have higher metabolic and growth rates. Spawning adults require high-quality water, because the stress of spawning leaves them more vulnerable to disease. These are only some examples that illustrate the importance of taking life stage requirements into consideration while proposing management actions.

3.2 Civil

3.2.1 Erosion Control Plan

The contractor will need to seek coverage under the National Pollutant Discharge Elimination System (NPDES) Construction Stormwater General Permit prior to beginning construction activities if soil disturbance is planned to be greater than 1 acre for the project. The Construction General Permit (CGP) requires temporary and post-construction Best Management Practices (BMPs) to prevent erosion and reduce sediment discharges from

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[1] Marblemount raises Rainbow Trout, Chinook Salmon, Coho Salmon, and Chum Salmon

[2] Kendall Creek raises Chinook, Coho, and Chum Salmon, steelhead trout, Rainbow Trout, Brown Trout, Cutthroat Trout, and kokanee

[3] Goldendale raises Rainbow, Brown, Tiger, Brook, and Cutthroat Trout

[4] Samish raises Chinook Salmon

construction sites. The contractor will also be required to obtain a Construction Stormwater General Permit (CSWGP) from the State of Washington.

Prior to permit issuance, submittal of an Erosion Control Plan (ECP) to the appropriate agency is required. The ECP shall include methods for controlling runoff, erosion, and sediment movement.

3.2.2 Hatchery Effluent Discharge

The Washington State Department of Ecology requires hatchery facilities that discharge effluent to obtain an NPDES permit to regulate the hatchery effluent discharge. Three of the four hatcheries in this climate change evaluation (Marblemount, Kendall, and Samish) operate under the Upland Finfish Hatching and Rearing General Permit, with effluent monitoring and reporting as established in the permit. Discharges from the cleaning treatment systems are monitored as follows:

- Total Suspended Solids (TSS): 1 to 2 times per month on composite effluent, maximum effluent, and influent samples
- Settleable Solids (SS): 1 to 2 times per week on effluent and influent samples
- In-hatchery water temperature: daily maximum and minimum readings

3.2.3 Stormwater Control

The federal Clean Water Act requires facilities that discharge stormwater runoff to obtain an NPDES permit to regulate the discharge of stormwater into surface waters. The design of the new hatchery facility will minimize the addition of impervious areas. The addition of impervious areas will be limited to rooftops and gravel surfacing around the site. The drainage from new impervious areas will be routed to a storm drain system that will provide treatment before discharge of stormwater.

3.2.4 Grading

According to the International Building Code, slopes shall be no steeper than 2 horizontal (H) to 1 vertical (V). Steeper slopes may be allowed if the Building Official determines they will be stable or if a geotechnical engineer certifies that the site has been investigated and that the proposed deviation will be and will remain structurally stable.

3.3 Geotechnical

To support final engineering efforts, the following geotechnical criteria will be required:

- Soil Bearing Pressure
- Water Table Height
- Active/Passive Lateral Earth Pressure
- Passive Soil Pressure (Lateral)
- Soil Weight
- Soil Friction Factor
- Site Class as Defined by ASCE 7-16 Table 3.13
- Frost Depth
- Minimum Footing Bearing Depth
- Minimum Footing Width
- Anticipated Total Settlement
- Anticipated Differential Settlement

3.4 Architectural

3.4.1 Applicable Codes and Standards

The following references will serve as the basis for preparation of the architectural design elements:

- 2018 International Building Code
- 2018 International Fire Code
- 2018 Washington State Energy Code
- National Electrical Code (NFPA 70)

3.5 Structural

The design criteria apply to all design procedures to be implemented during the future design phases for these facilities.

3.5.1 Applicable Codes and Standards

The following codes, standards, and specifications will serve as the general design criteria for the structural design of the facilities. The applicable version of each document is the latest edition in force unless noted otherwise.

The structural design, engineering, materials, equipment, and construction will conform to the codes and standards listed in Table 3-4.

Table 3-4. Structural Codes and Standards

Code	Standard
2018 IBC	2018 International Building Code
SEI/ASCE 7-16	Minimum Design Loads for Buildings and Other Structures, 2016 Edition
ANSI/AISC 360-16	Specification for Structural Steel Buildings, 2016 Edition
ACI 318-14	Building Code Requirements for Structural Concrete
ACI 350-06	Code requirements for Environmental Engineering Concrete Structures
ACI 350.4R-04	Design Considerations for Environmental Engineering Concrete Structures
ADM1-2015	Aluminum Design Manual, 2015 Edition
AWS D1.1-2020	Structural Welding Code – Steel, 2020 Edition
AWS D1.2-16	Structural Welding Code – Aluminum, 2016 Edition
AWS D1.6	Structural Welding Code – Stainless Steel

The following references are used in development of the structural design elements of the project:

- American Institute of Steel Construction (AISC) (2017). “Steel Construction Manual,” Fifteenth Edition.

3.5.2 Materials

The material properties assumed for preparation of the design and engineering are listed in Table 3-5.

Table 3-5. Structural Material Properties

Structural Stainless Steel	
Bars and shapes	ASTM A240, Type S31600
Plates	ASTM A240, Type S31600

Structural Stainless Steel	
Hollow sections	ASTM A312, Type S31600
Structural bolts	ASTM F593 Type 316
Nuts and washers	ASTM F593 Type 316
Anchor bolts	ASTM F593 Type 316
Structural Mild Steel	
Wide flanges	ASTM A992, Gr. 50
Other shapes, plates, angles, and bars	ASTM A36
Pipe	ASTM A53, Gr. B
Hollow structural sections (HSS)	ASTM A500. Gr. B
Structural Weathering Steel	
Wide flanges	ASTM A588, Gr. 50
Rectangular and square HSS	ASTM A847, Gr. 50
Other shapes, plates, and bars	ASTM A588, Gr. 50
Miscellaneous	
Grating	Fiberglass reinforced plastic (FRP)
Stair treads	Fiberglass reinforced plastic (FRP)
Handrails	Fiberglass reinforced plastic (FRP)
Ladders	Fiberglass reinforced plastic (FRP)
Aluminum alloy shapes	6061-T6
Aluminum alloy plates	5052-H32
Concrete	
Concrete	4,500 psi normal weight
Rebar	ASTM A615, Grade 60

3.5.3 Design Loads

The general loads considered in the design of the facilities are summarized in this section. All loads will be combined per the requirements of ASCE 7 for the various loading conditions to assess factors of safety. The actual design loads for each structure will be included on the structural drawings during the design phase.

3.5.3.1 Dead Load

The structural system for all project elements will be designed and constructed to support all dead loads, permanent or temporary, including but not limited to self-weight, pipe systems, fixed mechanical and electrical equipment, stairs, walkways, and railings.

3.5.3.2 Live Load

Live loads during construction and operation consist of workers on the structures, temporary stored materials or equipment on the project elements, impact, and construction equipment and vehicles. Live loads on the access stairways will be superimposed as per the IBC codes.

3.5.3.3 External Hydrostatic Loads

A triangular distribution of static water pressure is assumed to act normal to the upstream faces of all screen panels, stop logs, and gate structures.

3.5.3.4 Buoyancy Loads

Structures will be designed to resist upward hydrostatic pressures from high groundwater or river levels. Design factors of safety follow ACI 350.4R Section 3.1 guidelines recommending a factor of safety of 1.1 for groundwater to the top of wall, not considering soil, and 1.25 considering soil and groundwater elevations below the top of wall.

3.5.3.5 Earth Loads

Below-grade structures and water-holding basins will be designed for worst-case load combinations of full height of backfill plus a minimum 2-foot soil surcharge. Additional surcharge loads will be applied to account for unique conditions due to adjacent structure proximity and traffic or equipment loading.

3.5.3.6 Wind Loads

Wind loads will be applied in the design of the buildings and elevated structures. For structures, wind loads will be computed per the IBC using an ultimate design wind speed of 115 miles per hour and a minimum design wind pressure of 20 pounds per square foot (psf), exposure category C, Risk Category II, and an importance factor of 1.0.

3.5.3.7 Temperature Loads

Temperature changes for expansion and contraction will be considered based on the site location.

3.6 Mechanical

3.6.1 Applicable Codes and Standards

The following references will serve as the basis for preparation of the mechanical design elements:

- American Society of Testing and Material (ASTM)
- American National Standards Institute (ANSI)
- American Society of Mechanical Engineers (ASME)
- American Welding Society (AWS)
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
- National Fire Protection Association (NFPA)

The material properties assumed for preparation of the preliminary design are listed in Table 3-6. Yellow metals and galvanized systems that would come in contact with fish production water supply will not be allowed.

Table 3-6. Mechanical Materials

Component	Materials
Gates	Cast iron, Aluminum, Stainless Steel
Buried piping	PVC, Ductile Iron
Exposed piping	PVC, Carbon Steel, Ductile Iron
Valves	PVC, Ductile Iron
Hardware	Stainless, PVC
Ductwork	Galvanized Sheet Metal, Aluminum for high humidity areas
Transport flumes	Aluminum
Fish transport pipes	HDPE
Intake fish screens	Stainless steel, Mild Steel
Incubation trays	Fiberglass, Plastic
Feeding vessels	Fiberglass

3.6.2 Design Loads

The mechanical loads are listed in Table 3-7.

Table 3-7. Mechanical Loads

Load	Description
Pump loads	Net Positive Suction Head Required and Net Positive Suction Head Available will be determined to size all pumps to prevent cavitation.
Piping loads	Piping and fittings will be designed to the working pressure of the fluid, and the pipe wall thickness will be designed for a sufficient bursting pressure.
Gate loads	Load calculations will be for deflection for gates at the maximum expected head.
Valve loads	Valves will be designed for expected maximum pressure and expected maximum differential pressure.
Debris screens	Debris screens will be designed for a maximum differential pressure of 3 feet of water across the upstream and downstream faces.
Building cooling	Cooling will not be provided; air circulation will be provided by large high-volume wall mount fans to allow airflow across the building space. The ventilation system will be designed based on a maximum summer ambient temperature of the selected site.

3.6.3 HVAC

Heating and ventilation will be provided to the hatchery building and the administration building. Heating in all buildings will be provided by wall- or ceiling-mounted electric unit heaters. Cooling will not be provided.

3.7 Electrical

The electrical design criteria apply to all design procedures to be implemented during the project design phase. Electrical design considerations listed in this section, including detailing of electrical components, material selection, and design requirements, are intended to be incorporated into project design.

3.7.1 Applicable Codes and Standards

The following references and design standards will serve as the general design criteria for the electrical design of the project. The applicable version of each document is the latest edition enforced, unless noted otherwise. References to the specific codes and standards are included in the applicable technical specifications. The electrical design, materials, equipment, and construction will conform to the codes and standards listed in Table 3-8.

Table 3-8. Electrical Codes and Standards

Code	Standard
ANSI	American National Standards Association
IEEE	Institute of Electrical and Electronics Engineers
IESNA	Illuminating Engineering Society of North America – Lighting Application Handbook
ISA	Instrument Society of America
NEMA	National Electrical Manufacturers Association
NETA ATS	International Electrical Testing Association Acceptance Testing Specifications
NFPA 70	National Electrical Code (NEC)
NFPA 70E	Standard for Electrical Safety in the Workplace
NFPA 101	Life Safety Code
NFPA 110	Standard for Emergency and Standby Power Systems
OSHA	Occupational Safety and Health Act
UL	Underwriters Laboratory
ENERGY CODE	2018 Washington State Energy Code

3.7.2 Materials

The materials assumed for preparation of the preliminary design and applicable for engineering of the project are listed in Table 3-9.

Table 3-9. Electrical Materials

Material	Standard
Panelboards	NEMA PB 1, UL 67
Transformers, dry type	NEMA ST 1, UL 1561, 10 CFR – Part 431 DOE 2016
Circuit breakers	NEMA AB 1, UL 489
Switches	NEMA KS 1, UL 98
PLCs	NEMA ICS 1, UL 508
Terminal blocks	UL 1059
Instrumentation cable:	ASTM B8, NEMA WC 57, UL 13, UL 83, UL 1277

Material	Standard
THWN copper	
Power conductors/cable: THWN copper; XHHW-2 copper	ASTM B3, ASTM B8, ASTM B496, NEMA WC 70, UL 83
Splices, connectors, and terminations	UL 486A-486B, UL 486C, UL 510
Grounding: copper	UL 467
Boxes and enclosures: NEMA 1, 12, 3R, & 4	NEMA 250, UL 514A
Raceway: Rigid galvanized steel; intermediate metal conduit; PVC schedule 80; liquid-tight flexible metal conduit	NEMA C80.1, NEMA C80.6, NEMA RN 1, UL 6, UL 360, UL 514B, UL 651, UL 1242
Transfer switches	NEMA ICS 1, NEMA ICS 2, UL 1008
Motors: TEFC or submersible	IEEE 112, NEMA MG 1, UL 2111
Motor controls	NEMA ICS 2
Wiring devices	NEMA WD 1, NEMA WD 6
Luminaires: LED	IESNA HB-9, IESNA LM-80, IEEE C62.41.1, UL 1598, UL 2108, UL 8750, U.S. DOE Energy Star
Surge protective devices	UL 1449

3.8 Instrumentation and Controls

3.8.1 Applicable Codes and Standards

The following references and design standards will serve as the general design criteria for the instrumentation and control design of the facilities in future design phases. The applicable version of each document is the latest edition enforced, unless noted otherwise. References to the specific codes and standards are included in the applicable technical specifications. The instrumentation and control design, materials, equipment, and construction will conform to the codes and standards listed in Table 3-10.

Table 3-10. Instrumentation and Control Codes and Standards

Code	Standard
IEEE	Institute of Electrical and Electronics Engineers
ISA 5.1	Instrumentation Symbols and Identification
NEMA	National Electrical Manufacturers Association
NFPA 70	National Electrical Code (NEC)
UL	Underwriters Laboratory

4.0 Existing Facility Descriptions

This section is organized by each hatchery and includes a brief description of the facility and its location, water supply, existing infrastructure, fish health history, and a review of the current bioprogramming for each species present.

4.1 Bioprogramming Methods

Data collected from the questionnaires and interviews with WDFW staff was used to generate high-level existing bioprograms for each species produced at each hatchery. See the bioprogramming spreadsheets in Appendix B. Based on the volume and available flow to each rearing unit for each life stage, a minimum number of rearing units based on reported DI and FI values was calculated. By dividing the required flow by the available flow per rearing unit and dividing the required volume by rearing unit volume, the minimum number of tanks can be calculated to maintain the desired DI and FI values. The minimum number of rearing units required was calculated by determining which index—flow or density—was the limiting factor and required more tanks to maintain. Flow rate (gpm), biomass, and volumes are rounded to the nearest whole number in the bioprogram tables.

4.2 Marblemount Hatchery

The Marblemount Hatchery is located at Marblemount, Washington and was constructed in 1946. The hatchery raises several species including Ross Lake Rainbow Trout (*Oncorhynchus mykiss*), spring Chinook Salmon (*Onchorhynchus tshawytscha*), summer Chinook Salmon, Coho Salmon (*Onchorhynchus kisutch*), and Skagit River Chum Salmon (*Onchorhynchus keta*). The hatchery has multiple surface water sources including the Cascade River, Clark Creek, Jordan Creek (gravity source), and five groundwater wells. The delineation of the three watersheds is shown in Figure 4-1. Overall, the available water supply to the facility varies throughout the year with seasonal dry up of Clark and Jordan creeks and seasonal reduction in the output from wells during the summer months.

Figure 4-1. GoogleEarth view of Marblemount Hatchery.

4.2.1 Hatchery Water Supply

The hatchery staff provided the Skagit River Fall Chum Hatchery and Genetic Masterplan (HGMP) for a description of Marblemount hatchery's water sources and flow rates. No historical flow data was available, but a monthly water budget was documented by the hatchery staff on the interview questionnaire. Table 4-1 shows the water rights availability and temperature for each water source reported in the HGMP.

Table 4-1. Available Water Sources at Marblemount Hatchery

Water Source	Available Water Right (cfs)	Water Temperature (ºF)
Wells 1-5 (Groundwater)	10	46
Clark Creek (Surface - pumped)	25	40–45
Jordan Creek (Surface - gravity fed)	15	38–65
Cascade River (Surface - pumped)	30	38–58

Per the HGMP, wells supply the hatchery with stable, pathogen-free water that is used for incubation and rearing. Spring-fed Clark Creek provides a stable flow of water for broodstock collection and holding, and the water is also used for juvenile rearing and acclimation. The Cascade River is the most utilized water source and is used for rearing, but the river's heavy bedload movement requires the hatchery to discharge the pumped water into a settling pond to remove silt. The clean water then flows to the pumphouse and is supplied for fish rearing.

4.2.2 Hatchery Infrastructure

Overall, much of the Marblemount Hatchery infrastructure is in need of repairs and replacement as the original construction of the hatchery dates back to 1946. The surface water intake on the Cascade River is not in compliance with state and federal guidelines and has a loose intake screen that is in need of repair. Replacement of both the Cascade River Intake and the Clark Creek Intake is planned (proposed for the 2021–2023 biennial in WDFW's capital improvements plan [CIP]). Other proposed CIP improvements include construction of new adult ponds, new super raceways, and a 2-bay pollution abatement pond. WDFW is pursuing funding to address these CIP projects. The Jordan Creek Intake was rebuilt in 2018 and is in compliance with the 2011 National Marine Fisheries Service (NMFS) guidelines. All wells are due for rehabilitation, but the infrastructure is in good condition. During the summer, Jordan and Clark creeks dry up and are not used as a water source for the hatchery. The Cascade River and Jordan Creek intakes experience screen blinding from leafy debris that restricts flow into the hatchery. Special provisions are made during the summer months using sandbags to divert water from Jordan Creek into the facility's intake and fish ladder to facilitate operations.

The hatchery's incubation area includes the following:

- 132 Heath-style half-stack incubators (8 trays each)
- 6 Free-style incubators

Fish rearing vessels at the hatchery include the following:

- 24 concrete raceways (100 ft x 10 ft x 3 ft) (Of which, 3 are supplied by well water, and the remaining 21 are supplied by surface water. Three of the 21 surface water raceways may also be operated utilizing well water, if needed. Average flow rate to the raceways is 306 gpm per raceway.)
- 3, 12-foot-diameter circular fiberglass tanks with a 3-foot operating depth and an operating flow rate of 32 gpm per tank
- 4 asphalt lined 1/4-acre channel ponds (350 ft x 37 ft x 4.5 ft) with an average flow rate of 2,040 gpm per pond (Two ponds are currently operational.)

- 1, 1/4-acre adult pond (300 ft x 12 ft).
- 16 troughs (16 ft x 3 ft x 2.3 ft) with an operating flow rate of 25 gpm per trough
- 2 indoor 4-foot-diameter round tanks with an operating depth of 1.6 feet and a flow rate of 25 gpm per tank

4.2.3 Fish Health

Diseases routinely observed at Marblemount Hatchery include Bacterial Kidney Disease (BKD) and Bacterial Coldwater Disease (BCWD). BKD, caused by *Renibacterium salmoninarum*, typically infects Chinook Salmon and yearling Coho Salmon during the winter and early spring while water temperatures are low prior to smoltification. BCWD, caused by *Flavobacterium psychrophilum*, generally affects fry stages and outbreaks result from stress events such as increased rearing densities or handling.

A potential cause for concern is the proximity of infectious hematopoietic necrosis virus (IHNV) to the hatchery. The Cascade River, which provides water for the facility, flows directly into the Skagit River less than one mile from Marblemount Hatchery. IHNV is present in the Skagit River system (Emmenegger and Kurath, 2002); however, the virus has not been identified onsite at Marblemount Hatchery within the past 8 to 10 years.

Other diseases present at Marblemount include furunculosis, columnaris, costiasis, and trichodiniasis. Returning Spring Chinook adults show signs of furunculosis and columnaris disease late in their brood cycle near spawning time. Both diseases are caused by bacteria, furunculosis by *Aeromonas salmonicida*, and columnaris by *Flavobacterium columnare*. The external parasite Costia (*Ichthyobodo necator* or *Ichthyobodo pyriformis)* is present but has not severely impacted fish health. *Trichodina* sp. are also present at the hatchery, but this does not typically cause disease or mortalities in salmonids. These are often seen as secondary infections associated with a more virulent pathogen.

To control instances of disease, the hatchery exclusively uses formalin to treat broodstock populations, but will use formalin and/or salt to treat juvenile fish.

4.2.4 Bioprogram Review

4.2.4.1 Water Budget

Water use at Marblemount Hatchery is divided between surface and groundwater sources. Surface water is generally used for production of juvenile, yearling, and captive broodstock programs while higher-quality groundwater is reserved for egg incubation, fry, and returning adults. One exception is that surface water is used for Coho salmon production once the fry stage is reached. According to information gathered from WDFW staff, flow demand remains consistent from year to year, and water budgets from one year to the next are identical.

Peak surface water use occurs in August and September at 19.22 cfs (Table 4-2). Over 75% of the total demand (16.59 cfs) is allocated for Coho Salmon production during this period. Water use remains above 10 cfs for each month except in May and June when it decreases to 6.14 cfs. Peak surface water use coincides with periods of low flows in Jordan and Clark creeks. The facility relies on the Cascade River year-round, which provides up to 30 cfs according to the water rights described in the HGMP.

The maximum available well production for groundwater sources is 4.45 cfs. Groundwater use peaks in the late summer and early fall when returning adult salmon, egg incubation, and rainbow trout fry production all overlap (Table 4-3). August has the highest flow demand with 4.42 cfs, and October is next with 4.18 cfs. Outside of these months, flow demand is below 3 cfs. The period of lowest flow demand occurs from January through May, each below 2 cfs; this is the period in which the hatchery does not have any returning salmon broodstock onsite.

Total flow demand (Table 4-4) is highest from August to December, with each month requiring at least 20 cfs for hatchery operations. Flow demand is lowest in May and June with flow demands of 7.53 and 8.25 cfs each month, respectively. Table 4-2 summarizes the flow demand from surface water sources throughout the year for each production stage, and Table 4-3 summarizes the groundwater demand throughout the year for each production stage. Total water demand is shown in Table 4-4. In each of these tables, the peak flows are highlighted in red.

Table 4-2. Marblemount Hatchery Monthly Surface Water Flow Demand by Production Stage

Production Stage	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Incubation Flow Demand (gpm)	0	0	0	0	0	0	0	0	0	0	0	0
Fry Flow Demand (gpm)	0	612	918	918	918	918	3,366	3,366	3,366	3,366	3,366	3,366
Juvenile Flow Demand (gpm)	32	32	1,256	1,256	1,224	1,224	561	561	561	0	0	0
Yearling Flow Demand (gpm)	4,080	4,080	4,080	2,040	0	0	2,040	4,080	4,080	4,080	4,080	4,080

Production Stage	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Broodstock Flow Demand (gpm)	612	612	612	612	612	612	612	612	612	612	612	612
Total (gpm)	4,724	5,336	6,866	4,826	2,754	2,754	6,579	8,619	8,619	8,058	8,058	8,058
Total (cfs)	10.53	11.90	15.31	10.76	6.14	6.14	14.67	19.22	19.22	17.97	17.97	17.97

Table 4-3. Marblemount Hatchery Monthly Groundwater Flow Demand by Production Stage

Production Stage	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Incubation Flow Demand (gpm)	347	115	67	67	18	22	86	282	143	178	371	408
Fry Flow Demand (gpm)	375	475	225	125	300	0	0	165	165	165	0	150
Juvenile Flow Demand (gpm)	0	0	0	306	306	306	0	0	0	0	0	0
Broodstock Flow Demand (gpm)	0	0	0	0	0	618	618	1,536	918	1,530	612	612
Total (gpm)	722	590	292	498	624	946	704	1,983	1,226	1,873	983	1,170
Total (cfs)	1.61	1.32	0.65	1.11	1.39	2.11	1.57	4.42	2.73	4.18	2.19	2.61

Table 4-4. Marblemount Hatchery Monthly Total Flow Demand by Production Stage

Production Stage	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Incubation Flow Demand (gpm)	347	115	67	67	18	22	86	282	143	178	371	408
Fry Flow Demand (gpm)	375	1,087	1,143	1,043	1,218	918	3,366	3,531	3,531	3,531	3,366	3,516
Juvenile Flow Demand (gpm)	32	32	1,256	1,562	1,530	1,530	561	561	561	0	0	0

Production Stage	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Yearling Flow Demand (gpm)	4,080	4,080	4,080	2,040	0	0	2,040	4,080	4,080	4,080	4,080	4,080
Broodstock Flow Demand (gpm)	612	612	612	612	612	1,230	1,230	2,148	1,530	2,142	1,224	1,224
Total (gpm)	5,446	5,926	7,158	5,324	3,378	3,700	7,283	10,602	9,845	9,931	9,041	9,228
Total (cfs)	12.15	13.22	15.96	11.87	7.53	8.25	16.24	23.64	21.96	22.15	20.16	20.58

4.2.4.2 Ross Lake Rainbow Trout

The Rainbow Trout program at Marblemount releases approximately 360,000 fingerling-size fish (800 fish per pound [fpp]) and maintains a captive broodstock population. Eggs are incubated from May to July each year. The broodstock program sets aside 5,000 fry each year for future brood. These fish are spawned once they reach 3 years old, after which the males are stocked out and the females are held to spawn again as 4-year-olds. Fish start in the intermediate troughs until they reach 1.5 inches, at which point the majority are released. Adult broodstock are held in standard raceways. The DI reported by hatchery staff is 0.5, and the FI is kept between 1.8 and 2.7. The current bioprogram was evaluated with both FI options (Table 4-5).

Table 4-5. Marblemount Hatchery Rainbow Trout Bioprogram

								FI = 1.8		FI = 2.7	
Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required	Required Flow (gpm)	Minimum Rearing Units Required
Intermediate Trough											
Fry	396,605	1.02	2,319	171	110	335	25	93	4	62	4
Juvenile	360,550	1.5	665	542	110	723	25	201	8	134	7
Raceway											
Broodstock	5,000	21	0.3	16,666	3,000	1,587	306	441	2	294	1

Currently, 165 gpm of well water is used for the fry and juvenile rearing in intermediate troughs, which results in an FI of 1.02 for the fry and 2.2 for the juveniles. Assuming seven troughs are used with a total of 772.8 cubic feet (ft^3) and approximately 23.5 gpm each, the DI index for the fry would be 0.22 and the juveniles 0.47.

For the captive broodstock, 612 gpm of surface water supplies raceways where fish from this program are held year-round. There is an excess of available volume for the broodstock adults in a single raceway but keeping an FI of 1.8 requires more flow than a single raceway has available. Using an FI of 2.7 would require 294 gpm, which a single raceway can accommodate.

4.2.4.3 Spring Chinook Salmon

Approximately two million eggs are collected from adults held in June through August. Eggs are incubated until December. In June, approximately 787,500 juvenile fish are released, and in the following April another 400,000 are released as yearlings. Fry are started in intermediate troughs, then transferred to standard raceways until they reach 3.5 inches. Yearling fish raised to 7 inches are held in channel ponds. The DI values are kept below 0.2, and the FI between 1.8 and 2.7. The current bioprogram was evaluated with both FI options (Table 4-6).

Table 4-6. Marblemount Hatchery Spring Chinook Bioprogram

								FI = 1.8		FI = 2.7	
Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required	Required Flow (gpm)	Minimum Rearing Units Required
Intermediate Trough											
Fry	1,330,000	1.3	1,200	1,108	110	4,263	25	474	39	316	39
Raceway											
Juvenile	787,500	3.5	80	9,844	3,000	14,063	306	1,563	6	1,042	5
Channel Pond											
Yearling	400,000	7.0	8	50,000	58,275	35,714	2,040	3,968	2	2,646	2

Current water usage includes up to 375 gpm of well water supplied to intermediate troughs for fry rearing in January and February, which results in an FI of 2.28. This flow is enough to supply a minimum of 15 troughs with 25 gpm each. Since 39 troughs are required to maintain a DI of 0.2 and only 16 existing troughs, this program is limited by the rearing volume available.

Once fish are transferred to raceways, 1,224 gpm of surface water is used according to the water budget. This equates to four raceways at full flow (306 gpm per raceway) and would provide an FI of 2.3. To maintain a DI of 0.2, five raceways at a minimum are required; if only four raceways are used (12,000 ft^3) the DI increases to 0.235.

The channel ponds are supplied with 2,040 gpm, the flow capacity of a single pond. If the FI is to remain below 2.7, two channel ponds are required. If all yearling fish are stocked into a single channel pond, the resulting FI would be 3.5. In the context of extremely large rearing unit volumes and low densities such as this, the FI is not considered crucial to maintain oxygen levels. If DO becomes an issue, emergency in-pond aerators could be used during periods of high density prior to release.

4.2.4.4 Summer Chinook Salmon

Adult summer Chinook Salmon are held from August to October and approximately 254,100 eggs are incubated from October to January each year. In June, approximately 200,000 fingerlings are released once they reach 3.1 inches. Intermediate troughs are used for the fry and juveniles are held in standard raceways. The DI and FI target values are the same as those of the spring Chinook program, 0.2 and 1.8 to 2.7, respectively. The current bioprogram was evaluated with both FI options (Table 4-7).

Table 4-7. Marblemount Hatchery Summer Chinook Bioprogram

								FI = 1.8		FI = 2.7	
Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required	Required Flow (gpm)	Minimum Rearing Units Required
Intermediate Trough											
Fry	220,000	1.3	1,200	183	110	705	25	78	7	52	7
Raceway											
Juvenile	200,000	3.1	100	2,000	3,000	3,226	306	358	2	239	1

The fry life stage requires seven intermediate troughs to maintain the DI of 0.2, but there remains sufficient flow even with an FI of 1.8. According to the water budget, 100 gpm of well water is used in February and March, resulting in an FI of 1.41. Flows could be reduced by 20 gpm without increasing the FI over 1.8. However, assuming the 100 gpm is used to supply four troughs (441.6 ft^3 total) with 25 gpm each, the DI would be 0.32. If seven troughs (772.8 ft^3 total) are used with a flow rate of 14.28 gpm each, the DI is decreased to 0.185.

Juveniles are provided 306 gpm of well water in the raceways from April to June; this is the full capacity of a single raceway and creates an FI of 2.11. It is important to note that the DI increases to 0.22 when a single raceway is used. The required volume to maintain a DI of 0.2 for this life stage is 225 ft^3 more than is available in a single raceway. Increasing the water depth of the raceway by 4 inches to 3.25 feet would provide adequate volume for a DI of 0.2 if the walls of the raceway permit the increase in operating depth.

4.2.4.5 Coho Salmon

Approximately 1,439,535 eggs are incubated from October to February. Juveniles are released in two separate stages the following year, in January, as 4.7-inch fish and as 5.5-inch fish in May, with release totals of 630,000 and 500,000 fish, respectively. Fry and early release juveniles are grown in standard raceways, with channel ponds used to grow fish to 5.5 inches. The DI used for this program is 0.3, with the FI target between 1.8 and 2.7. An assumed FI value of 1.8 was used to evaluate the current bioprogram to determine requirements for optimal operation (Table 4-8).

Table 4-8. Marblemount Hatchery Coho Salmon Bioprogram

								FI = 1.8		FI = 2.7	
Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required	Required Flow (gpm)	Minimum Rearing Units Required
Raceway											
Fry	1,218,335	1.0	2,400	508	3,000	1,692	306	282	1	188	1
Juvenile	630,000	4.7	25	25,200	3,000	17,872	306	2,979	10	1,986	10
Channel Pond											
Sub-yearling	500,000	5.5	17	29,412	58,275	17,825	2,040	2,971	2	1,981	1

According to the water budget, 612 gpm are used for fry rearing in the raceways during February, which would mean a minimum of two raceways used. According to information provided by WDFW staff, water usage increases from 612 gpm (two raceways) to 918 gpm (three raceways) in March, and to 3,366 gpm (11 raceways) in July. It is assumed that fry reach 1 inch in length and are split in March. However, fry could be reared to a 1-inch length in a single raceway with 306 gpm, which would result in a DI of 0.17 and an FI of 1.66.

The maximum water used for the juvenile cohort held in raceways is 3,366 gpm, which equates to 11 raceways used at full flow capacity; assuming all 11 raceways are used the DI would be 0.163 and the FI 1.6, both below target values.

Sub-yearling production takes place in channel ponds, and there is 2,040 gpm allotted for this production in the water budget. This is enough flow to run a single channel pond at full capacity, and results in an FI of 2.63. The maximum DI for yearlings held in a channel pond would be below 0.1.

4.2.4.6 Skagit River Chum Salmon

The Skagit River Chum Salmon Program is relatively new, with only 850,000 fish released in its third year of operation. The theoretical maximum production for this program was provided by WDFW staff and is used as the basis for this bioprogramming effort (Table 4-9). Adults are held at the hatchery from October to December, and 6,050,000 eggs will be incubated from November to April. Up to five million juveniles are slated for release when they are between 1000 and 600 fpp in May. Currently, fish are grown in intermediate troughs, but we assume this will change as the program produces more fish in the future. The bioprogram calculated the minimum rearing units required for scenarios in which the fish are raised in intermediate troughs, raceways, or channel ponds. Future production may use a mixture of these vessels, but a more detailed discussion with hatchery staff would be needed to determine specifics. The goal DI for this program is 0.4, and the FI is to remain between 1.8 and 2.7.

Table 4-9. Marblemount Hatchery Skagit River Chum Salmon Bioprogram

								FI = 1.8		FI = 2.7	
Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required	Required Flow (gpm)	Minimum Rearing Units Required
Intermediate Troughs											
Fry	5,500,000	1.0	2,400	2,292	110	5,729	25	1,273	52	849	52
Juvenile	5,000,000	1.7	800	6,250	110	9,191	25	2042	84	1,362	84
Raceways											
Fry	5,500,000	1.0	2,400	2,292	3,000	5,729	306	1,273	5	849	3
Juvenile	5,000,000	1.7	800	6,250	3,000	9,191	306	2042	7	1,362	5
Channel Ponds											
Fry	5,500,000	1.0	2,400	2,292	58,275	5,729	2,040	1,273	1	849	1
Juvenile	5,000,000	1.7	800	6,250	58,275	9,191	2,040	2042	2	1,362	1

The current calculations assume the program will take place in the intermediate troughs according to the data collected by WDFW staff. Rearing space would be the limiting factor in this scenario, as there are only 16 available intermediate troughs. Use of other rearing units is required to produce the theoretical maximum of this program. Assuming that standard raceways are used for the fry, the program would need a minimum of three raceways to keep the FI below 2.7. For juveniles, five raceways would be required to keep the FI below 2.7; alternatively, a single channel pond could accommodate the entire cohort with an FI of 1.9.

4.3 Kendall Creek Hatchery

The Kendall Creek Hatchery is located in Deming, Washington. The original site dates back to 1897. The current hatchery building was built in 1952. The hatchery raises several species including spring Chinook Salmon, Kendall Creek Coho Salmon, North Fork Nooksack River fall Chum Salmon, Kendall Creek winter steelhead (*Onchorhynchus mykiss*), Goldendale Rainbow Trout, Ford Hatchery Brown Trout (*Salmo trutta*), Eel Springs Hatchery Cutthroat Trout (*Oncorhynchus clarkia*), Lake Whatcom kokanee salmon (*Oncorhynchus nerka*), Skookum Creek Hatchery Coho Salmon, Samish Hatchery fall Chinook Salmon, and Kendall Hatchery Captive Brood steelhead.

Figure 4-2. GoogleEarth view of Kendall Creek Hatchery.

4.3.1 Hatchery Water Supply

A total of five wells and a gravity system from Kendall Creek serve as the source water for the Kendall Creek Hatchery. Figure 4-2 shows the delineation of the Kendall Creek watershed. The hatchery staff provided the Kendall Creek Coho HGMP for a description of Kendall Creek Hatchery's water sources and flow rates. No historical flow data was available, but a monthly water budget was documented by the hatchery staff on the interview questionnaire. Table 4-10 shows the water availability and temperature for each water source reported by the Kendall Creek Coho HGMP.

Table 4-10. Available Water Sources at Kendall Creek Hatchery

Water Source	Available Water Flow (cfs)	Water Temperature (^{0}F)
Wells 1,2 (Groundwater)	11	47
Wells 3-5 (Groundwater)	24.55	
Kendall Creek (Surface water – gravity and pumped)	22.36	30-50

Per the HGMP, Kendall Creek Hatchery’s well water is of excellent quality, pathogen-free, at a constant temperature of 47^{0}F, and is available year-round. Well water is passed through a degassing tower to reduce high levels of nitrogen and increase the dissolved oxygen content. Kendall Creek is a seasonal stream that can run dry during the summer months. When available, the creek water can be mixed with well water and used for adult attraction and holding as well as rearing and acclimation.

4.3.2 Hatchery Infrastructure

The Kendall Creek gravity intake system does not meet current NMFS standards and is currently non-compliant. In the past, a major flood event damaged the primary production well infrastructure and the hatchery had only surface water supply during that time. The wells are currently producing a fraction of their original design output and multiple water control valves and well pumps are non-functional. Well 1 does not have pumps installed. Outputs from Well 2 are highly variable depending on the season, and currently only one of the two pumps is functional. In short, equipment replacement and rehabilitation for the well water system is required to provide the hatchery with a consistent source of groundwater.

The hatchery's incubation area includes the following:

- 37 Heath-style full-stack incubators (16 trays each)
- 20 Free-style incubators
- 9 Redd-Zone incubators (held in a shipping container placed near asphalt ponds)

Fish rearing vessels at the hatchery include the following:

- 2 asphalt ponds (220 ft x 70 ft x 3.5 ft) with an operating flow rate of 1,500 gpm per pond
- 12 concrete raceways (96.5 ft x 10 ft x 3.25 ft) with an operating flow rate of 200 gpm per raceway
- 3 "super" raceways (128.5 ft x 20 ft x 4.5 ft) with an operating flow rate of 1,200 gpm per raceway
- 2 modified adult ponds (120 ft x 20 ft x 4.5 ft) with an operating flow rate of 1,200 gpm per pond
- 2, 20-foot-diameter circular fiberglass ponds with an operating depth of 3.5 feet and an operating flow rate of 125 gpm per pond
- 8, 16-foot-diameter circular fiberglass ponds with an operating depth of 2.5 feet and an operating flow rate of 125 gpm per pond
- 4, 6-foot-diameter circular ponds with an operating depth of 2.5 feet and an operating flow rate of 75 gpm per pond
- 10 aluminum Capilano troughs (20 ft x 3 ft x 1.5 ft) with an operating flow rate of 75 gpm per trough
- 6 fiberglass intermediate troughs (11 ft x 3 ft x 2.5 ft) with an operating flow rate of 75 gpm per trough
- 34 fiberglass shallow troughs (11.7 ft x 1 ft x 58 ft) with an operating flow rate of 10 gpm per trough

4.3.3 Fish Health

Kendall Creek Hatchery deals with similar diseases as Marblemount, including BKD, BCWD, and furunculosis. Kendall Creek has effectively managed disease outbreaks by maintaining good biosecurity practices and decreasing fish stress through limiting fish handling and sampling. This effort has led to a reduction in antibiotic use and no need for vaccines in recent years.

BKD is not a major concern, and typically only impacts one raceway of Coho yearlings shortly before smoltification and release. BCWD outbreaks primarily occur in steelhead and Coho shortly after the fry swim up and as densities increase in early rearing units. Furunculosis was only recently diagnosed in the Coho but is not a concern and has not caused significant health issues to date. The only routine treatment used is formalin to control fungal growth during egg development.

4.3.4 Bioprogram Review

4.3.4.1 Water Budget

Table 4-11 summarizes the flow demand for each production stage throughout the year, as well as the total flow demand for each month. Peak demand is highlighted in red. Water demand is lowest from June to November, remaining under 6.70 cfs. Flow demand increases gradually from early winter to early spring, from 8.94 cfs in December to its peak at 18.49 cfs in March. Currently, wells and pumps can provide up to 14.48 cfs of groundwater that can be supplied throughout the facility. At full capacity of available wells and water rights, groundwater flows could be as high as 33.53 cfs. Surface water from Kendall Creek is used to supply the standard raceways. The current use is 8.06 cfs, but rights for 22.36 cfs are available.

Table 4-11. Kendall Creek Hatchery Monthly Flow Demand by Production Stage

Production Stage	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Incubation Flow Demand (gpm)	400	260	120	0	0	0	0	60	120	160	160	160
Fry Flow Demand (gpm)	1,800	230	470	670	950	0	0	0	0	0	0	1,100
Juvenile Flow Demand (gpm)	0	2,400	1,200	1,150	1,200	1,050	800	500	500	750	750	750
Outplant Flow Demand (gpm)	3,550	4,200	6,500	3,900	2,250	500	950	1,800	1,950	2,050	1,450	2,000
Total (gpm)	5,750	7,090	8,290	5,720	4,400	1,550	1,750	2,360	2,570	2,960	2,360	4,010
Total (cfs)	12.82	15.81	18.49	12.76	9.81	3.46	3.90	5.26	5.73	6.60	5.26	8.94

4.3.4.2 Spring Chinook Salmon

Approximately two million eggs are incubated from August to November to eventually release the goal of 1.2 million fish with a total biomass of 13,000 lbs. in the late spring and early summer. Fish are raised in concrete raceways until they reach 2.37 inches, at which point modified adult ponds are used. The DI used for this program is 0.2, and the FI is 1.91.

The maximum amount of water used for fry rearing is 1,800 gpm in January, which would supply a minimum of nine raceways with 200 gpm each and create an FI of 0.5 and a maximum DI of 0.031. Using three raceways with 200 gpm each (600 gpm total) would keep the FI at 1.5 and the DI at 0.095.

For juvenile rearing in raceways, the maximum water usage occurs in February with 2,400 gpm, enough to supply all 12 existing raceways. This would result in an FI of 0.98 and a DI of 0.062, both well below the target values of the program. If seven raceways were used with their full flow capacity (21,953.75 ft^3 and 1,400 gpm total), the FI would be 1.67 and the DI less than 0.11.

Table 4-12. Kendall Creek Hatchery Spring Chinook Salmon Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required
Raceway									
Fry	1,424,000	1.45	1,101	1,294	3,136	4,460	200	467	3
Juvenile	1,400,000	2.4	250	5,600	3,136	11,667	200	1,222	7
Modified Adult Pond									
Juvenile	1,100,000	3.2	100	11,000	10,800	17,188	1,200	1,800	2
Juvenile	400,000	3.5	80	5,000	10,800	7,143	1,200	748	1

In March, fish are transferred to modified adult ponds and water usage is a maximum of 2,000 gpm. This is enough to supply a minimum of two ponds. This would maintain a peak DI of 0.16 and an FI of 1.73 for 1.1 million fish at 100 fpp. The lowest flow for the modified adult ponds occurs in May with 750 gpm. If all 400,000 fish at 80 fpp are present, this is directly in line with the maximum desired FI of 1.91; the DI would be 0.14, comfortably below the target of 0.2.

4.3.4.3 Kendall Creek Coho Salmon

The Coho salmon program produces a half-million 5.5-inch fish each year by incubating 575,000 eggs from January to March. Fry are raised in concrete raceways then transferred to "super" raceways until release. The DI and FI for this program are 0.3 and 1.91 (Table 4-13).

Table 4-13. Kendall Creek Hatchery Coho Salmon Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required
Raceway									
Fry	546,250	1.33	1,202	455	3,136	1,139	200	178.89	1
Juvenile	518,938	2.42	200	2,595	3,136	3,574	200	561.35	3
"Super" Raceway									
Juvenile	518,938	2.42	200	2,595	11,565	3,574	1,200	561.35	1
Sub-yearling	500,000	5.5	17	29,412	11,565	17,825	1,200	2799.78	3

Fry rearing in the raceways takes place from March through May, with maximum flows in May at 200 gpm. This is enough flow to maintain an FI of 1.71 and, assuming a single raceway is used, a DI of 0.11.

The maximum water use in the "super" raceways occurs in April and May, with 1,500 gpm used. This would require a minimum of two "super" raceways used and would result in a DI of 0.24. Assuming that each unit is supplied with 750 gpm, the FI would be approximately 3.6, well over the target of 1.91.

4.3.4.4 North Fork Nooksack River Fall Chum Salmon

This is the largest program at Kendall Creek in terms of total fish; 5.6 million eggs are incubated from November to January and five million juveniles are released in the late spring and early summer. This program uses asphalt ponds for fry and juvenile production. The DI and FI for this program are 0.3 and 2.864, respectively.

Table 4-14. Kendall Creek Hatchery NF Nooksack River Fall Chum Salmon Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required
Asphalt Pond									
Fry	5,092,500	1.33	1,202	4,237	53,900	10,618	1,500	1,112	1
Juvenile	5,000,000	1.94	400	12,500	53,900	21,478	1,500	2,249	2

The asphalt ponds used for this program are large enough to maintain DI levels well below the 0.3 target, with a maximum DI of 0.12 for the juvenile group. According to the provided water budget, the maximum flow for this program is 750 gpm in May. This flow would only be sufficient to provide an FI of 8.6, well over the 2.864 target. It is not feasible to maintain an FI of 2.864 unless two asphalt ponds are used, since the total flow required would be approximately 2,250 gpm and a single pond can only be supplied 1,500 gpm. If flow was increased to 1,500 gpm, the FI would be lowered to 4.3.

4.3.4.5 Kendall Creek Winter Steelhead Trout

Approximately 200,000 eggs are incubated in January and February, with 150,000 yearling fish released the following April (Table 4-15). Fry are started in fiberglass shallow troughs and are transferred to concrete raceways once they reach 1.13 inches. Fish are transferred to “super” raceways once they reach 2.4 inches; they are raised there until release. The DI and FI for this program are 0.3 and 1.91, respectively.

Table 4-15. Kendall Creek Hatchery Winter Steelhead Trout Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required
Shallow Trough									
Fry	190,000	1.13	2,000	95	6.79	280	10	44	42
Raceway									
Juvenile	180,500	2.42	200	903	3,136	1,243	200	195	1
“Super” Raceway									
Yearling	150,000	8.76	5	30,000	11,565	11,416	1,200	1793	2

It is assumed that transfers of fry from the shallow troughs to raceways is staggered to make room for recently hatched fish. To maintain a DI of 0.3, 42 shallow troughs are required compared to the 34 troughs currently available. According to the water budget, only 20 gpm are used for the shallow troughs in March and April during the fry stage. Assuming that the entire cohort is held with 20 gpm of total flow, the FI would then be 4.2, higher than the target of 1.91.

Juveniles raised in raceways are supplied with a maximum of 150 gpm in June and July. Assuming they are held in a single raceway, the DI and FI would be 0.12 and 2.5, respectively. The FI is greater than the target of 1.91 that could be reached if the raceway was supplied with the full 200-gpm capacity.

Yearling fish are grown in “super” raceways, and the peak water use is 1,500 gpm in March and April. A minimum of two “super” raceways must be used to supply this amount of water, which would result in a DI of 0.15. However, the flow currently used would only support an FI of 2.3. If each “super” raceway was supplied with 900 gpm (1,800 gpm total), the FI would then be within the target of 1.91.

4.3.4.6 Goldendale Rainbow Trout

Approximately 160,000 eggs are incubated in January (Table 4-16). Fish are raised and released at sizes ranging from 3 to 18 inches. Fry are started in aluminum Capilano troughs and are transferred to concrete raceways once they reach 1 inch in length. Fish are transferred into “super” raceways once they reach an average length of 1.8 inches. Fish grown to 18 inches are held in fiberglass circular ponds. The DI and FI for this program are 0.5 and 1.91, respectively.

Table 4-16. Kendall Creek Goldendale Rainbow Trout Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required
Capilano Trough									
Fry	128,000	1	2,500	51	90	102	75	27	2
Raceway									
Juvenile	115,200	1.8	400	288	3,136	320	200	84	1
“Super” Raceway									
Juvenile	103,680	2.92	100	1,037	11,565	710	1200	186	1
Juvenile	37,000	4.07	37	1,000	11,565	491	1200	129	1
Adult	43,000	10	2	21,500	11,565	4,300	1200	1,126	1

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required
Circular Pond (20-inch diameter)									
Adult	8,000	18	1	8,000	1,100	889	125	233	2

According to the water budget, 80 gpm are used to supply Capilano troughs water in February and March; since a single trough can only accommodate 75 gpm, it is assumed that two troughs are used with 40 gpm of flow each. This would result in a DI of 0.29 and an FI of 0.64, both well below the target values. If flow is limited elsewhere throughout the hatchery, the flow rate for fry production could be reduced by approximately 50 gpm without the FI exceeding 1.91.

Juveniles grown in raceways to a length of 1.8 inches are supplied with 150 gpm May through July. It is assumed that this stage of production uses a single raceway and raises these fish at a DI of 0.06 and an FI of 1.07. Since densities are low for this group of fish, flow rates could be reduced by approximately 60 gpm while still maintaining an FI below 1.91.

The water budget information provided does not detail how much water is used for each additional production group (2.92-, 4.07-, and 10-inch fish). Therefore, an accurate record of the DI and FI for each group cannot be established. The lowest flow rate for the “super” raceways in this program is 250 gpm, which occurs in August and September. This is sufficient to maintain an FI below 1.91 for the 2.92- and 4.07-inch fish. Flow rates increase to 350 gpm in October and November, and finally to 500 gpm in December. Assuming the 10-inch fish are grown in the “super” raceways using 500 gpm of flow, the FI would be 4.35; the entire cohort of 10-inch fish could be held in a single “super” raceway with a DI of 0.19. Water flow for the fiberglass circular ponds was not included in the water budget for the facility. Assuming the full 125 gpm are used for each 20-foot-diameter tank and both tanks are used, the DI and FI would be 0.20 and 1.78. If a single circular pond is used with 125 gpm, the DI would increase to 0.40 with an FI of 3.55.

4.3.4.7 Ford Hatchery Brown Trout

The Brown Trout program at Kendall Creek incubates 90,000 eggs in January and February to produce 32,000 3.45-inch fish for release (Table 4-17). Fry are started in aluminum Capilano troughs before being transferred to concrete raceways once they reach 1 inch in length. Fish are raised in raceways from April to October, when they are released. The DI and FI for this program are 0.5 and 1.91, respectively.

Table 4-17. Kendall Creek Hatchery Ford Brown Trout Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required
Capilano Trough									
Fry	58,500	1	2,500	23	90	47	75	12	1
Raceway									
Juvenile	46,800	1.8	400	117	3,136	130	200	34	1
Juvenile	32,000	3.45	60	533	3,136	309	200	81	1

According to the water budget, 40 gpm are used for rearing fry in March. It is assumed that this is supplied to a single Capilano trough, which would result in a DI of 0.26 and an FI of 0.59.

For the juveniles grown to 1.8 inches, the maximum flow rate used is 150 gpm in May and June. Assuming production occurs in a single raceway, the DI would be below 0.03 and the FI would be 0.45. As fish grow to the release size of 3.45 inches, flow rate increases to 200 gpm, which can be supplied to a single raceway. If one raceway is used, the DI and FI would be 0.05 and 0.78, respectively.

This program is not limited by available rearing space or flow rates. The DI and FI values for all production stages are well below target levels. Flow can be reduced by 15, 80, and 40 gpm for the fry, 1.8-inch, and 3.45-inch stages, respectively, while maintaining an FI below 1.0.

4.3.4.8 Eels Springs Hatchery Cutthroat Trout

Approximately 160,000 eggs are incubated in January and February, of which 77,000 are released. Fry are reared in fiberglass shallow troughs before being transferred to concrete raceways in April once they reach 1 inch in length. Juveniles are grown in raceways until June, when 5,000 fish are stocked at 1.8 inches. Another 72,000 fish are kept until they reach approximately 3.46 inches in October when they are stocked out (Table 4-18). The DI and FI for this program are 0.3 and 1.91, respectively.

Table 4-18. Kendall Creek Hatchery Eels Springs Cutthroat Trout Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required
Shallow Trough									
Fry	112,000	1	2,500	45	7	149	10	23	22
Raceway									
Juvenile	95,200	1.8	400	238	3,136	441	200	69	1
Juvenile	72,000	3.46	80	900	3,136	867	200	136	1

Fry raised in shallow troughs are supplied with 40 gpm in March, resulting in an FI of 1.12. However, this stage is space-limited since it requires a minimum of 22 troughs to maintain a DI below 0.3. These troughs are also used by other species programs at Kendall Creek during the same time of year.

Once fish are transferred to raceways, they are provided with a maximum flow rate of 150 gpm in May and June. It is assumed they are raised in a single raceway, which would result in a DI below 0.05 and an FI of 0.9, comfortably below the goal criteria of the program.

The maximum flow rate for fish raised to 3.46 inches is 200 gpm in September and October. Since this is the full flow capacity for a raceway, it is assumed that a single raceway is used for this production which results in a DI of 0.09 and an FI of 1.3.

4.3.4.9 Lake Whatcom Kokanee

The Kokanee program incubates 120,000 eggs in January and February that are grown to 2.92 inches before being released in October (Table 4-19). Fry are kept in fiberglass shallow troughs in April until they reach 1 inch, they are then transferred to concrete raceways and grown until they are stocked out in October. The DI and FI for this program are 0.3 and 1.91, respectively.

Table 4-19. Kendall Creek Hatchery Lake Whatcom Kokanee Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required
Shallow Trough									
Fry	114,000	1	2,500	46	7	15	10	24	23
Raceway									
Juvenile	108,300	1.8	400	271	3,136	501	200	79	1
Juvenile	100,000	2.92	100	1,000	3,136	1,142	200	179	1

Fry are raised in shallow troughs that are supplied with 40 gpm in March, resulting in an FI of 1.15. Similar to the Cutthroat Trout program, space is limited; to maintain a DI below 0.3, fry would need to be split into 23 shallow troughs.

After fish are transferred to raceways, they are supplied with 150 gpm in May and June while they reach 1.8 inches in length. Assuming a single raceway is used for this production, the DI and FI would be 0.05 and 1.01, respectively.

During the last stage of growth to 2.92 inches, the peak flow rate is 200 gpm in September and October. Once again, assuming production uses a single raceway, the calculated DI is 0.11 and the FI would be 1.72.

4.3.4.10 Skookum Creek Hatchery Coho Salmon

Approximately 1.2 million eggs are incubated in Redd-Zone Containers in December and January (Table 4-20). Fish are raised until they reach 4.32 inches at which point 1 million are stocked out in the following March. The DI and FI for this program are 0.3 and 2.865, respectively.

Table 4-20. Kendall Creek Hatchery Skookum Creek Coho Salmon Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Minimum Rearing Units Required
Asphalt Pond									
Fry	1,140,000	1.33	1,202	948	53,900	2,377	1,500	249	1
Juvenile	1,083,000	2.42	200	5,415	53,900	7,459	1,500	781	1
Yearling	1,000,000	4.32	35	28,571	53,900	22,046	1,500	2,308	2

Space is plentiful for all production stages to remain well below the 0.3 DI criteria. Flow rate is the limiting factor, with only 200 gpm supplied to the fry in May as they reach 1.33 inches, resulting in an FI of 3.58. As fish reach 2.42 inches and the flow rate increases to 750 gpm in October through December, the FI decreases to 2.99, still above the criteria of 2.865 for the program. These two stages assume a single asphalt pond is in use since the rearing volume is more than enough.

After fish reach 2.42 inches in length, it is assumed that they are split into two asphalt ponds since the flow rate increases to 1,800 gpm in January. In this case, the DI would be 0.062 but the FI would be 3.68.

4.3.4.11 Samish Hatchery Fall Chinook

This program is only responsible for egg incubation for Samish Hatchery fall Chinook Salmon; no hatching or fish rearing takes place at the Kendall Creek Hatchery. Eggs are incubated in Free-style incubators that are supplied with 60 gpm of flow in September and October. When eggs reach the eyed stage, they are transferred back to the Samish Hatchery.

4.4 Samish Hatchery

The Samish Hatchery is located in Burlington, Washington and dates back to 1895. The hatchery is a single-species hatchery raising 5.2 million sub-yearling Samish River fall Chinook Salmon.

Figure 4-3. GoogleEarth view of the Samish Fish Hatchery (left; Hatchery) and Samish Broodstock and Adult Holding Pond Facility (right; Adult Ponds).

4.4.1 Hatchery Water Supply

The hatchery is supplied water from Friday Creek via a gravity intake system. A pump station on the Samish River provides water for the adult pond. Hatchery staff report a maximum water usage from Friday Creek in March of 17.4 cubic feet per second (cfs) and maximum water usage from the Samish River in May of 15.8 cfs.

Per the Samish Fall Chinook HGMP, well water was available for use until spring 2012. Since the fall 2012, all collected eggs have been transported, fertilized, and incubated to the eyed stage at the Kendall Creek Hatchery. WDFW is exploring the possibility of acquiring new water rights to keep the entire Samish production on-station.

Table 4-21 shows the water availability and temperature for each water source reported by hatchery staff and the Samish Fall Chinook HGMP.

Table 4-21. Available Water Sources at Samish Hatchery

Water Source	Available Water Flow (cfs)	Water Temperature (ºF)
Well (domestic only)	.06 (28 gpm)	47
Friday Creek (surface – hatchery only)	23	32-58
Samish River (surface – adult ponds only)	25	39-58

4.4.2 Hatchery Infrastructure

In 2021, a new intake and Obermeyer weir was constructed for the Samish River, but there are reported mechanical issues at the Samish River Intake. The Friday Creek Intake is not compliant with NMFS standards and is on the capital budget list for replacement. Under high flows, the Friday Creek intake screens become plugged, impeding water flow to the hatchery. The adult pond was built in 1980 and is on the capital budget list for replacement; steel walls replaced the wood pickets in 2005. Raceways 1–8 were constructed in 2002 and remain in good condition, while raceways 9–12 are reportedly worn and leaking on the outer walls. The asphalt pond has cracks throughout the pond and the water manifold is rusted.

The hatchery's incubation area includes the following:

- 144 MariSource half-stacks (8 trays each) are fed from 6 head troughs (24 stacks per head trough) for a total of 1,008 trays.

Fish rearing vessels at the hatchery include the following:

- 8 concrete raceways (100 ft x 10 ft x 3.3 ft) with an operating flow rate of 400 gpm per raceway
- 4 concrete raceways (80 ft x 8 ft x 3.5 ft) with an operating flow rate of 500 gpm per raceway
- 1, 1/4-acre asphalt pond (120 ft x 60 ft x 4.5 ft) with an operating flow rate of 3,000 gpm of serial reuse water from the other 12 raceways

4.4.3 Fish Health

Samish Hatchery has issues associated with external parasite infections including Ich, caused by *Ichthyophthirius multifiliis*, and Costia (*Ichthyobodo necator*). Disease presence increases as water temperatures increase in the spring and into summer.

Eggs are treated with formalin as necessary to keep fungal growth under control. Formalin is also used to treat columnaris, Ich, and Costia in raceways. Typically, only a single dose is required for effective disease control.

4.4.4 Bioprogram Review

4.4.4.1 Water Budget

The Samish Hatchery has two separate areas: (1) the hatchery, which uses Friday Creek as a water source, and (2) the adult holding pond, which uses the Samish River as a water source. Samish currently has a serial reuse system in which Pond 13 can receive flows from Pond 1–12. While calculating total flows, we have focused on the total amount that is drawn from the Friday Creek Intake. The maximum draw from Friday Creek occurs during March, while egg incubation and pond production overlaps for a short period of time (Table 4-22). The maximum process flow demand for fish production occurs in April, once all fish are hatched and transferred to production rearing units. Table 4-22 summarizes the monthly flow demand in each rearing area throughout the year. Peak demand is highlighted in red.

Table 4-22. Samish Hatchery Monthly Flow Demand by Rearing Units*

Rearing Area	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Incubation Flow Demand (gpm)	780	650	130	0	0	0	0	0	0	0	780	780
Ponds 1-8 Flow Demand (gpm)	0	2,000	2,400	3,200	3,400	0	0	0	0	0	0	0

Rearing Area		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Pond 9 Flow Demand (gpm)		0	400	500	500	0	0	0	0	0	0	0	0
Pond 10 Flow Demand (gpm)		0	0	500	500	0	0	0	0	0	0	0	0
Pond 11 Flow Demand (gpm)		0	0	500	0	0	0	0	0	0	0	0	0
Pond 12 Flow Demand (gpm)		0	0	500	0	0	0	0	0	0	0	0	0
Pond 13 Flow Demand (gpm)**		0	0	2,400	3,200	3,200	0	0	0	0	0	0	0
Pond 14 Flow Demand (gpm)***		0	0	0	3,000	4,000	0	0	0	3,000	3,000	0	0
Total Friday Creek Flow Demand	(gpm)	780	3,050	4,530	4,200	3,400	0	0	0	0	0	780	780
	(cfs)	1.74	6.80	10.09	9.36	7.58	0	0	0	0	0	1.74	1.74
Total Flow Demand Including Reuse	(gpm)			6,930	7,400	6,600							
	(cfs)			15.44	16.49	14.70							

* Flows directed to the fish ladder were not used in total flow calculations.

**Pond 13 flows are all serial reuse from Ponds 1–12, and Pond 13 flows were not used to calculate total flows.

***Pond 14 uses water from the Samish River Intake; all other areas use the Friday Creek Intake.

4.4.4.2 Samish River Fall Chinook Salmon

The only production at the Samish River Hatchery is the fall Chinook Salmon program, and current production does not meet the goals set forth in the HGMP of 7.6 million eggs collected and 6.5 million fish released (Table 4-23). These goals are used to determine future management actions described in Section 8.0. Presently, approximately 5.72 million eggs are collected in September and October, which are then incubated at the Kendall Creek hatchery. Fry are stocked into Ponds 1–12 and are grown to 1.3 inches, after which they are split into Ponds 1–14 and grown to 2.42 inches. Ponds 9–12 are not used to raise fish from 2.42 to 4.42[5] inches.

The information provided by WDFW staff does not specify the loading densities for the various types of ponds; Ponds 1–8, 9–12, 13, and 14 all have different dimensions and volumes. For this bioprogram, the total rearing volume of all ponds for each production stage was used to determine the actual DI. Details on how fish are split among the ponds and specific densities for each type of pond require in-depth discussions with hatchery staff and are outside the

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[5] Per Piper et al. (1982) the typical length for a 90 fpp Chinook Salmon is approximately 3.4 inches as opposed to 4.42 inches information provided by the Samish Hatchery staff in the questionnaire.

scope of this analysis. As a result, only the required volume and flow rates were calculated and not the minimum rearing units required. The DI and FI goals provided by the hatchery for this program are 0.3 and 1.41, respectively.

Table 4-23. Samish Hatchery Fall Chinook Salmon Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Type	*Total Rearing Volume (ft^3)	Required Volume (ft^3)	**Total Available Flow (gpm)	Required Flow (gpm)
Fry	5,500,000	1.3	1,300	4,231	Ponds 1-12	48,800	10,848	5,200	2,308
Juvenile	5,200,000	2.42	200	26,000	Ponds 1-14	162,610	35,813	14,200	7,620
Juvenile	5,200,000	4.42	90	57,778	Ponds 1-8 and 13-14	140,210	43,573	12,200	9,271
Future Goal	6,500,000	4.42	90	72,222	Ponds 1-8 and 13-14	140,210	54,466	12,200	11,589

*Because rearing units are not a uniform size and specific information about how fish are split among them, total rearing volume and total available flow for each production stage were used instead of volume and flow per rearing unit.

**Total flow does not differentiate serial reuse water from Ponds 1–12 that is used to supply Pond 13. It is the cumulative flow available for each rearing unit used at a specific production stage.

Based on the information provided, we can determine that the actual densities being used are well within the target DI of 0.3. The DIs for the various production stages from smallest to largest fish are as follows: 0.067, 0.067, and 0.094. Since some ponds are supplied with serial reuse water, and there are no other species or production programs at this hatchery, densities can be maintained well below the criteria provided by WDFW.

Flows used for each production stage vary, and the final grow-out period incorporates serial reuse from Ponds 1–12. The provided water budget shows that 4,400 gpm are supplied to Ponds 1–12 in March. Using the biomass and size of fish during fry production, the FI would be approximately 0.74. According to the species production tab in the questionnaire completed by WDFW, the next production stage uses Ponds 1–14; however, the water budget does not specify flows to Ponds 11 and 12 in April. The total flow in April supplies Ponds 1–10, 13, and 14; assuming the total flow of 10,400 gpm is used for production of 2.42-inch fish, the FI would be approximately 1.04. For the final stage of production of 4.42-inch fish, the water budget specifies that 10,600 gpm are used between Ponds 1–8 and 14; this results in an FI of 1.24. It is important to note that the FI does not differentiate between fresh water and the reused water that supplies Pond 13. Based on these assumptions, the Chinook production at Samish hatchery is within both the DI and FI targets. There is excess space available for each production stage to increase production to the goal of 6.5 million fish released. The last stage of growth to 4.42-inch fish would require using at least two ponds from the 9–12 bank in addition to the ponds currently used for this production stage. This would ensure enough flow to maintain an FI below 1.56.

4.5 Goldendale Hatchery

The Goldendale Hatchery is located in Goldendale, Washington. The original construction occurred in 1938 with a new incubation area and office built in 1995. The hatchery raises Rainbow Trout, Ford Stock Brown Trout, Tiger Trout (*Salmo trutta* x *Salvelinus fontinalis*), Ford Stock Eastern Brook Trout (*Salvelinus fontinalis*), and King Lake Cutthroat Trout.

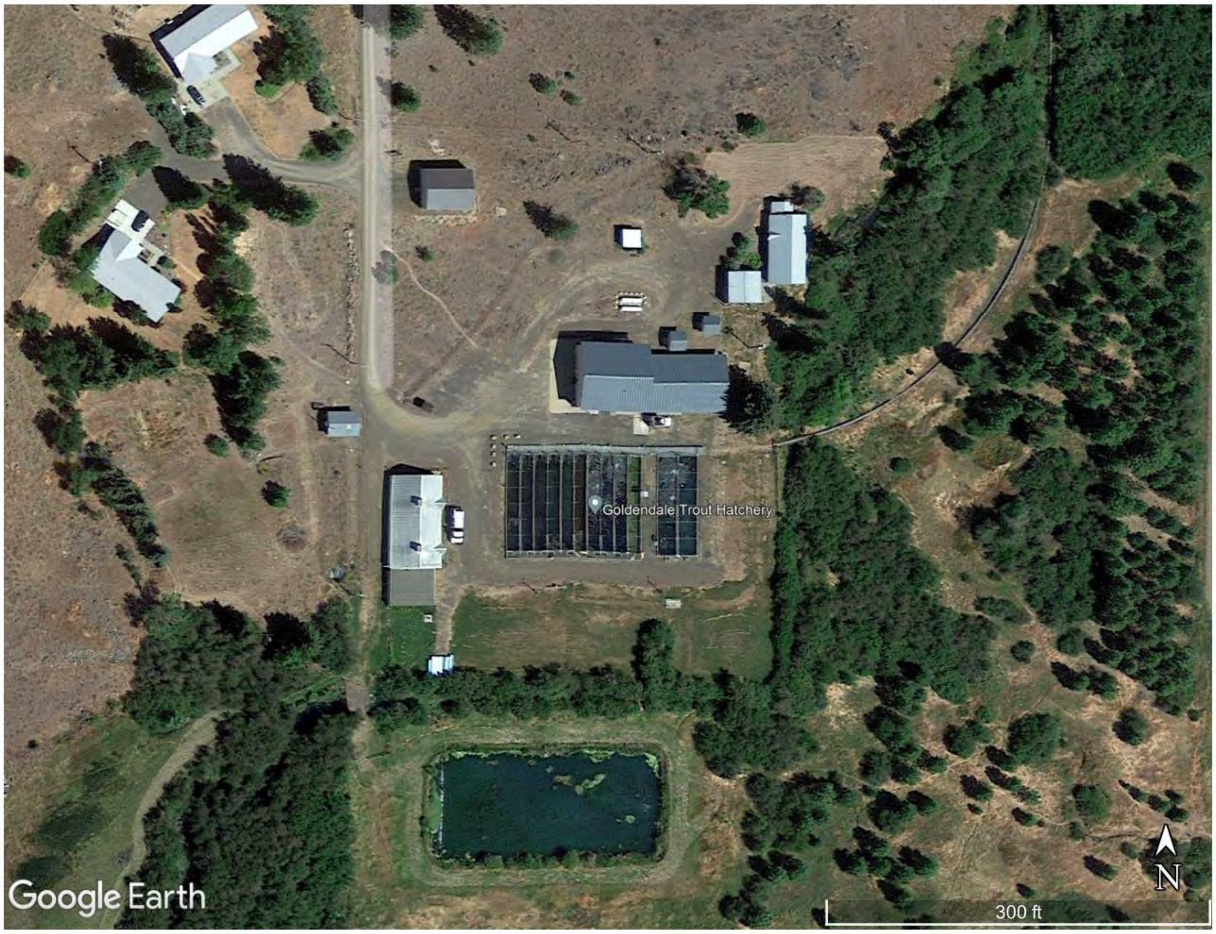

Figure 4-4. GoogleEarth view of Goldendale Hatchery.

4.5.1 Hatchery Water Supply

The hatchery has a single water source in Spring Creek (artesian spring) supplying 10 cfs. The only water treatment consists of pumping spring water to a degassing tower to remove radon gas before it enters the incubation room. The spring water supply decreases in the late fall and early spring resulting in reduced flow rates and low oxygen saturation levels, which is problematic as it aligns with the period of highest fish densities on-station. Table 4-24 shows the water availability and temperature reported by the hatchery staff for spring at the Goldendale Hatchery.

Table 4-24. Available Water Sources at Goldendale Hatchery

Water Source	Available Water Flow (cfs)	Water Temperature (ºF)
Spring Creek (artesian spring)	10	51.3

4.5.2 Hatchery Infrastructure

The intake is in good condition; the dam boards were replaced in 2019. The raceways are weathered, chipped, and have plant growth on the walls throughout the year, which makes proper cleaning and disinfection extremely difficult.

The hatchery's incubation area includes the following:

- 16 troughs with eggs incubated in metal baskets within the troughs

Fish rearing vessels at the hatchery include the following:

- 38 troughs (13.9 ft x 1 ft x.75 ft) with an operating flow rate of 10 gpm per trough
- 3 intermediate raceways (28.75 ft x 4 ft x 1.75 ft) with an operating flow of 60 gpm per raceway
- 10 concrete raceways (80 ft x 10 ft x 2.2 ft) with an operating flow rate of 380 gpm per raceway
- 2 concrete adult raceways (80 ft x 15 ft x 4 ft) with an operating flow rate of 489 gpm per raceway

4.5.3 Fish Health

The primary pathogen of concern at Goldendale Hatchery is *F. psychrophilum*, the causative agent of BCWD. Disease outbreaks typically occur during the late spring and early summer as small fry are transferred from the incubation room to the raceways. Formalin is used to treat BCWD upon veterinary approval after diagnosis.

4.5.4 Bioprogram Review

The water budget provided was not broken down by species but was a representative sample of the total flow demand for each month throughout the facility. When calculating FIs and the minimum number of rearing units required, it was assumed that each rearing unit was supplied with the maximum flow rate available to it. The target flow index is 1.0 for broodstock populations in raceways, and 1.3 for other production raceways. The target DI for all programs for the facility is 0.3.

For each species production, WDFW staff provided a number for the specific production stage's rearing tank. This is assumed to be the number of tanks used for that production effort. The existing DI was calculated based on this assumption.

4.5.4.1 Water Budget

Information about the water use at Goldendale was differentiated by production stage and rearing vessel but not by species raised. Fry production uses both troughs and intermediate raceways, which were not differentiated in the water budget. Since the water budget was variable over 2 years but did not have specific information on which program's water use changed, Table 4-25 summarizes the highest flow demand of each month within the 2-year period from which data was available. Peak flow demand occurs in April and July at 11.13 cfs, highlighted in red. The hatchery is currently exceeding its water right of 10 cfs for several months during the year (highlighted in yellow).

Table 4-25. Goldendale Hatchery Maximum Monthly Flow Demand by Production Stage

Production Stage	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Incubation Flow Demand (gpm)	14	0	0	0	0	5	0	0	0	14	77	98
Fry Flow Demand (gpm)	64	246	314	880	323	194	147	0	0	20	0	119
Juvenile Flow Demand (gpm)	3,548	3,724	3,202	3,143	3,354	3,167	3,796	2,918	3,073	3,394	3,414	3,697
Outplant/ Brood Flow Demand (gpm)	647	718	971	969	1,072	1,065	1,050	1,050	1,111	851	851	813

Production Stage	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Total Flow Demand (gpm)	4,273	4,688	4,487	4,992	4,749	4,431	4,993	3,968	4,184	4,279	4,342	4,727
Total Flow Demand (cfs)	9.53	10.46	10.00	11.13	10.59	9.88	11.13	8.85	9.33	9.54	9.68	10.54

4.5.4.2 Rainbow Trout

The Rainbow Trout program at the Goldendale Hatchery (Table 4-26) requires the most flow and rearing space of all the programs due to the captive broodstock population. Length information was not provided by WDFW staff; Piper et al. (1982) was used to estimate average length when fpp was known. The standard relationship between weight and length, calculated using the condition factor, changes as fish grow. Adult fish increase their weight in proportion to their length more quickly than young fish; that is, fish length increases at a slower rate in the adult stage even as weight increases. The length used in the bioprogramming for fish over 1 lb. may be a slight overestimate, which would lead to an underestimation of the required rearing volumes and flows. To avoid excessive underestimations, calculations assumed fish length remained the same between the 0.2 and 0.1 fpp groups. According to the raceway loading spreadsheet from WDFW staff, the target FI for the adult raceways is 1.0, all other raceways 1.3. The DI target used for this bioprogram was 0.3.

Table 4-26. Goldendale Hatchery Rainbow Trout Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Assumed Number of Rearing Units in Use	Minimum Rearing Units Required
Trough										
Fry	220,000	1.8	250	880	11	1,630	10	376	19	157
Raceway										
Juvenile	200,000	4.6	25	8,000	1,760	5,797	380	1,338	5	4
Yearling	155,000	9.9	2.5	62,000	1,760	20,875	380	2,685	10	12
Adult Raceway										
Adult	12,500	13	1	12,500	4,800	3,205	489	962	2	2
Adult	4,500	16	0.5	9,000	4,800	1,875	489	563	1	2
Adult	1,500	20.2	0.33	4,545	4,800	750	489	225	1	1

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Assumed Number of Rearing Units in Use	Minimum Rearing Units Required
Adult	4,700	23.2	0.2	23,500	4,800	3,376	489	1,013	2	3
Adult	800	23.2	0.1	8,000	4,800	1,149	489	345	2	1

It is assumed that 19 troughs are used, which provide a total rearing volume of 198.17 ft^3 and a DI of 2.46; in this case the FI would be 2.57 using all available water for the troughs (190 gpm). To maintain a DI below 0.3, 157 troughs would be required. To maintain an FI below 1.3, 38 troughs would be required, with each receiving 10 gpm of flow.

Juvenile production uses five raceways to grow fish to 4.6 inches; with a total volume of 8,800 ft^3 the DI is an estimated 0.2. If production was consolidated into four raceways each with 380 gpm for a total of 7,040 ft^3 and 1,520 gpm, the DI and FI would be 0.25 and 1.14, respectively.

Growing fish to 9.9 inches in ten raceways (17,600 ft^3 total volume) results in a DI of 0.36; assuming 308 gpm (3,080 gpm total), the FI would be 2.03. To maintain a DI below 0.3, production would require 12 raceways. Assuming each raceway was supplied with 308 gpm, this would result in a DI of 0.29 and an FI of 1.37.

For fish raised in adult raceways, data collected by WDFW showed separated size-groups in some instances: two groups of 0.2 fpp and two groups of 0.1 fpp. This is likely done at the hatchery to organize broodstock operations, but further detailed site visits and discussions with staff would be required to create a detailed program that is outside the scope of this analysis. For the existing bioprogram, groups of fish that are the same size were combined to determine the total rearing volume and flow requirements for each size-group of fish.

Once fish are transferred to the adult raceways, the required volume for each production stage is less than the available volume of a single raceway. However, flow requirements are above the 489-gpm capacity of a single raceway for the 1, 0.5, and 0.2 fpp size-groups.

4.5.4.3 Brown Trout

Approximately 22,000 eggs are incubated to produce 9,000 fish for release (Table 4-27). Fry are raised until they reach approximately 2 inches in length; they are then transferred until they reach a release size of 2.92 inches. The target DI and FI for this program are 0.3 and 1.56, respectively.

Table 4-27. Goldendale Hatchery Brown Trout Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Assumed Number of Rearing Units in Use	Minimum Rearing Units Required
Trough										
Fry	11,000	2.02	300	37	10	61	10	12	4	6
Intermediate Raceway										
Juvenile	9,000	2.92	100	90	201	103	60	20	1	1

If it is assumed that fry are raised in four troughs with a total volume of 41.72 ft^3; the DI would be 0.44. With a total flow of 40 gpm, the FI would be 0.45. Reducing flows to 3 gpm per tank or 12 gpm total, the FI would be 1.51. To maintain the target index values, six troughs would require 2 gpm each.

The DI for juveniles raised in a single intermediate raceway would be 0.16, and only 20 gpm is needed for an FI below 1.56.

4.5.4.4 Tiger Trout

The Tiger Trout program incubates 20,000 eggs to produce 10,800 fish for release (Table 4-28). Fry are grown until they reach a length of approximately 2 inches; they are then transferred and raised until they reach a release size of 2.92 inches. The target DI and FI for this program are 0.3 and 1.56, respectively.

Table 4-28. Goldendale Hatchery Tiger Trout Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Assumed Number of Rearing Units in Use	Minimum Rearing Units Required
Trough										
Fry	12,000	2.02	300	40	10	66	10	13	4	7
Intermediate Raceway										
Juvenile	10,800	2.92	100	108	201	123	60	24	1	1

Assuming four troughs are used for fry rearing for a total volume of 41.72 ft^3, the maximum DI during this stage is 0.48; only 3.25 gpm is required for each trough to maintain an FI below 1.56.

Juveniles grown in a single intermediate raceway would have a DI of 0.19; with 23.70 gpm of flow the FI would be below 1.56.

4.5.4.5 Eastern Brook Trout

Approximately 32,000 eggs are incubated to produce 17,000 fish for release (Table 4-29). Fry are transferred from troughs to raceways when they reach 300 fpp and approximately 2 inches in length. Fish are grown to a release size of 100 fpp and 2.92 inches. The target DI and FI for this program are 0.3 and 1.56, respectively.

Table 4-29. Goldendale Hatchery Eastern Brook Trout Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Assumed Number of Rearing Units in Use	Minimum Rearing Units Required
Trough										
Fry	19,000	2.02	300	63	10	105	10	20	4	10
Intermediate Raceway										
Juvenile	17,000	2.92	100	170	201	194	60	37	1	1

Assuming four troughs are used for fry rearing for a total volume of 41.72 ft^3, the maximum DI during this stage is 0.75; each trough would need 5 gpm to have an FI below 1.56.

Juveniles grown in a single intermediate raceway would have a DI of 0.29; with 37.31 gpm of flow the FI would remain below 1.56.

4.5.4.6 King Lake Cutthroat Trout

Approximately 20,000 eggs are incubated to produce a 10,000 fry at 2.25 inches (Table 4-30). The hatchery states that the final production goal is 6,800 fish at a total biomass of 250 lbs., which would be an average size of 27.2 fpp and 4.7 inches. Information on how fish are handled and transferred after the fry stage was not available. The existing bioprogram was calculated to determine required flows and volumes to meet this production. The target DI and FI for this program are 0.3 and 1.56, respectively.

Table 4-30. Goldendale Hatchery King Lake Cutthroat Trout Bioprogram

Production Stage	Number of Fish	Fish Length (in.)	Fish per Pound (fpp)	Biomass (lbs.)	Rearing Unit Volume (ft^3)	Required Volume (ft^3)	Rearing Unit Flow (gpm)	Required Flow (gpm)	Assumed Number of Rearing Units in Use	Minimum Required Rearing Units
Trough										
Fry	10,000	2.25	250	40	10	59	10	12	4	6
Intermediate Raceway										
Juvenile	6,800	4.7	27.2	250	201	177	60	34	1	1

Assuming four troughs are used for fry rearing for a total volume of 41.72 ft^3, the maximum DI during this stage is 0.43. If each trough is supplied with 3 gpm of flow, the FI would stay below the target of 1.56.

Juveniles grown in a single intermediate raceway would have a final DI of 0.27 before release and would only require 34.09 gpm of flow to maintain the target FI of 1.56.

5.0 Climate Impacts Evaluation

5.1 Climate Stressors

Each facility will be sensitive to climate change impacts in unique ways that depend on their location and operational strategies. If a proactive adaptive management approach to these issues is not adopted, WDFW can expect degradation of existing infrastructure earlier than the expected useful life, which will in turn require more investment to repair and maintain equipment while experiencing a potential reduction in fish production.

5.1.1 Water Availability

Climate impacts will include more prolonged periods of lower flows in surface waters, which in turn will limit water availability for hatchery operations. Without adaptive management, total process flow for fish culture operations will decrease and lead to conditions that favor disease, stress, and mortality. Alternatively, fish production could be reduced in response to this loss of flow, to the detriment of commercial and recreational fishing, riverine ecosystems, and southern resident orcas. Groundwater sources from wells and natural springs will be somewhat insulated against this change relative to river and creek sources. However, new well development will likely be needed to support the continued population growth of Washington State. If areas around a hatchery have an increase in new wells for domestic or agricultural use, it may negatively impact available groundwater for fish culture; this could have severe effects on Kendall Creek and Goldendale hatcheries that both rely heavily on groundwater sources.

5.1.2 Water Quality and Temperature

Increasing water temperatures is a well-known impact of climate change, and it will have far reaching implications for hatchery operations in the future. All species raised at the hatcheries are salmonids that require clean, cold water for optimal rearing conditions. Research has shown that chronic exposure over multiple days to temperatures greater than approximately 61°F for trout species and 59°F for Pacific salmon can lead to increased stress and mortality (Bear, E. et al. 2007; Carter, K. 2005, Richter, A. and Kolmes, A. 2005). In addition to deteriorating rearing conditions, increased water temperatures will alter the current growth patterns of each facility. As water temperatures increase, fish will grow more quickly and consume more oxygen and feed. In some cases, this is desirable, but compounded by uncontrolled climate change impacts such as decreased flows, this will lead to deteriorating conditions for fish. Hatcheries may experience higher density and flow indices earlier in the production cycle that can contribute to stress and subsequent disease outbreaks and may require additional rearing space for early life stages. Warmer temperatures will also lead to increased proliferation of some pathogens that cause severe mortality in fish, primarily the bacteria that cause Columnaris disease, which is already affecting wild and captive fish populations in Washington.

5.1.3 Flood Events

Effects of climate change will also include more frequent and more severe flooding events. Natural flooding disasters with severity that used to only occur every 50 years will occur more frequently and will wreak havoc on facility intake structures and filtration equipment. The excess debris carried by flood waters can block access to or irreparably damage intake structures that may lead to a reduction or complete loss of water flowing into the hatchery. Heavy silt loads can also be introduced into the water supply of a hatchery, and foul water treatment equipment, such as filtration and aeration devices. This will cause costly maintenance issues for valuable hatchery equipment and infrastructure. If equipment is not working properly or high loads of suspended solids are allowed in the process water, it will cause an increased risk of fish stress or require reductions in hatchery production.

5.1.4 Air Temperature Extremes

Increasing air temperatures may create conditions unsafe for hatchery staff to work outside for extended periods of time. Increased air temperatures and sun intensity will also transfer heat to process water in outdoor fish rearing systems; this may move rearing conditions outside of optimal ranges and potentially sunburn fish if water clarity is exceptionally high.

5.1.5 Snowpack Declines

Declining snowpack levels can have drastic effects on the overall climate experienced in a region. As temperatures increase and snowpack decreases, historically cold and dry winters become less frequent. As a result, periods with high flows due to spring melt runoffs begin to occur earlier or may disappear completely. Decreasing snowpack levels will also exacerbate the increasing temperatures in surface waters that rely on snowmelt to provide cool water for wild and hatchery run salmonids.

5.2 Climate Evaluation Methods

This section summarizes the methods and data used to estimate changes in stream flows and water temperatures at each hatchery. A more detailed discussion, including references to specific datasets, is provided in Appendix C.

5.2.1 Available Data

5.2.1.1 Projections of Future Climate and Hydrology

This study uses future hydrologic projections based on global climate model (GCM) simulations associated with the dataset known as CMIP5, which was part of the fifth assessment report of the Intergovernmental Panel on Climate Change[6]. The hydrologic changes discussed in the following sections are based on results from 10 different global climate models and two future greenhouse gas emissions scenarios (referred to as RCPs). RCP8.5, sometimes called the "business as usual" scenario, assumes little progress in reducing worldwide greenhouse gas emissions by the end of the 21st century. RCP4.5 represents a more optimistic scenario, with modest reductions in global emissions compared to current levels.

For each model and emissions scenario, simulated daily flows, air temperatures, and other variables are available for a 150-year period, encompassing a simulated historic period (1950–2005) and projections for 2006–2099. This study considers 30-year time horizons, including a contemporary (2010–2039), mid-century (2040–2069), and end-century (2070–2099) periods. Daily results from 10 climate models within each 30-year horizon provide statistically robust datasets to estimate values and changes in variables of interest.

Daily flow projections were developed from gridded model outputs covering the drainage areas of the primary surface and/or ground water sources for each hatchery. For Marblemount Hatchery, which lies at a higher elevation than the others evaluated, model projections of snowpack water storage (measured as snow water equivalent) over the Cascade River basin were also obtained.

Water temperature projections were not included in the model dataset from which flow projections were obtained. For streamflows, an approach developed by the NorWeST project (Isaak et al. 2017) was used to project August water temperatures based on projected August air temperatures and streamflow. Where available, observed water temperatures were used to determine regression parameters. For watersheds with no water temperature observations, a regional parameter determined in the NorWeST project was applied. Since August water temperatures are typically the highest of the year due to hotter weather and lower flows, this addresses an expected maximum impact on hatcheries but did not allow for evaluation of changes in high temperature durations.

For groundwater sources, no water temperature data were provided by the hatcheries. The groundwater source is assumed to be shallow groundwater. To estimate future changes in

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[6] https://www.ipcc.ch/assessment-report/ar5/

groundwater temperatures, it was assumed that shallow groundwater temperature change would track with changes in mean annual air temperature[7].

5.2.1.2 Observed Data

Observed flow and water temperature data were requested from each hatchery to characterize current conditions and recent trends, but only anecdotal information, if any, was available. External sources, listed in Table 5-1, were identified for the Cascade and Samish rivers and used to develop temperature projections (as discussed above) and for comparison with simulated historic and/or contemporary period conditions as available.

Table 5-1. Summary of Observed Data

Water Source (Hatchery)	Variable	Agency & Site ID	Time Step	Period of Record
Cascade River (Marblemount)	Flow	USGS 12182500	Daily	Oct 1928 – Oct 1979; June 2006 – present
	Water Temp		Daily	May 1952 – Sep 1973; Oct 2016 – present
Samish River (Samish)	Flow	USGS 12201500	Daily	Aug 1943 – Oct 1971; Oct 1996 – present
	Water Temp	Dept of Ecology Samish River near Burlington	30-minute	Aug 2002 – Aug 2008[(a)]
	Water Temp		Daily	June 2016 – Sep 2018
	Air Temp		30-minute	Jul 2001 – Sep 2018

[a] Summer data only, most observations in August

5.2.2 Quantitative Climate Analyses

At each hatchery location, air temperature, precipitation, flow, and water temperature projections were evaluated for the contemporary, mid-century, and end-century periods to assess the magnitude and pace of future change. Flow and water temperature projections were analyzed for the primary flow source(s) at each hatchery, listed in Table 5-2. Key metrics (listed in Table 5-3) focus on changes in streamflow volume (through the year and during critical low-flow periods), timing and magnitude of extreme flows (both floods and low flows), summer water temperature of hatchery source flows, and—for the higher elevation

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[7] E.g., https://www.ngwa.org/what-is-groundwater/About-groundwater/groundwater-temperature's-measurement-and-significance

Marblemount watershed—changes in snowpack water storage. Analysis results are summarized by hatchery in Section 5.3, with additional plots and details in Appendix C.

Table 5-2. Hatchery Main Water Sources

Hatchery	Surface Water Source(s)	Groundwater Source(s)
Marblemount	Cascade River	Local wells
Kendall Creek	Kendall Creek	Local wells
Samish	Friday Creek and Samish River	Local wells
Goldendale	N/A	Spring

Table 5-3. Climate Change Metrics

Variable	Metric (units)	Relevance to Hatchery Management
Air Temperature	Seasonal daily mean and range (°F)	Information on projected air temperature rise is important for planning worker protection.
	Monthly mean (°F)	Monthly mean temperature may highlight hot months. It also may help provide an understanding of the projected transition from snow to rain in the coldest months, which impacts the streamflow regime.
Precipitation	Seasonal mean and range (inches/day)	Information on projected precipitation helps provide an understanding of some of the projected streamflow changes.
Streamflow	Seasonal mean and range (cfs)	Informs about future water availability for the hatchery and potential competing water users.
	High-/low-flow timing	Low-flow timing informs about future water availability at different stages of fish life cycle. High-flow timing informs about risk of flood and potentially high sediment transport associated with high flows at different stages of fish life cycle.
	High-flow recurrence	Informs the hatchery how it can expect to have operational or recovery costs from high-flow occurrence.

Variable	Metric (units)	Relevance to Hatchery Management
	Low-flow recurrence	Informs the hatchery how it can expect to have production costs from low-flow occurrence
Water Temperature	August daily mean and range (°F)	August is typically the hottest month for water temperature. It is also the only month for which water temperature estimates are available for most of the hatchery sites.

In the absence of threshold values of interest communicated by any of the hatcheries, it was assumed that peak flows that historically have been surpassed every 5 years, every 10 years, and every 50 years represent meaningful high-flow thresholds of interest in terms of flood risk, sediment load, or other challenges posed by peak flows. Similarly, low-flow thresholds that have historically been reached every 5, 10, and 50 years on average were adopted as low-flow thresholds of interest in this study.

To determine the value of these flow thresholds, frequency analyses of peak flows and low flows were carried out as reported in Appendix C. The projected frequency of violating these flow thresholds is expressed in terms of projected return periods for each threshold for a given hatchery.

5.2.3 Uncertainty and Limitations

It is important to acknowledge the uncertainty associated with these and any projections of climate and hydrology. While there is a need to provide climate projections for a variety of planning purposes, such as peak flow frequency analysis and seasonal water resources availability, the underlying projections of climate change are subject to large and unquantifiable uncertainty.

The temperature, precipitation, and streamflow projections developed in this work should therefore be considered as plausible representations of the future, given the best current scientific information, and do not represent specific predictions. The actual future realizations of these variables over the rivers studied will differ from any of the projections considered here, and their differences compared to historical climate may be greater or smaller than the differences in the projections considered.

Uncertainty is also added by the application of a hydrologic model to future conditions despite qualitative changes in hydrologic processes resulting from climatic changes. In this study, the Cascade River watershed is projected to transition from a snow-dominated to a rainfall-dominated regime. Another important aspect of hydrologic model uncertainty is that low streamflows are more difficult to model accurately in hydrologic models, compared to moderate flows and even peak flows, because they depend more strongly on the properties of soils and vegetation cover. Therefore, the August low streamflow results presented in this study should be treated with additional caution.

In addition to the direct effects of projected climatic changes as simulated by the hydrologic model, there are foreseeable indirect effects that are outside the project's scope but will also modify flood risk. These include changes in sediment transport and channel geometry, and increased incidence of tree die-off due to more frequent and extensive insect infestations and hotter summers, leading to more frequent and extensive wildfires.

5.3 Climate Evaluation Results

5.3.1 Marblemount Hatchery

Projected changes in climate, hydrology, and water temperature of the Cascade River near Marblemount are characterized in this section, using the hydrologic projections and analysis methods described in Section 5.2.

5.3.1.1 Streamflow Projections

The streamflow regime of the Cascade River is projected to change as a result of warming, which will cause a transition from snow to rain, and as a result of precipitation changes. Projected changes in the average streamflow of each day of the year are shown in Figure 5-1, and changes in the streamflows distribution are shown in Figure 5-2. In each of these figures, the two scenarios of greenhouse gas emissions, RCP4.5 and RCP8.5, are shown separately, and for each scenario the results from all 10 global climate models are pooled together. Figure 5-1 and Figure 5-2 illustrate three major changes in the streamflow regime:

A. The snowmelt freshet peak, which has so far occurred mainly within the period from May to July, will shift to earlier dates (mostly April-June) before the end of the century, as seen in Figure 5-1. In the case of RCP8.5, the snowmelt peak is projected to decrease greatly.

B. Rainfall events, which so far have been rare occurrences in the November through March period, will become commonplace as seen in Figure 5-2, as temperatures rise above 32°F. This leads to streamflow peaks in the previously dry cold season.

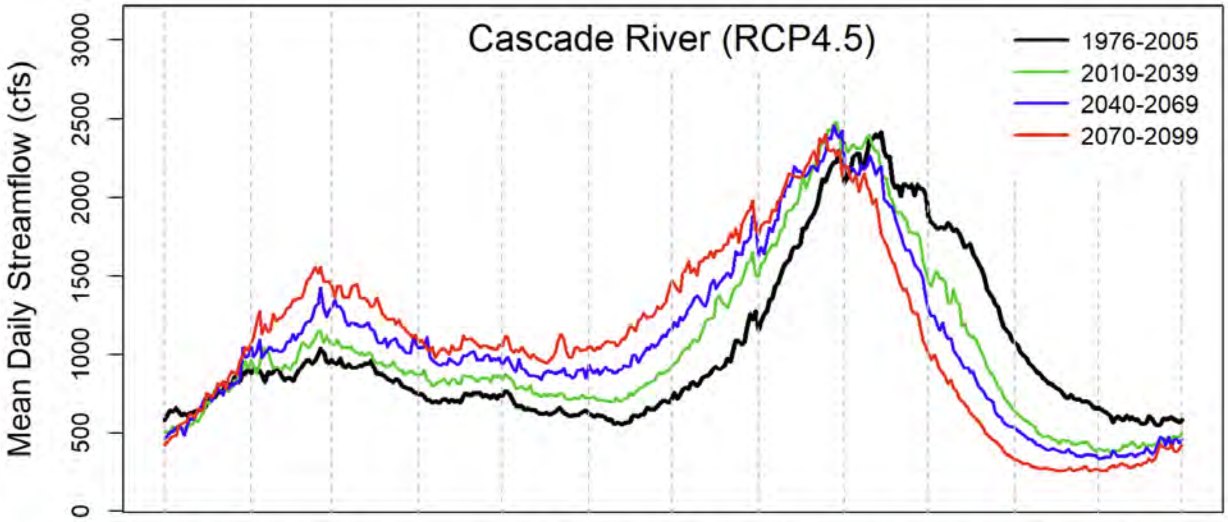
C. The late summer and fall (August through October) will become increasingly dry and experience prolonged low-flow periods, seen in Figure 5-1. In addition to the earlier melt of the smaller snowpack, summer rainfall is projected to decrease (see Appendix C).

Projected streamflow changes A and B lead to more frequent years where the annual maximum streamflow occurs outside the freshet period and is associated with a rainfall event (Figure 5-2). Projected streamflow changes A, B, and C explain why the annual minimum streamflow will occur with increased frequency in October or November rather than the historically more common January through March period.

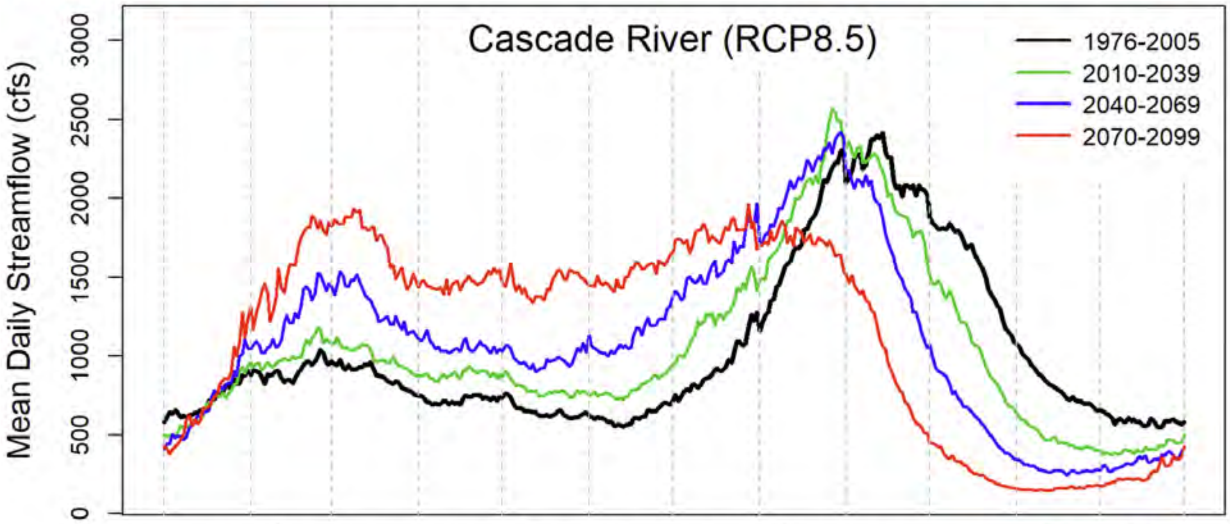
As explained in Section 5.2.2, peak flows with 5-, 10- and 50-year return periods are adopted as thresholds of interest in this project. Similarly, low-flow thresholds that have historically been reached every 5, 10, and 50 years on average are adopted as low-flow thresholds of interest.

To determine the value of these flow thresholds, frequency analyses of peak flows and low flows were carried out as reported in Appendix C. The projected frequency of violating these flow thresholds is expressed in terms of projected return periods for each threshold, given in Table 5-4 for peak flows and Table 5-5 for low flows.

The reference period 1976–2005 was chosen for being a historical period of 30 years that has the same climate and hydrology data for both RCP4.5 and RCP8.5. The flow thresholds used in these tables represent the 5-, 10-, and 50-year return period high and low flows estimated from the flow simulations for the reference period. Because the projections of the 10 GCMs are pooled together, the equivalent sample size is 300 years (10 GCMs x 30 years).

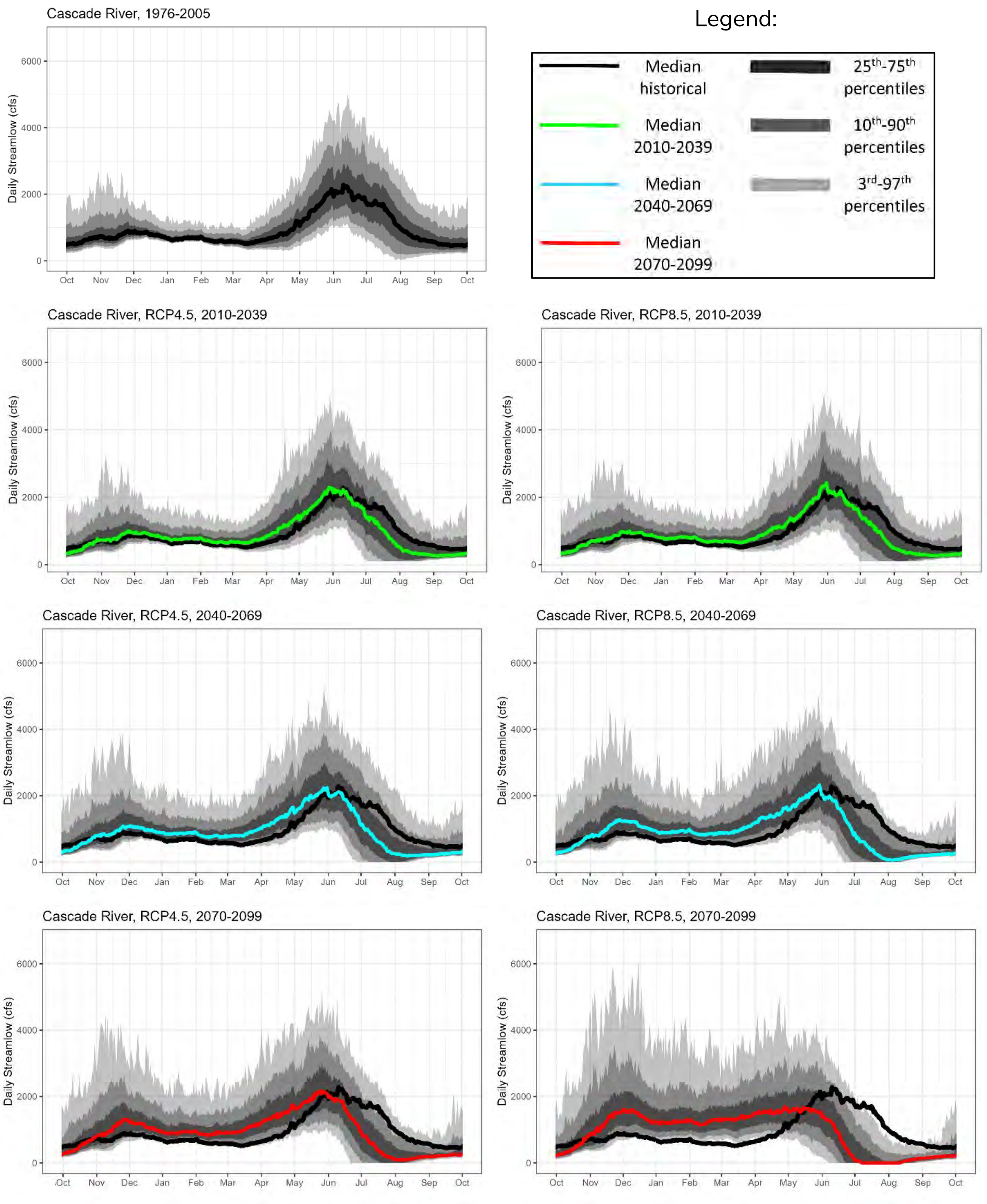


	Oct	Nov	Dec	Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sep	
1976-2005	726	915	869	725	646	620	937	1,754	2,183	1,584	814	588	cfs
2010-2039	-6%	+10%	+12%	+16%	+17%	+23%	+33%	+14%	-4%	-28%	-41%	-28%	%
2040-2069	-2%	+25%	+30%	+35%	+38%	+58%	+57%	+20%	-11%	-45%	-52%	-33%	%
2070-2099	-2%	+45%	+48%	+45%	+58%	+87%	+77%	+21%	-20%	-59%	-68%	-45%	%



	Oct	Nov	Dec	Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sep	
1976-2005	726	915	869	725	646	620	937	1,754	2,183	1,584	814	588	cfs
2010-2039	-7%	+11%	+15%	+22%	+21%	+28%	+32%	+13%	-5%	-29%	-41%	-30%	%
2040-2069	-2%	+37%	+50%	+46%	+51	+82%	+69%	+20%	-21%	-61%	-68%	-43%	%
2070-2099	-1%	+73%	+97%	+103%	+126%	+145%	+90%	-1%	-53%	-85%	-86%	-58%	%

Figure 5-1. Projected changes in the mean streamflow of each day of the year for the Cascade River. The projections use 10 GCMs to calculate these mean daily values under a low (RCP4.5) and high (RCP8.5) greenhouse gas scenario. The tables list the average monthly flows for the 2020s, 2050s and 2080s, as a percent change relative to modeled historical. Under both greenhouse gas scenarios, streamflow is projected to increase in winter and spring and decrease in summer for the Cascade River.


Cascade River, 1976-2005

Cascade River, RCP4.5, 2010-2039

Cascade River, RCP8.5, 2010-2039

Cascade River, RCP4.5, 2040-2069

Cascade River, RCP8.5, 2040-2069

Cascade River, RCP4.5, 2070-2099

Cascade River, RCP8.5, 2070-2099

Figure 5-2. Projected changes in the daily streamflow for each day of the year in the Cascade River near the hatchery. Under both greenhouse gas scenarios and all future time horizons, peak flows are projected to increase across all seasons, with the largest projected changes occurring in winter.

Table 5-4. Projected change in daily peak flow frequency for the Cascade River near Marblemount. The flow values in the header row represent the 5-, 10-, and 50-year return period daily peak flows from the historical simulations. By end of century, the peak daily flow associated with the historical 50-year event is projected to occur every 4 to 7 years.

Time Horizon	Emissions Scenario	6,600 cfs Return Period (yr)	7,500 cfs Return Period (yr)	9,700 cfs Return Period (yr)
1976–2005	Reference period	5	10	50
2010–2039	RCP4.5	3.9	6.7	22.6
	RCP8.5	3.6	6.4	23.9
2040–2069	RCP4.5	2.6	3.8	8.7
	RCP8.5	2.5	3.7	9.4
2070–2099	RCP4.5	2.2	3.1	7.1
	RCP8.5	1.7	2.2	4.1

Table 5-5. Projected change in low-flow frequency for daily streamflow for the Cascade River near Marblemount. The flow values in the header row represent the 5-, 10-, and 50-year return period low flows from historic simulations. Results suggest that the historical 50-year low flow will occur approximately every 3 to 8 years by end of century.

Time Horizon	Scenario of Greenhouse-Gas Emissions	146 cfs Return Period (yr)	131 cfs Return Period (yr)	107 cfs Return Period (yr)
1976–2005	Reference period	5	10	50
2010–2039	RCP4.5	4.3	7.5	25.9
	RCP8.5	3.7	5.9	16.4
2040–2069	RCP4.5	3.0	4.5	11.2
	RCP8.5	2.4	3.8	11.5
2070–2099	RCP4.5	2.3	3.4	8.8
	RCP8.5	1.4	1.8	3.0

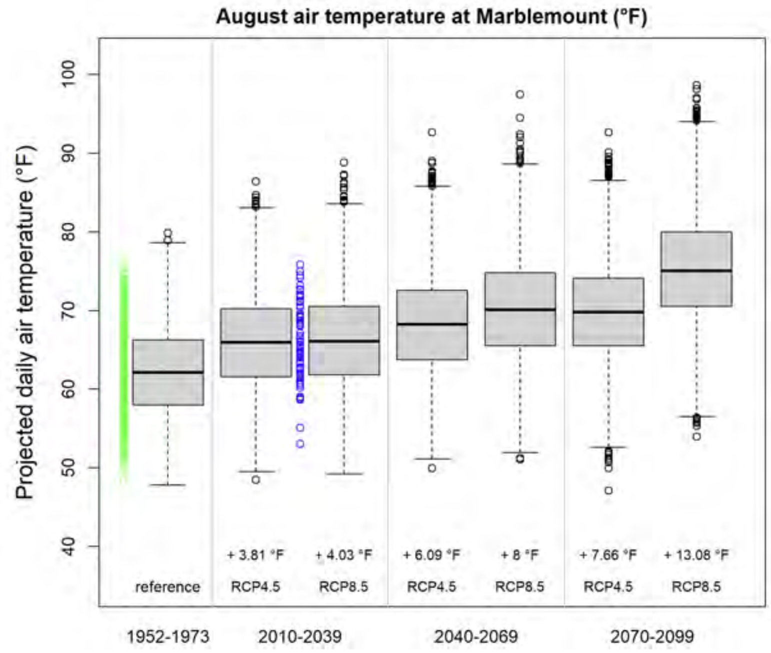
Note: Large uncertainty is associated with hydrologic-model estimates of low streamflows.

5.3.1.2 Water Temperature Projections

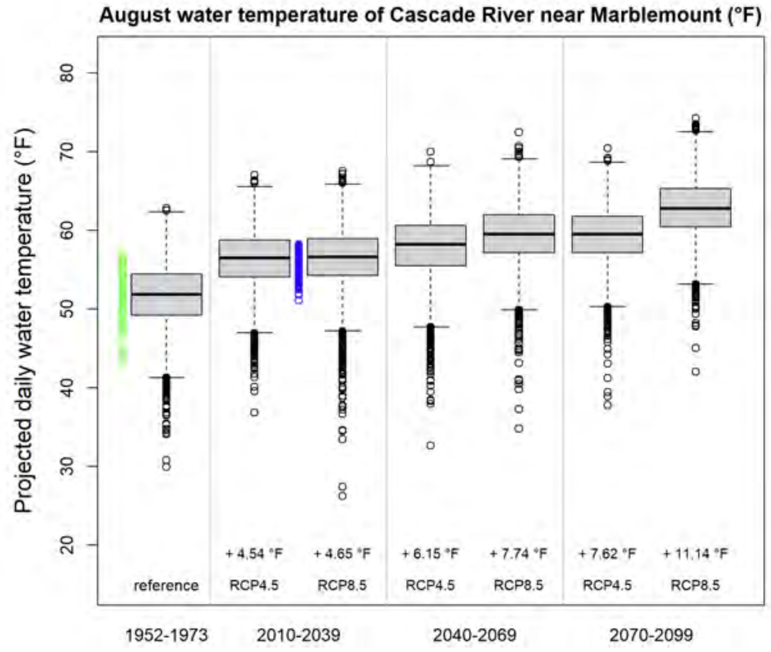
Surface Water Temperature

Figure 5-3 shows the projected distributions of air temperature (higher panel) and water temperature (lower panel) in the form of box and whisker plots for the Cascade River near Marblemount. All daily values simulated by the 10 GCMs are included. The green points in Figure 5-3 represent daily observations available for the period 1952–1973 (green points). The blue points represent more recent daily observations, which were available for 2017–2018 in the case of air temperature and 2017–2022 in the case of water temperature. The modeled projections represented by the box plots show temperature increases from the period 1952–1973 to 2010–2040 that are compatible with the limited available observations.

Mean projected changes for air temperature, streamflow, and water temperature from the contemporary period into the future are summarized in Table 5-6.



O observations in 1952–1973 O observations in 2017–2018



O observations in 1952–1973 O observations in 2017–2022

Figure 5-3. August air temperature and August water temperature at Marblemount hatchery are both projected to increase on the Cascade River near Marblemount (upper and lower panel, respectively). The boxplot represents the statistical distribution of all daily values simulated by 10 GCMs. The green points represent observations for 1952–1973 and blue points represent observations for 2017–2022.

Table 5-6. Projected changes in August mean air temperature, streamflow, and water temperature for the Cascade River. Projected values shown for contemporary period, with changes from those values for future periods.

Time Horizon	Emissions Scenario	August Air Temperature (°F)	August Stream Flow (cfs)	August Water Temperature (°F)
2010–2039	RCP4.5	66.0°F	572 cfs	56°F
	RCP8.5	66.2°F	570 cfs	56°F
2040–2069	RCP4.5	+2.3°F	-14%	+1.6°F
	RCP8.5	+4.0°F	-32%	+3.1°F
2070–2099	RCP4.5	+3.8°F	-33%	+3.1°F
	RCP8.5	+9.0°F	-58%	+6.5°F

Shallow Groundwater Temperature

As noted in Section 5.2.1, water temperatures from hatchery groundwater sources were not available. Shallow groundwater temperature change is expected to track with changes in mean annual air temperature. Projected mean annual air temperature and changes in groundwater temperature at Marblemount Hatchery are shown in Table 5-7.

Table 5-7. Projected changes in mean annual air temperature and shallow groundwater temperature at Marblemount hatchery. Projected air temperature values shown for each period, with projected change in water temperature from contemporary.

Time Horizon	Scenario of greenhouse-gas emissions	Mean Annual Air Temperature (°F)	Mean Annual Water Temperature Change (°F)
2010–2039	RCP4.5	39.2°F	n/a
	RCP8.5	39.5°F	n/a
2040–2069	RCP4.5	41.0°F	+1.8°F
	RCP8.5	42.3°F	+2.8°F
2070–2099	RCP4.5	42.1°F	+2.9°F
	RCP8.5	45.8°F	+6.3°F

5.3.1.3 Summary

Projected changes in the hydrologic regime of the Cascade River for the next few decades are significant and represent a challenge for adaptation of Marblemount Hatchery operations. Not only are minimum annual streamflows projected to decline further and August water temperature (a critical variable for the hatchery) projected to increase significantly, but the seasonality of low flows and peak flows is projected to change markedly as the watershed transitions from a snow-dominated to a rainfall-dominated hydrologic regime. Observed surface water temperatures in 2017–2022 averaged for the month of August were 3.8°F higher than in 1952–1973. This observed increase is in line with the water temperature projections presented in this study for the contemporary period.

Projected changes of main consequence to Marblemount Hatchery are summarized in Table 5-4 through Table 5-7, which inform future risk of not meeting the water quantity and water temperatures required to maintain current operations if no adaptation measures take place at the hatchery.

Other potential impacts of climate change could not be directly estimated in this study. These include heightened fire risk, increased sediment released to streams, and additional mechanisms that may contribute to further warming of stream water beyond that estimated in this study, which considered only the direct effects of the climatic and hydrologic projections. The drier and more prolonged summer dry season implies greater fire risk in the watershed and, consequently, the possibility of fall and winter peak flows amplified by the hydrophobic properties of post-fire soils. Higher peak flows will increase landslide risk and sediment transport in the Cascade River and Jordan Creek. Changes in the Cascade River watershed's riparian vegetation, resulting from climatic and hydrologic alterations and fire occurrence, may contribute to further warming of stream water. The decline of glaciers (not studied) may further contribute to reducing summer minimum flows compared to the projections in this study, and the warming of water temperatures in summer, as well as contributing to the release of sediment to streams.

5.3.2 Kendall Creek Hatchery

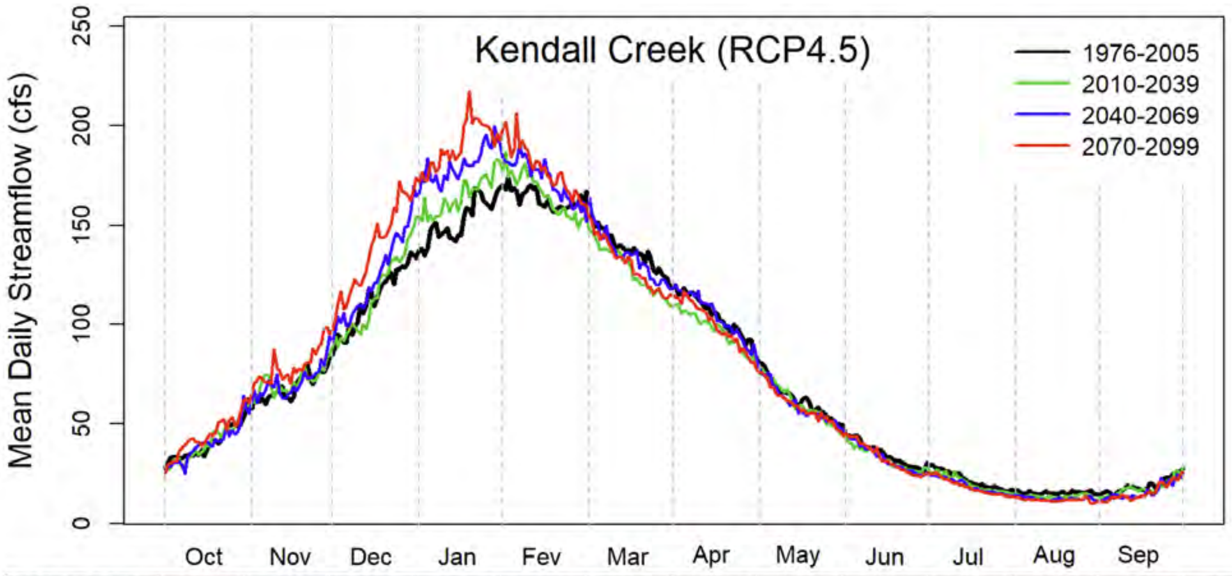
Projected changes in climate, hydrology, and water temperature of Kendall Creek near the hatchery are characterized in this section, using the hydrologic projections and analysis methods described in Section 5.2.

5.3.2.1 Streamflow Projections

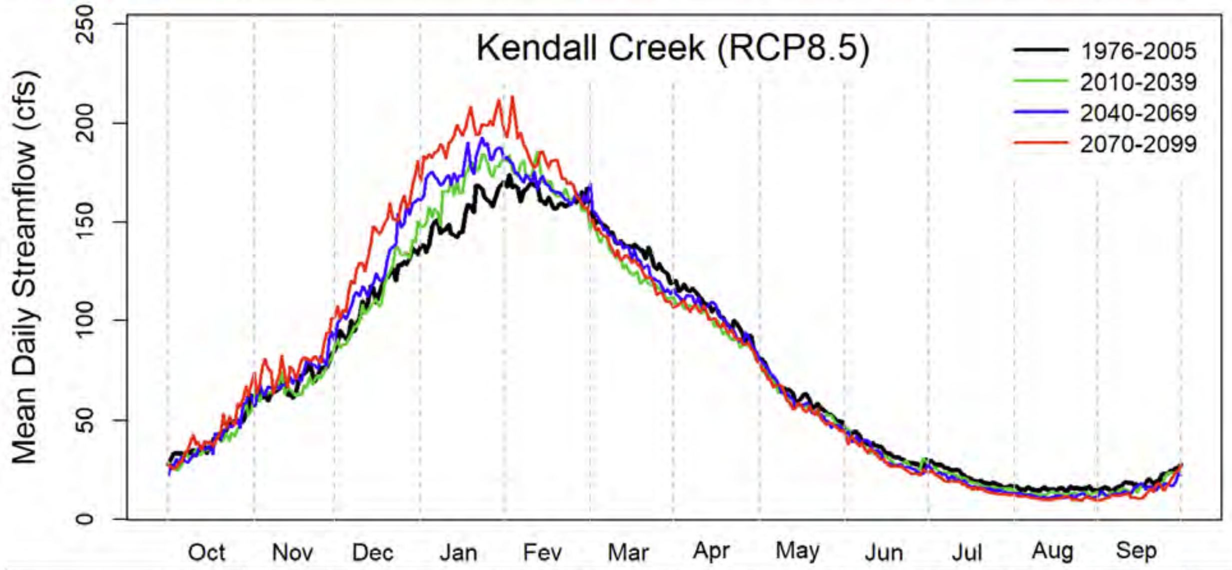
Projected changes in the average streamflow value of each day of the year are shown in Figure 5-4, and changes in the distribution of streamflows are shown in Figure 5-5. In each of these figures, the two scenarios of future greenhouse gas emissions, RCP4.5 and RCP8.5, are shown separately, and for each emissions scenario the results from all 10 global climate models are pooled together. Streamflow increases are projected for winter, but declines are projected for summer. Kendall Creek has a rain-dominated hydrologic regime but has historically received snowfall, mostly between December and March. Snowfall and snow accumulation are projected to decline (Appendix C). Summer rainfall is projected to decrease, and the warmer air will increase evapotranspiration (Appendix C).

As explained in Section 5.2.2, peak flows with 5-, 10- and 50-year return periods are adopted as thresholds of interest in this project. Similarly, low-flow thresholds that have historically been reached every 5, 10, and 50 years on average are adopted as low-flow thresholds of interest.

To determine the value of these flow thresholds, frequency analyses of peak flows and low flows were carried out as reported in Appendix C. The projected frequency of violating these flow thresholds is expressed in terms of projected return periods for each threshold, given in Table 5-8 for peak flows and Table 5-9 for low flows.



	Oct	Nov	Dec	Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sep	
1976-2005	42	70	116	154	163	137	104	62	35	22	15	19	cfs
2010-2039	-2%	+2%	+1%	+8%	+1%	-6%	-6%	-1%	-6%	-5%	-12%	-8%	%
2040-2069	-1%	+4%	+11%	+17%	+6%	-2%	≈0	-4%	-6%	-14%	-19%	-15%	%
2070-2099	+1%	+13%	+21%	+24%	+9%	-4%	-3%	-3%	-4%	-14%	-23%	-19%	%



	Oct	Nov	Dec	Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sep	
1976-2005	42	70	116	154	163	137	104	62	35	22	15	19	cfs
2010-2039	-8%	-3%	-1%	+10%	+4%	-7%	-5%	-3%	-5%	-7%	-14%	-15%	%
2040-2069	-1%	+6%	+12%	+16%	+3%	-2%	-2%	-3%	-8%	-16%	-23%	-18%	%
2070-2099	+3%	+12%	+22%	+26%	+10%	-5%	-4%	-4%	-10%	-20%	-30%	-27%	%

Figure 5-4. Projected changes in the mean streamflow of each day of the year for the Kendall Creek. The projections use 10 GCMs to calculate these mean daily values under a low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenario. The tables list the average monthly flows for the 2020s, 2050s, and 2080s, as a percent change relative to modeled historical. Under both greenhouse gas scenarios, streamflow is projected to increase sign in winter in Kendall Creek.

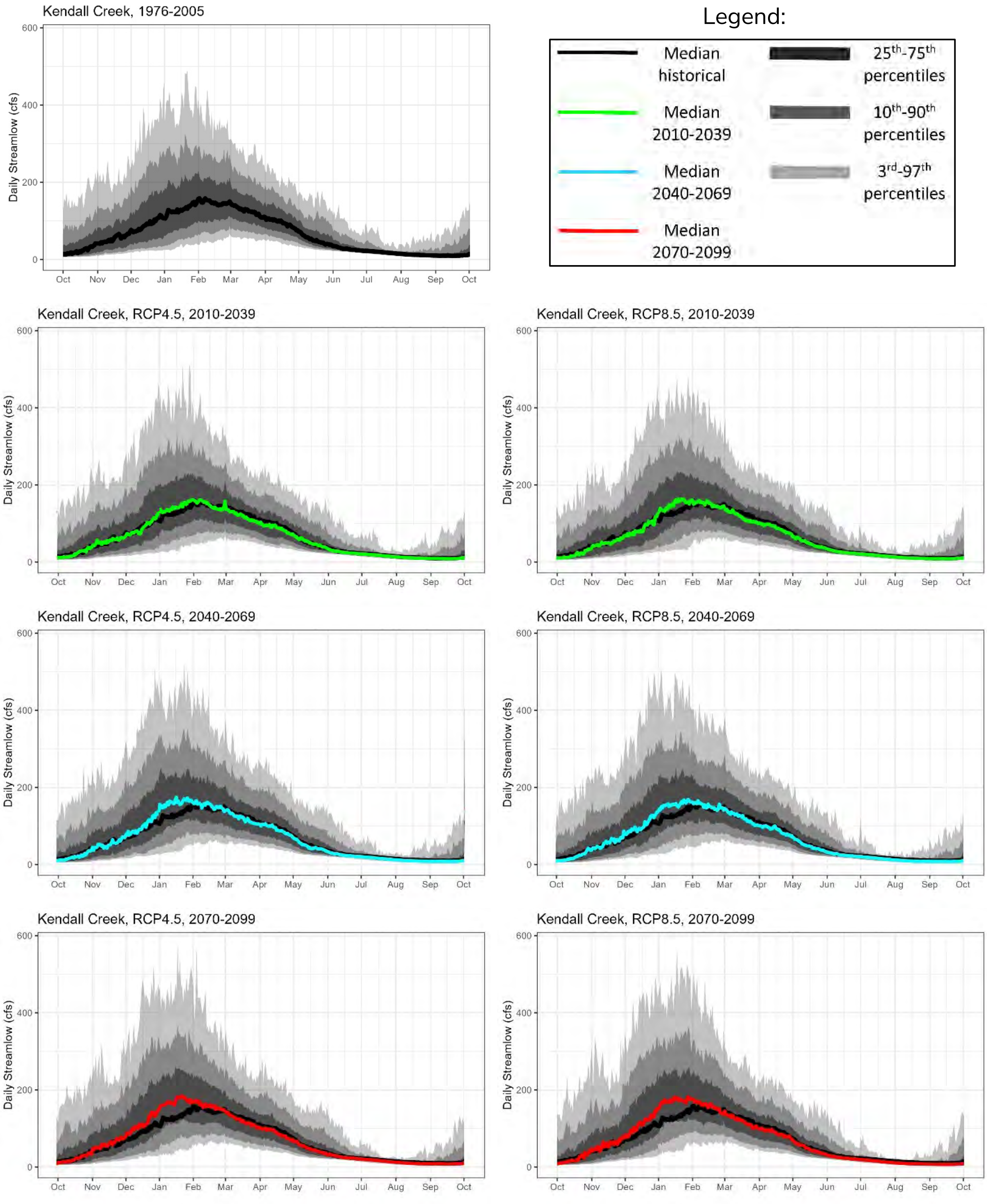


Figure 5-5. Projected change in daily streamflow for each day of the year in Kendall Creek. Under both greenhouse gas scenarios and all future time horizons, winter peak flows are projected to increase.

Table 5-8. Projected change in daily peak flow frequency for Kendall Creek near the hatchery. The flow values in the header row represent the 5-, 10-, and 50-year return period daily peak flows from the historical simulations. By the end of the century, the peak daily flow associated with the historical 50-year event is projected to occur approximately every 10 years on average.

Time Horizon	Scenario of greenhouse-gas emissions	627 cfs Return period (yr)	718 cfs Return period (yr)	905 cfs Return period (yr)
1976–2005	Reference period	5	10	50
2010–2039	RCP4.5	4	6.3	15.2
	RCP8.5	3.9	5.9	13.2
2040–2069	RCP4.5	3.6	5.5	12.7
	RCP8.5	3.3	5.2	12.7
2070–2099	RCP4.5	2.9	4.4	9.8
	RCP8.5	2.9	4.2	9.9

Table 5-9. Projected change in low-flow frequency for daily streamflow for Kendall Creek near the hatchery. The flow values in the header row represent the 5-, 10-, and 50-year return period low flows from historic simulations. Results suggest that the historical 50-year low flow will occur approximately every 5 to 7 years by end of century.

Time Horizon	Scenario of greenhouse-gas emissions	6.6 cfs Return period (yr)	6.3 cfs Return period (yr)	6.1 cfs Return period (yr)
1976–2005	Reference period	5	10	50
2010–2039	RCP4.5	3.1	4.6	9.3
	RCP8.5	3.0	5.1	11.3
2040–2069	RCP4.5	2.4	3.7	7.0
	RCP8.5	2.1	3.1	6.1
2070–2099	RCP4.5	2.2	3.4	6.8
	RCP8.5	1.8	2.7	5.0

Note: Large uncertainty is associated with hydrologic-model estimates of low streamflows.

5.3.2.2 Water Temperature Projections

Surface Water Temperature

No water temperature records were identified for Kendall Creek. However, the NorWeST scientific project offers an estimate for the average August water temperature in the time period, 1993–2011. The NorWeST August temperature estimate, equal to 56.82°F, and corresponding time period 1993–2011 serves as the base reference for the water temperature projections for Kendall Creek in this project. The same model that was used in this project for the Cascade River (Section 5.3.1.2) is used for Kendall Creek.

Daily water temperature projections for the month of August were obtained using linear regression on daily air temperature and streamflow, as described in Appendix C. In Figure 5-6, the projected distributions of air temperature (higher panel) and water temperature (lower panel) are displayed in the form of boxplots for Kendall Creek near the hatchery. All daily values simulated by the 10 GCMs are included. Projected changes in mean values are annotated under each boxplot. Mean projected changes for air temperature, streamflow, and water temperature are summarized in Table 5-10.

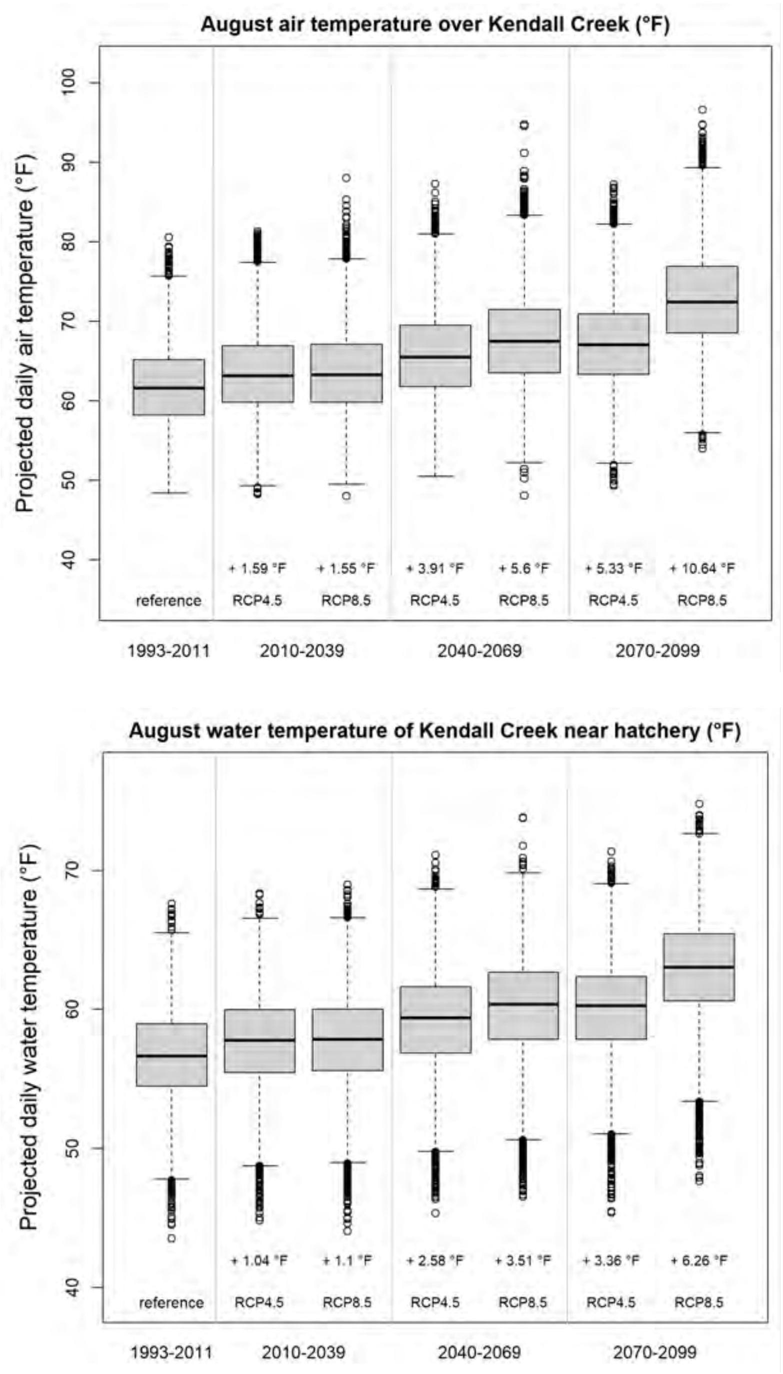


Figure 5-6. August air temperature and August water temperature at Kendall Creek are both projected to increase on the Cascade River near Marblemount (upper and lower panel, respectively). The boxplot represents the statistical distribution of all daily values simulated by 10 GCMs.

Table 5-10. Projected changes in August mean air temperature, streamflow, and water temperature for Kendall Creek. Projected values shown for contemporary period, with change from those values for future periods.

Time Horizon	Emissions Scenario	August Air Temperature (°F)	August Stream Flow (cfs)	August Water Temperature (°F)
2010–2039	RCP4.5	63.7°F	11 cfs	57.8°F
	RCP8.5	63.7°F	11 cfs	57.9°F
2040–2069	RCP4.5	+2.3°F	-9%	+1.6°F
	RCP8.5	+4.0°F	-9%	+2.4°F
2070–2099	RCP4.5	+3.7°F	-18%	+2.4°F
	RCP8.5	+9.0°F	-18%	+5.2°F

Shallow Groundwater Temperature

Kendall Creek Hatchery's groundwater sources were reported in the questionnaire to be at an approximately constant 47°F. This is not far from the mean annual air temperature of 48.9°F given for the hatchery's location for the past 5 years in the Livneh gridded modeled (but observations based) dataset available from NOAA[8]. Groundwater temperature change is also expected to rise by the same amount as mean annual air temperature. Projected changes in mean annual air temperature and groundwater temperature are given in Table 5-11.

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[8] https://psl.noaa.gov/thredds/dodsC/Datasets/livneh/metvars/

Table 5-11. Projected changes in mean annual air temperature and shallow groundwater temperature at Kendall hatchery. Projected air temperature values shown for each period, with projected change in water temperature from contemporary.

Time Horizon	Scenario of greenhouse-gas emissions	Mean Annual Air Temperature (°F)	Mean Annual Water Temperature Change (°F)
2010–2039	RCP4.5	49.2°F	47.3°F
	RCP8.5	49.6°F	47.7°F
2040–2069	RCP4.5	51.0°F	+1.8°F
	RCP8.5	52.4°F	+2.8°F
2070–2099	RCP4.5	52.2°F	+3.1°F
	RCP8.5	55.9°F	+6.3°F

5.3.2.3 Summary

Projected changes in the hydrologic regime of Kendall Creek for the next few decades are significant, stemming from intense rise of air temperatures, an increase in precipitation intensity, and decline in summer precipitation. August water temperature in Kendall Creek is projected to increase significantly (a critical variable for the hatchery) and August streamflows are projected to decline further.

Projected changes of main consequence to Kendall Creek Hatchery are summarized in Table 5-8 through Table 5-11, from which the future risk can be estimated for not meeting the water quantity and water temperatures required to maintain current operations if no adaptation measures take place at the hatchery.

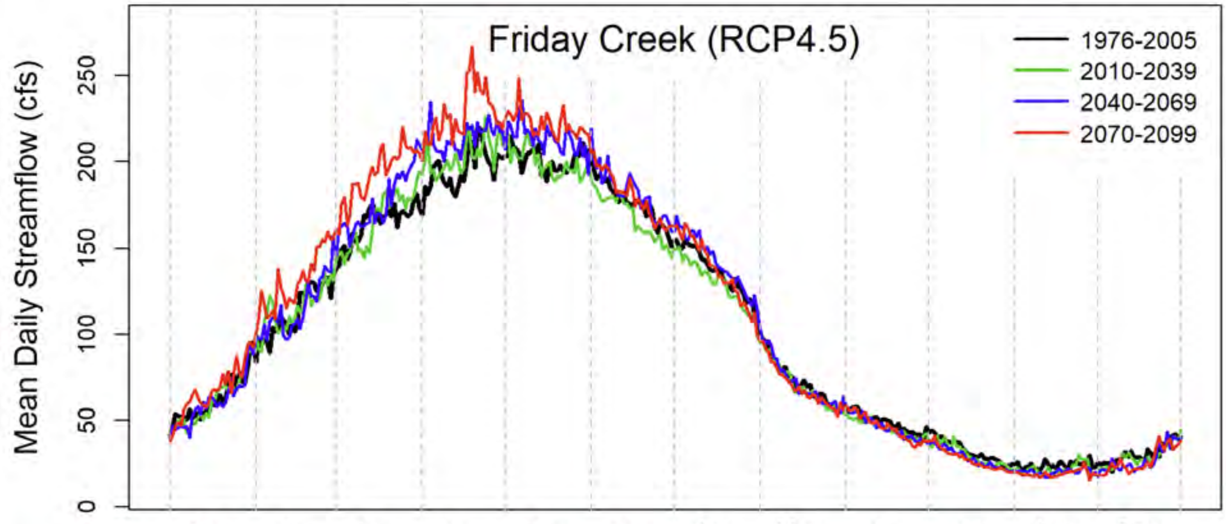
The indirect changes mentioned in this final paragraph were not analyzed in this study. These indirect changes include heightened fire risk, increased sediment released to streams as a result of the higher projected runoff peaks, and additional mechanisms that may contribute to further warming of stream water beyond the projected warming estimated in this study, which considered only the direct effects of the climatic and hydrologic projections. The drier and more prolonged summer dry season implies greater fire risk in the watershed and, consequently, the possibility of fall and winter peak flows amplified by the hydrophobic properties of post-fire soils. Higher peak flows may increase landslide risk and sediment transport in Kendall Creek. Changes in the creek's riparian vegetation, resulting from climatic and hydrologic alterations and fire occurrence, may contribute to further warming of stream water.

5.3.3 Samish Hatchery

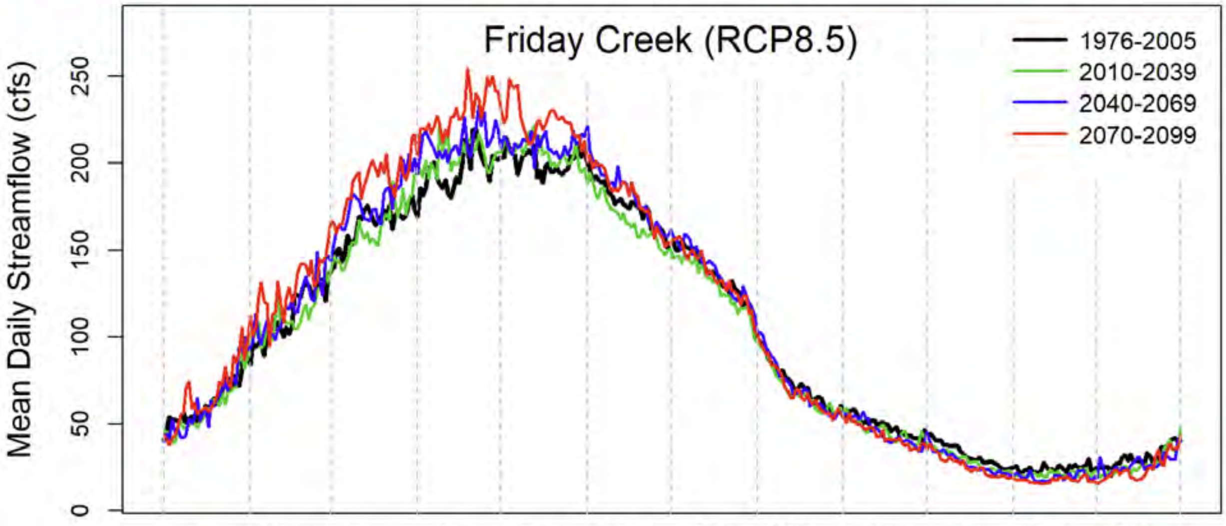
5.3.3.1 Streamflow Projections

The distributions of projected daily streamflows of Friday Creek near the hatchery are displayed in Figure 5-7, for each of the two emissions scenarios. Streamflow increases are projected for winter as a result of rainfall increases but declines in rainfall and streamflow are projected for summer. Friday Creek has a rain-dominated hydrologic regime, and snowfall and snow accumulation are projected to further decline. Summer rainfall is projected to decrease, and the warmer air will increase evapotranspiration.

Table 5-12 lists the observed and projected frequency of surpassing fixed high thresholds of daily peak streamflow of Friday Creek near the hatchery. The three thresholds were chosen because in the reference period 1976–2005 they had return periods of 5 years, 10 years, and 50 years (estimated from the hydrologic model simulations). Table 5-13 lists the observed and projected frequency of lower streamflows and the 5-year, 10-year, and 50-year minimum thresholds. Large uncertainty is associated with hydrologic-model estimates of low streamflows. The flow frequency analyses of peak flows and minimum flows are presented in Appendix C.



	Oct	Nov	Dec	Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sep	
1976-2005	64	115	166	197	201	176	136	73	49	33	24	31	cfs
2010-2039	-4%	+1%	+1%	+4%	-1%	-4%	-3%	≈0	-6%	-5%	-9%	-7%	%
2040-2069	-2%	+2%	+7%	+9%	+6%	+3%	+4%	-1%	-5%	-13%	-17%	-10%	%
2070-2099	+5%	+14%	+16%	+16%	+10%	+3%	+2%	-2%	-3%	-13%	-21%	-14%	%



	Oct	Nov	Dec	Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sep	
1976-2005	64	115	166	197	201	176	136	73	49	33	24	31	cfs
2010-2039	-7%	-2%	-2%	+4%	+3%	-4%	-3%	-2%	-5%	-9%	-12%	-13%	%
2040-2069	-1%	+4%	+8%	+8%	+5%	+4%	+2%	-1%	-7%	-15%	-20%	-12%	%
2070-2099	+3%	+11%	+14%	+17%	+12%	+4%	+1%	-1%	-10%	-19%	-28%	-21%	%

Figure 5-7. Projected changes in the mean streamflow of each day of the year for Friday Creek. The projections use 10 GCMs to calculate these mean daily values under a low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenario. The tables list the average monthly flows for the 2020s, 2050s, and 2080s, as a percent change relative to modeled historical. Under both greenhouse gas scenarios, winter streamflow is projected to increase.

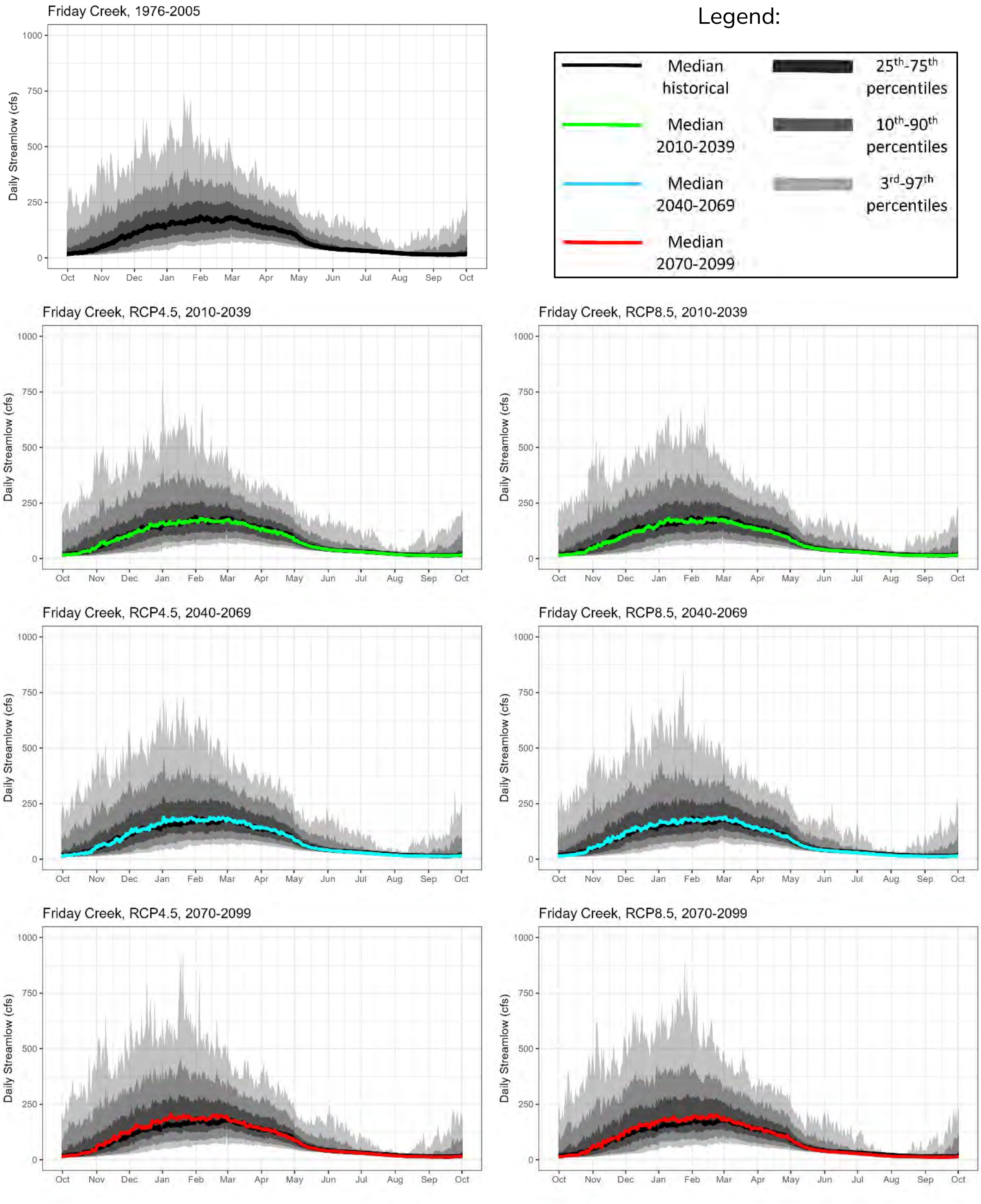


Figure 5-8. Projected change in the daily streamflow for each day of the year in the Friday Creek near the hatchery. Under both greenhouse gas scenarios and all future time horizons, peak flows are projected to increase across all seasons, with the largest projected changes occurring in winter.

Table 5-12. Projected change in daily peak flow frequency for Friday Creek near the hatchery. The flow values in the header row represent the 5-, 10-, and 50-year return period daily peak flows from the historical simulations. By the end of the century, the peak daily flow associated with the historical 50-year event is projected to occur approximately every 11 years on average.

Time Horizon	Scenario of greenhouse-gas emissions	1,150 cfs Return period (yr)	1,350 cfs Return period (yr)	1,850 cfs Return period (yr)
1976–2005	Reference period	5	10	50
2010–2039	RCP4.5	4.4	7.1	18.5
	RCP8.5	4.8	7.6	18.6
2040–2069	RCP4.5	3.9	6.4	18.0
	RCP8.5	3.4	5.3	13.3
2070–2099	RCP4.5	3.1	4.7	11.0
	RCP8.5	3.2	4.8	10.9

Table 5-13. Projected change in low-flow frequency for daily streamflow for Friday Creek near the hatchery. The flow values in the header row represent the 5-, 10-, and 50-year return period low flows from historic simulations. Results suggest that the historical 50-year low flow will occur approximately every 5 to 7 years by end of century.

Time Horizon	Scenario of greenhouse-gas emissions	11.5 cfs Return period (yr)	11.2 cfs Return period (yr)	10.9 cfs Return period (yr)
1976–2005	Reference period	5	10	50
2010–2039	RCP4.5	3.5	6.0	13.9
	RCP8.5	3.0	4.6	8.6
2040–2069	RCP4.5	2.6	3.7	6.1
	RCP8.5	2.3	3.3	5.4
2070–2099	RCP4.5	2.4	3.8	7.0
	RCP8.5	1.9	2.8	4.7

Note: Large uncertainty is associated with hydrologic-model estimates of low streamflows.

5.3.3.2 Water Temperature Projections

While no observational data was found for Friday Creek, there are daily data for water temperature, air temperature, and streamflow for Samish River near Burlington (Section 5.2.1.2).

Surface Water Temperature for Samish River

Two alternative models were fit to the Samish River data, yielding similar results for mean August water temperature, though differing in the highest water temperatures achieved (see Appendix C). As the projected air temperature increases in the future (Figure 5-9), these two models represent a range of water temperature response. Both estimates are presented in Figure 5-10 and summarized in Table 5-14.

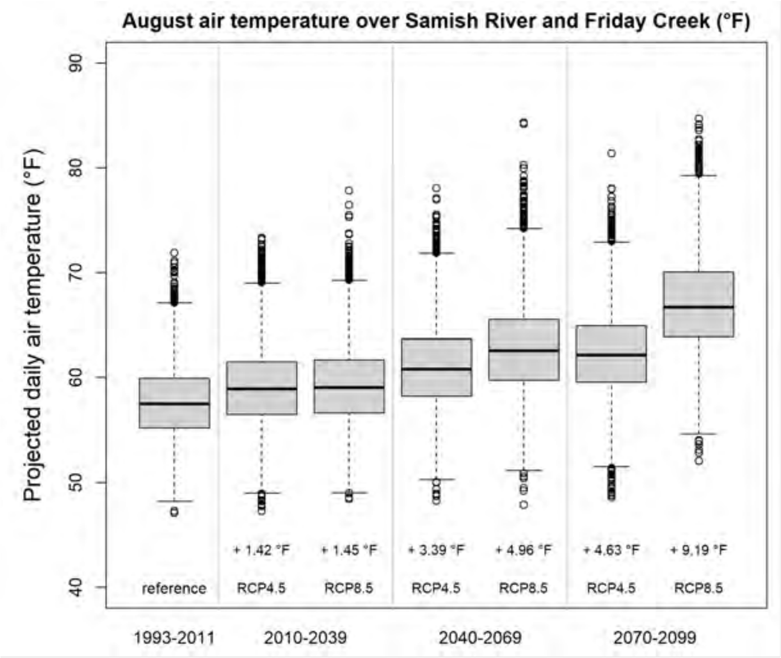
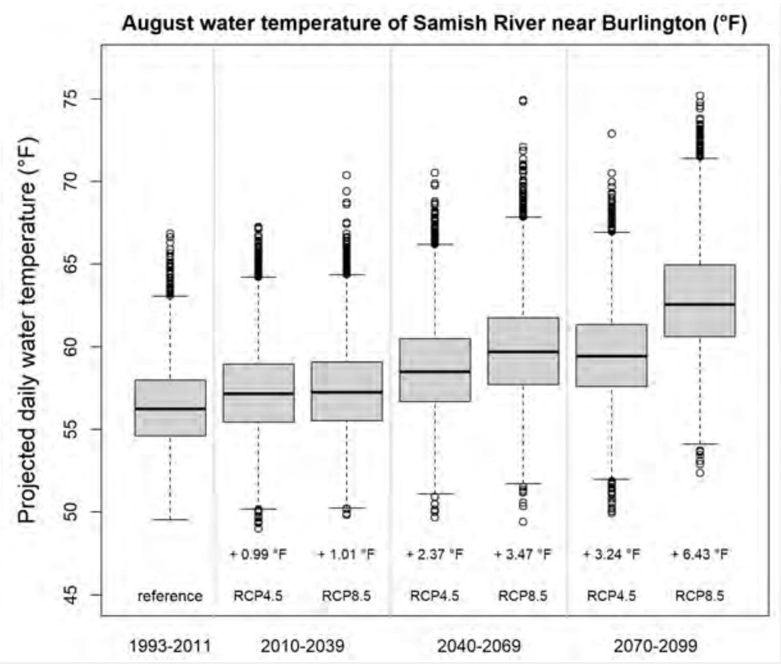


Figure 5-9. Projected August air temperature over the Samish River (including the Friday Creek tributary).

Higher Estimate



Lower Estimate

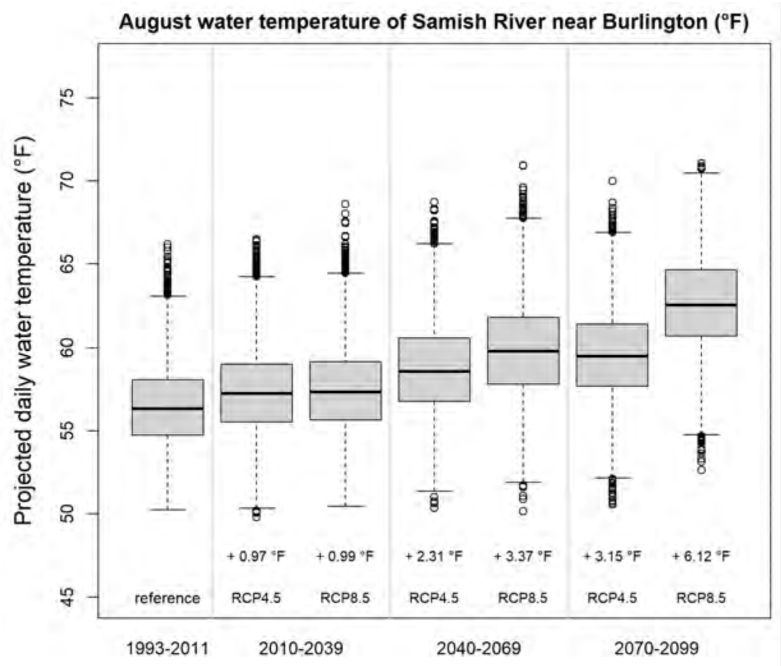


Figure 5-10. Projected August Water Temperature of the Samish River near Burlington by the Two Different Models, using Projected Air Temperature as a Predictor (shown in the preceding figure).

Table 5-14. Projected changes in August mean air temperature, streamflow, and water temperature for Samish River. Projected values shown for contemporary period, with change from those values for future periods.

Time Horizon	Emissions Scenario	August Air Temperature (°F)	August Water Temperature (°F) (Higher estimate)	August Water Temperature (°F) (Lower estimate)
2010–2039	RCP4.5	63.7°F	59.7°F	59.7°F
	RCP8.5	63.7°F	59.7°F	59.7°F
2040–2069	RCP4.5	+2.0°F	+1.4°F	+1.3°F
	RCP8.5	+3.5°F	+2.5°F	+2.4°F
2070–2099	RCP4.5	+3.2°F	+2.2°F	+2.1°F
	RCP8.5	+7.7°F	+5.4°F	+5.1°F

Surface Water Temperature for Friday Creek

No water temperature or streamflow records were identified for Friday Creek, and the water temperature model with parameters developed for Samish River (presented above) was applied to Friday Creek. The Samish River watershed at the gauge near Burlington encompasses the Friday Creek watershed. The NorWeST project (Section 5.2) offers an estimate for the average August water temperature for Friday Creek in the time period 1993–2011, equal to 59.92°F, which serves as the base reference for the creek's water temperature projections in this project.

In Figure 5-11, the projected distributions of air temperature (higher panel) and water temperature (lower panel) are displayed in the form of boxplots for Friday Creek near the hatchery. All daily values simulated by the 10 GCMs are included. Projected changes in mean values are annotated under each boxplot. Mean projected changes for air temperature, streamflow, and water temperature are summarized in Table 5-15.

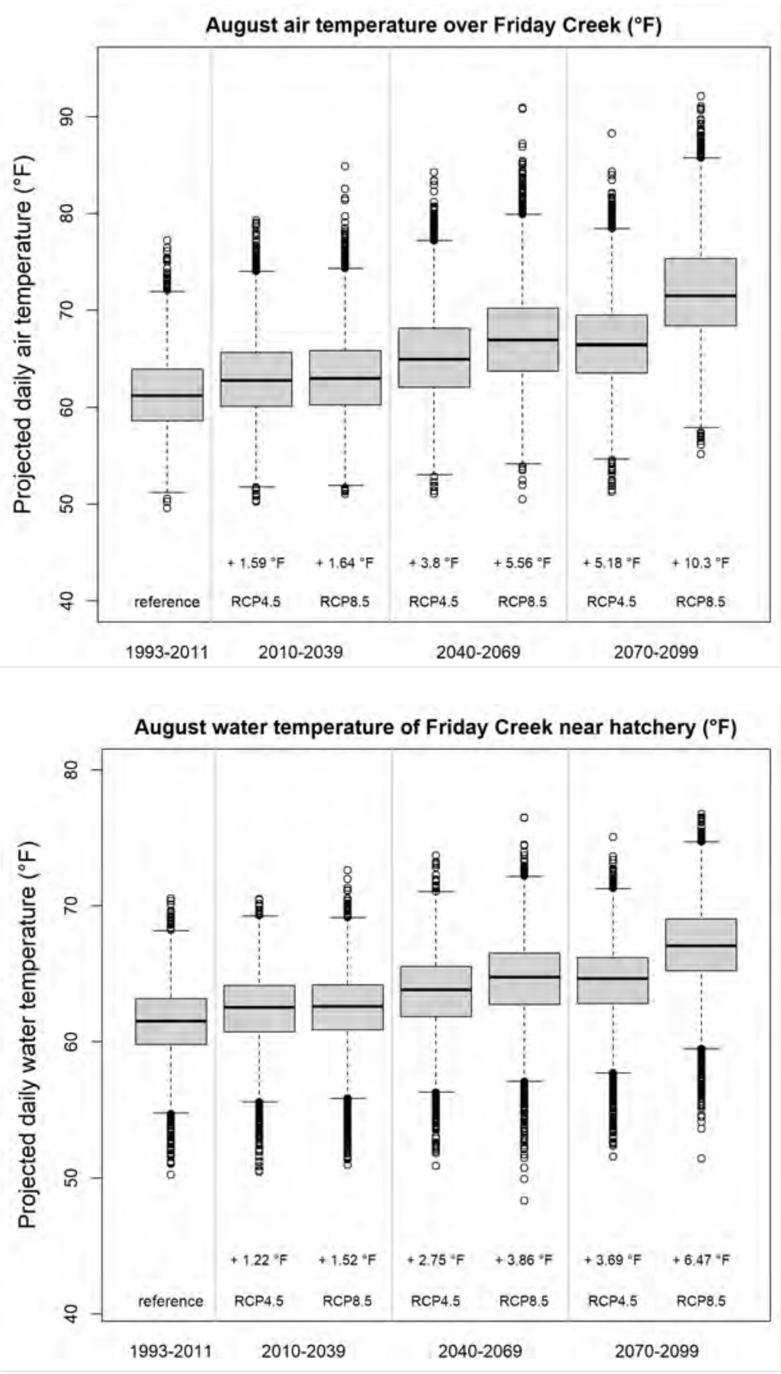


Figure 5-11. August air temperature and August water temperature at Friday Creek are both projected to increase (upper and lower panel, respectively). The boxplot represents the statistical distribution of all daily values simulated by 10 GCMs.

Table 5-15. Projected changes in August mean air temperature and water temperature for Friday Creek. Projected values shown for contemporary period, with change from those values for future periods.

Time Horizon	Emissions Scenario	August Air Temperature (°F)	August Water Temperature (°F)
2010–2039	RCP4.5	63.7°F	61.1°F
	RCP8.5	63.7°F	61.4°F
2040–2069	RCP4.5	+2.2°F	+1.6°F
	RCP8.5	+3.9°F	+2.4°F
2070–2099	RCP4.5	+3.6°F	+2.5°F
	RCP8.5	+8.5°F	+5.0°F

Shallow Groundwater Temperature

The temperature of groundwater sources in the vicinity of the Samish Hatchery is not known. In the future, groundwater temperature is expected to rise by the same amount as mean annual air temperature. Projected changes in mean annual air temperature and groundwater temperature are given in Table 5-16.

Table 5-16. Projected changes in mean annual air temperature and shallow groundwater temperature for Friday Creek. Projected air temperature values shown for each period, with projected change in water temperature from contemporary.

Time Horizon	Scenario of greenhouse-gas emissions	Mean Annual Air Temperature (°F)	Mean Annual Water Temperature Change (°F)
2010–2039	RCP4.5	52.3°F	n/a
	RCP8.5	52.7°F	n/a
2040–2069	RCP4.5	+1.8°F	+3.1°F
	RCP8.5	+2.7°F	+4.4°F
2070–2099	RCP4.5	+2.9°F	+4.2°F
	RCP8.5	+6.2°F	+7.9°F

5.3.3.3 Summary

Projected changes in the hydrologic regime of Friday Creek and Samish River for the next few decades are significant, stemming from intense rise of air temperatures, an increase in precipitation intensity, and decline in summer precipitation. August water temperature in Friday Creek is projected to increase significantly (a critical variable for the hatchery), and August streamflows are projected to decline further. Minimum flows near the hatchery, already in the recent past, have occasionally reached flows as low as 2 cfs (estimated), as reported by hatchery staff.

Projected changes of main consequence to Samish Hatchery are summarized in Table 5-12 through Table 5-16, from which the future risk can be estimated for not meeting the water quantity and water temperatures required to maintain current operations if no adaptation measures take place at the hatchery.

The indirect changes mentioned in this final paragraph were not analyzed in this study. These indirect changes include heightened fire risk, increased sediment released to streams as a result of the higher projected runoff peaks, and additional mechanisms that may contribute to further warming of stream water beyond the projected warming estimated in this study, which considered only the direct effects of the climatic and hydrologic projections. The drier and more prolonged summer dry season implies greater fire risk in the watershed and, consequently, the possibility of fall and winter peak flows amplified by the hydrophobic properties of post-fire soils. Higher peak flows may increase landslide risk and sediment transport in Friday Creek and the Samish River. Changes in the creek's riparian vegetation, resulting from climatic and hydrologic alterations and fire occurrence, may contribute to further warming of stream water.

5.3.4 Goldendale Hatchery

Quantification of the response to projected climate change of the artesian aquifer that feeds Spring Creek would require a model of this aquifer, along with the identification of its recharge zones. No such model or study was available for this project, so only the directions of change are projected in this section. The direction of change is indicated by the net surface water balance given by precipitation minus evapotranspiration, based on the hydrologic model projections for the area topographically upstream from Spring Creek. Projections of groundwater temperatures are also provided, assuming they will increase by the same amount as mean annual temperatures.

5.3.4.1 Streamflow Projections

The location of the source area or areas of recharge of the confined aquifer that discharges to Spring Creek was unavailable for this study. A wide area of upstream terrain to the north and west was estimated for extracting projections of precipitation and evapotranspiration to give an indication of the future direction of change in spring water availability. This area is shown in Figure 5-12 using a GoogleEarth view.

Figure 5-12. Area for which precipitation and evapotranspiration projections are studied in this section to represent potential groundwater recharge areas for Spring Creek.

Daily precipitation projections (shown in Appendix C) indicate increases in all seasons except the summer, which shows small declines. The upper end of the distribution of daily precipitation is projected to increase in all seasons.

In the absence of flow data or projections for Spring Creek, changes in water available at the ground surface were investigated by computing the difference of projected precipitation and evapotranspiration. While evapotranspiration is also projected to increase in response to rising temperatures, the net annual water flux (shown in Table 5-17) increases even faster. This implies a projected increase in available water for groundwater recharge.

Table 5-17. Projected changes in mean annual precipitation, evapotranspiration, and their difference over the region topographically upstream from Spring Creek.

Time Horizon	Scenario of greenhouse-gas emissions	Mean Annual Precipitation (in/yr)	Mean Annual Evapo-Transp. (ET) (in/yr)	Mean Annual Flux (Precip-ET) (in/yr)
1976–2005	Reference period	20.8	17.6	3.2
2010–2039	RCP4.5	21.3	17.7	3.6
	RCP8.5	21.1	17.7	3.5
2040–2069	RCP4.5	21.6	17.9	3.7
	RCP8.5	21.9	17.9	4.0
2070–2099	RCP4.5	22.2	18.2	4.0
	RCP8.5	22.6	18.2	4.4

Because the specific location of its artesian groundwater infiltration sources is not known, the projected change in Spring Creek streamflow cannot be quantified. However, the direction of change indicated by the projections of precipitation minus evapotranspiration over the Spring Creek area is one of future increase (Table 5-17). The increase is a projected long-term trend and, as with all projections, is uncertain. Due to the natural variability of climate and the occurrence of multi-year periods of below-average as well as periods of above-average precipitation, such as the decadal variability associated with the Pacific Decadal Oscillation, temporary declines as well as increases in spring flow may also occur in future. Also, the possible presence and addition of extraction wells could change this direction to a decline.

5.3.4.2 Groundwater Temperature Projections

The temperature of the spring water at Goldendale Hatchery was not reported in the questionnaire. In the future, groundwater temperature is expected to rise by the same amount as mean annual air temperature. Projected changes in mean annual air temperature and groundwater temperature are given in Table 5-18.

Table 5-18. Projected changes in mean annual air temperature and groundwater temperature at Goldendale hatchery. Projected changes in mean annual air temperature and (assumed shallow) groundwater temperature source for Spring Creek. Projected air temperature values shown for each period, with projected change in water temperature from contemporary.

Time Horizon	Scenario of greenhouse-gas emissions	Mean Annual Air Temperature (°F)	Mean Annual Water Temperature Change (°F)
2010–2039	RCP4.5	48.8°F	n/a
	RCP8.5	49.0°F	n/a
2040–2069	RCP4.5	+0.9°F	+0.9°F
	RCP8.5	+1.5°F	+1.5°F
2070–2099	RCP4.5	+1.4°F	+1.4°F
	RCP8.5	+3.2°F	+3.2°F

5.3.4.3 Summary

Quantifying the response to projected climate change of the artesian aquifer that feeds Spring Creek would require a model of this aquifer, along with the identification of its recharge zones. This information was not available for the project, and only the direction of change is projected in this section. The direction of change is indicated by the net surface water balance given by precipitation minus evapotranspiration, a quantity which is projected to increase on average over the potential source area identified in Figure 5-12. Even under a long-term increasing trend, temporary multi-year periods of below-average spring flow may occur due to the natural variability of climate. Extraction wells in the area can also affect aquifer storage and spring outflow.

Groundwater temperatures in the area of the hatchery are projected to increase by the same amount as mean annual temperatures. The projected air temperature increases for the Spring Creek area are notably less than for any of the other three hatcheries in this study.

6.0 Future Facility Impacts

This section considers results from the climate change impacts evaluation and introduces potential changes to fish health conditions in general and for each specific facility. The bioprogramming sections for each hatchery highlight the primary issues found in the existing bioprogram reviews and emphasize how climate change will exacerbate these shortcomings in the future.

6.1 General Impacts to Fish Health

Disease outbreaks are caused by a combination of factors that include host condition, environmental stressors, and pathogen presence. This concept of intersectionality is shown in Figure 6-1, and Snieszko (1974) popularized its application to fish health. Disease outbreaks will only occur if the host (fish) is susceptible to a virulent pathogen that is present, and the environmental conditions are right.

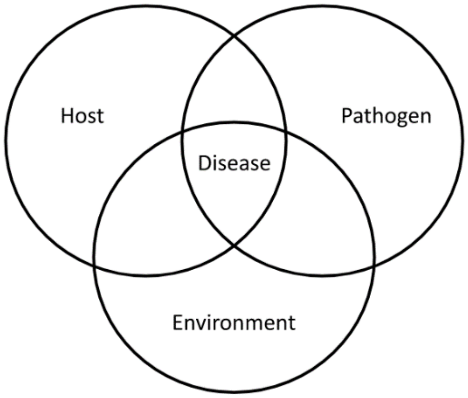


Figure 6-1. Traditional Disease Model Demonstrating the Relationships Involved in Causing Disease

Climate change will significantly alter the environment of fish and pathogens. In many cases these changes will have negative effects on fish health. When the aquatic environment shifts outside of the ideal range for a fish, it creates a stressful situation that impacts the fish's ability to resist infection and disease.

As temperatures continue to increase and exceed thresholds for fish, there will be a subsequent increase in the risk of disease outbreaks. Climate change will also lead to lower water availability and flows, negatively affecting density and flow indices, and shifting the environment toward unhealthy conditions for fish. Lower flow rates would increase the flow index and contact time between fish and pathogens because of the reduced flushing and turnover in rearing units. Climate change will also contribute to an increased frequency of peak flow events. Short periods of intense flooding are often characterized by a decrease in water quality and can lead to excessive total suspended solids (TSS) levels. Increased TSS can obstruct and damage gills, leaving fish more susceptible to parasitic and bacterial infection. Any decrease in gill function will also impact fish respiration; when combined with warming temperatures, this will require even more energy for fish to maintain a healthy physiological condition.

Climate change will also impact pathogens in the aquatic environment. Like fish, each pathogen has an ideal temperature for growth and production. Table 6-1 lists diseases present at the four facilities, as noted by hatchery staff, along with the causative pathogen and the temperature range at which the disease often occurs in salmonids.

Table 6-1. Identified Pathogens of Concern and Their Thermal Range of Disease in Salmonids

Disease	Pathogen Type	Pathogen	Ideal Temperature for Disease Outbreak	Maximum Temperature for Disease Outbreak	Reference
Bacterial kidney disease (BKD)	Bacterial	*Renibacterium salmoninarum*	46°F–59°F	68°F	Jones et al. 2007
Bacterial coldwater disease (BCWD)	Bacterial	*Flavobacterium psychrophilum*	39°F–61°F	68°F	Holt et al. 2012
Furunculosis	Bacterial	*Aeromonas salmonicida*	53.5°F–68°F	71.5°F	Dallaire-Dufresne et al. 2014
Columnaris	Bacterial	*Flavobacterium columnare*	53.5°F–68°F	>73°F	Holt et al. 1975
Infectious hematopoietic necrosis (IHN) disease	Viral	Novirhadovirus sp.	53.5°F–59°F	64.5°F	Lapatra 1998
Ichthyobodiasis (costiasis)	Parasitic	*Ichthyobodo necator or Ichthyobodo pyriformis*	50°F–77°F	>77°F	Rogers 1994

Disease	Pathogen Type	Pathogen	Ideal Temperature for Disease Outbreak	Maximum Temperature for Disease Outbreak	Reference
Ichthyopthiriasis (Ich)	Parasitic	*Ichthyophthirius multifiliis*	59°F–77°F	89.5°F	McCovey and Strange 2008

6.2 Marblemount Hatchery

6.2.1 Climate Stressors

This section describes how each climate stressor will potentially impact operations at Marblemount hatchery. A summary of the climate stressors and their impacts can be found Table 6-2.

Water availability from the Cascade River will become severely limited during the period of highest water demand and peak fish biomass at the hatchery in August and September (Figure 5-1). Currently, Jordan and Clark Creeks often run dry during this period. Past attempts to increase groundwater capacity have failed. This poses an extreme risk to operation of Marblemount throughout the year, but primarily during the summer and fall.

The average water temperature in the Cascade River may be greater than 60°F during summer months, creating a stressful environment for fish reared with surface water (Figure 5-3). Peak daily water temperatures may be near 70°F, which can cause severe mortality if fish are exposed to it for multiple days. Groundwater will be relatively insulated and may provide relief for particularly sensitive life stages (eggs and fry). However, these increases may require emergency fish evacuations and stocking efforts that could set Marblemount production back two years due to the yearling Coho program.

Flood events are projected to become more frequent and more severe; with 50-year events having between a 14% and 25% chance of occurring each year by the end of the century (7- and 4-year events respectively) (Table 5-4). These disasters can severely damage intake structures and block water conveyance to the hatchery, potentially leading to massive fish mortalities. Floods will also further degrade water quality by introducing excessive suspended particles that can severely damage fish gills.

Extreme air temperatures will have negative impacts on both the fish and hatchery staff. Peak temperatures may be more than 20°F warmer than current records and will require shading of outdoor rearing areas to keep water cool and to protect workers (Appendix C). These temperatures will likely be experienced during August, during one of the busiest periods of the facility as far as maintaining rearing areas.

Snowpack decline will be severe for the region and have cascading effects on other climate stressors including water availability, temperature, and flood events. Snowmelt runoff will occur sooner and will not be as prolonged, reducing water availability earlier in the summer months. A lack of snowmelt feeding into tributaries and rivers will exacerbate water temperature increases. Finally, as temperatures increase and precipitation shifts from snow to rain during the winter months, winter flooding will become more common and severe (Figure 5-2). These issues will severely impact the normal operations of Marblemount and will likely require a drastic shift of the production cycle and strategies throughout the year.

Table 6-2. Impact of climate stressors on Marblemount hatchery including the severity, likelihood, and overall risk to facility operations.

Climate Stressor	Severity	Likelihood of Occurrence	Risk to Operations
Water availability	Reduction of flows by more than 50% during period of highest water demand (August and September). This cannot be mitigated without substantial investment in water reuse technology and a large increase in power consumption.	Very Likely	High
Water quality and temperature	The average August temperatures in the Cascade River may be 60°F by the end of century. Peak temperatures may be above 70°F, which could be lethal to salmonid species on site. This cannot be mitigated without significant investment in water treatment equipment and large increases in power consumption.	Likely	High
Flood events	More frequent severe flood events with potential to damage intake infrastructure and degrade water quality. Can be mitigated with proper equipment and infrastructure.	Likely	Moderate
Air temperature extremes	Hottest days have a potential to increase by as much as 20°F to nearly 100°F. This will cause health and safety issues for both fish and staff but can be mitigated by relatively simple changes (shade covering, etc.).	Possible	Moderate

Climate Stressor	Severity	Likelihood of Occurrence	Risk to Operations
Snowpack declines	Will result in cascading effects on water availability, temperature, and flooding events. This will exacerbate negative effects of reduced water availability, increasing temperatures, and increased flooding events as well as drastically disrupt long-term operations of the facility. This cannot be mitigated.	Very Likely	High

6.2.2 Fish Health Impacts

Presently, BKD is seen in yearling Chinook and Coho salmon during the late spring and early summer. These outbreaks could increase in severity and appear earlier in the production cycle because of climate change impacts. Warming temperatures increase the growth rate of the bacteria, increasing bacterial load in the environment and infectivity. Increased growth rates of the fish will result in higher rearing density earlier in the production cycle, so densities and temperatures that spark disease may occur earlier in the winter or fall.

Instances of BCWD may decrease due to climate change since this bacterial disease typically occurs and is most effective between 44.5°–50°F (Piper et al. 1982). The causative bacteria do not typically cause severe disease at temperatures above 60.5°F. In general, fish are most susceptible at early life stages since their immune systems develop with age. In this circumstance with increasing water temperatures, BCWD may be less prevalent if water temperatures increase past the threshold of tolerance for the bacteria that causes the disease, during stressful events such as increased densities or transfer and handling activities.

Potential impacts to IHNV prevalence at Marblemount Hatchery are complex due to variety of virus types and IHNV distribution in wild populations along the West Coast. Disease most often occurs at 59°F. This temperature may occur more regularly in surface water sources in the future. Wild fish present in the Skagit and Cascade rivers will likely be in worse health due to compounding impacts of climate change. Subsequently, they may have higher viral loads and shedding rates, which could impact hatchery fish where surface water is used and not disinfected.

Warming water temperatures will likely increase instances of both furunculosis and columnaris disease in the returning spring Chinook adults. Both diseases increase in severity as water temperature increases (Table 6-1). The overall health impacts described in Section 6.1 will affect returning adults in addition to the stress of upstream migration and spawning. In the future, these fish will likely enter the hatchery in poorer condition and be more susceptible to disease outbreaks than they are currently. General health impacts caused by climate change will create a more suitable host for infection of the external parasites found at Marblemount Hatchery, leaving all life stages more susceptible to infection from other pathogens that have the potential to cause severe mortality.

6.2.3 Bioprogramming

Marblemount Fish Hatchery in future years will likely be faced with increasing water temperatures, less surface water availability, and major changes to the seasonality of surface water flows. These factors can lead to worsening fish health issues and are coupled with rearing space limitations that need to be addressed to meet hatchery production goals. The specific impacts to returning adult salmon due to changes in hydrologic regime from snow- to rain-dominated are not fully understood in this analysis, but incorporating operational flexibility into designs will be important to create hatcheries resilient to climate change impacts.

The current well production is less than half of the total water rights for the facility (10 cfs). Redevelopment would provide flexibility and a safety factor in operations, particularly as the Chum Salmon program continues to grow. The extra well water could also be used to temper surface water in other areas of the hatchery as surface water temperatures increase more rapidly than those of groundwater sources. The facility is currently limited by available rearing space for early life stages, particularly Chinook fry. Spring Chinook Salmon production requires 39 troughs to maintain a DI of 0.2, and only 16 troughs exist. As such, this program is limited by available rearing space, especially considering that use of these troughs overlaps with the summer Chinook production in February. It is assumed that the hatchery currently staggers transfers of fry into these troughs as eggs hatch and juveniles are transferred to raceways. There is enough groundwater available for Chinook Salmon fry production from December to March right now, but increasing well production to take advantage of the full water rights will provide a much-needed factor of safety as water temperatures continue to increase in the future.

Marblemount's production will continue to increase as it fully incorporates the Chum Salmon production goals. According to the HGMP for the Chum Salmon program, density requirements for fish prior to release are 0.35 lbs/ft^3 and 3 lbs/gpm. The theoretical maximum biomass for this program is 6,250 lbs, which would require a minimum volume of 17,858 ft^3 and minimum flow rate of 2,084 gpm. The volume requirement could be accomplished by using six raceways or one channel pond; the flow criteria would require seven raceways or two channel ponds. Incorporating water reuse for a small fraction of a channel pond's supply, 44 gpm, the flow would be sufficient for the target criteria (2,040 gpm + 44 gpm = 2,084 gpm total). However, this production would overlap with the Chinook and Coho programs that currently use the available channel ponds. From March through May, when Chum Salmon are on the station, there are a maximum of 10 raceways used by the Chinook, Coho, and Rainbow Trout programs. With 24 available, there are enough existing raceways for the Chum Salmon program requirement of seven. However, early life stages of Chum Salmon will require more troughs, 52, than are currently available. This production will also overlap with the summer Chinook Salmon production, further constraining rearing space.

Additional rearing units that can easily incorporate recirculation technology—such as round, Cornell-style tanks with double drains—will provide much needed rearing space for fry production of overlapping species. Adoption of partial reuse systems with additional equipment for chilling water may be needed in the future to accommodate some species as water temperature increases over the next century, as predicted by NHC's modeling results. Additionally, this would allow other equipment, such as microscreen drum filters and UV sterilization, to be utilized in a cost effective and efficient manner to provide biosecurity and water quality parameters more appropriate for the various species cultured at Marblemount Fish Hatchery.

6.3 Kendall Creek Hatchery

6.3.1 Climate Stressors

This section describes how each climate stressor will potentially impact operations at Kendall Creek hatchery. A summary of the climate stressors and their impacts can be found in Table 6-3.

Kendall Creek heavily relies on groundwater for its operation with some supplementation from Kendall Creek. Peak water demand occurs in February and March (Table 4-11); the average streamflow in Kendall Creek is not expected to change drastically during this period, with the most pessimistic projections showing a decrease from 137 to 131 cfs (Figure 5-4). The most drastic reductions in average surface water availability will occur from July through September (Figure 5-4). It is difficult to determine the directional change of groundwater availability as annual precipitation is projected to increase slightly, which could improve groundwater availability, but it is expected that other water users (agricultural and domestic) will increase demand and potentially reduce availability. More detailed studies on the water table used by Kendal Creek hatchery should be performed to determine the ability of existing wells to provide consistent water into the future.

Groundwater temperatures are projected to increase between 3.1° and 6.3°F to final temperatures of 50.3° and 54°F by the end of the century (Table 5-11); this would maintain an optimal temperature range for all species raised at the hatchery. For Kendall Creek, the projected daily water temperature in August will increase above 60°F by the end of the century, and as high as 63°F for the more pessimistic RCP8.5 scenario (Table 5-10); these temperatures would be outside of the optimal range for salmonid rearing and potentially lead to a higher risk of stress, disease, and mortality. If peak temperatures increase near 70°F, which is possible based on projections (Figure 5-6), it will require the facility to use large amounts of groundwater or chill a small sidestream flow to temper water and bring it within a safe range for fish. If no action is taken, it may trigger emergency fish stocking and evacuation efforts. Chilling the water requires high operational costs but may be required in the future.

Flood events that surpass what is currently a 50-year event will have a 10% chance of occurring each year, becoming 10-year events, by the end of the century (Table 5-8). This is not as drastic of a shift as Marblemount will experience but will still impact hatchery operations. It is especially concerning given the fact that flooding in Kendall Creek can be erratic, with rapidly changing water levels. This issue is compounded by the fact that production of some wells at Kendall Creek is dependent on the river level, and past storms have collapsed primary production wells. More common flood occurrences and increasing severity of those floods will likely impact both the surface and groundwater sources used by the hatchery.

Monthly average air temperatures in August are projected to increase between 3.7° and 9.0°F to 67.4° and 72.7°F for the two climate scenarios analyzed (Table 5-10). The hottest summer days may be as much as 18°F warmer than currently observed records, which would surpass 95°F (Appendix C). Measures to maintain worker safety during these heat waves are necessary, as well as mitigation for sensitive life stages of fish onsite. Of great concern is the handling and processing of spring Chinook during August when these heat waves will likely occur. This effort is labor intensive for staff and stressful for fish, severe heat waves will pose a risk for the safety of all involved.

Kendall Creek is already located in a rain-dominated hydrologic region, and therefore will not experience the drastic shifts that Marblemount will. However, snowfall and snow accumulation are projected to decrease and be restricted primarily from mid-December to mid-February, with instances of spring snowfall disappearing. This is not likely to pose a significant risk to hatchery operations.

Table 6-3. Impact of climate stressors on Kendall Creek hatchery including the severity, likelihood, and overall risk to facility operations.

Climate Stressor	Severity	Likelihood of Occurrence	Risk to Operations
Water availability	Kendall Creek flows during periods of high-water demand will decrease slightly. More detailed groundwater studies are required to quantify the loss of availability.	Possible	Moderate
Water quality and temperature	Increases in groundwater temperature are not expected to negatively impact fish. Increases in surface water temperatures will lead to stressful and potentially lethal conditions for fish if it is not tempered or chilled.	Likely	High
Flood events	Severity and frequency of floods will increase. This has the potential of impacting both surface and groundwater source availability.	Likely	High
Air temperature extremes	Severe heat waves, with temperatures projected to be as much as 18°F higher than current records, will likely occur during the spring Chinook egg-take effort. This will pose great risk to the fish and workers during this period.	Possible	High
Snowpack declines	Snowfall and snow accumulation will decline. The facility already experiences a rain-dominated regime and will not be significantly impacted.	Likely	Low

6.3.2 Fish Health Impacts

Maintenance of good biosecurity management and limiting fish handling has been successful at preventing severe disease outbreaks to date. However, climate change impacts will make fish more susceptible to diseases even with exceptional husbandry practices. If water temperatures warm and fish grow faster, they could reach critical densities prone to BCWD outbreaks sooner. Warmer temperatures will also cause disease outbreaks to move more quickly through populations, so long as it remains below the maximum temperature threshold for the pathogen. The current practice of catching and treating BCWD early may be effective, but overall losses could increase because of the increased pace of the infection and the growth of the fish. BKD is not a major concern presently, but increased water temperatures and decreasing flows are likely to stress the fish and provide more opportunities for infection and disease throughout the facility.

6.3.3 Bioprogramming

Based on the NHC modeling and projected changes in the hydrologic regime of Kendall Creek, coupled with sub-optimal density and flow indexes for the various species and life stages cultured, it is imperative that the hatchery explore alternatives to mitigate these issues to continue to reach production goals.

Based on review of the provided information, it appears that using the full capacity of available wells and water rights, groundwater flows of 33.53 cfs are feasible. This increase, from the currently available 14.48 cfs, would provide much needed water with a better temperature profile for many of the species reared at the hatchery. Surface water use from Kendall Creek can also be increased to maximize the available water for the hatchery during periods of increased water demand. This will be important to maintain water quality as impacts from climate change continue to alter water availability and temperature. Currently, both Coho Salmon programs and the fall Chum Salmon program have FIs above the target threshold. Increasing water availability will result in a higher quality rearing environment for these fish.

It appears that for many species reared at the hatchery, there is a lack of rearing space and enough water to maintain DIs and FIs in the optimal ranges throughout the rearing cycles. A specific concern is the ability to maintain target densities outlined in the HGMP (0.35 lbs/ft^3 and 3 lbs/gpm) for Coho Salmon production. Currently, production does not meet the DI and FI criteria provided by hatchery staff or the HGMP criteria. The ending biomass for 5.5-inch fish is 29,412 lbs; assuming they are held in two “super” raceways (23,130 ft^3 total volume) based on the total flow of 1,500 gpm, the ending density would be 1.27 lbs/ft^3 and 19.6 lbs/gpm. To maintain density criteria, pre-release fish must be held in 84,034 ft^3 of rearing space, requiring eight “super” raceways or two asphalt ponds. The required flow rate would be 9,804 gpm. Using all three “super” raceways would provide 3,600 gpm at a maximum, and using two asphalt ponds results in a maximum flow rate of 3,000 gpm. Further discussions with staff are required to develop a detailed bioprogram that can meet HGMP density criteria without sacrificing other species production.

Early life stage rearing is limited by available space when using the fiberglass shallow troughs. Some troughs are used for incubation of kokanee, steelhead, Rainbow, Brown, and Cutthroat trout, and some are used for rearing kokanee, steelhead, and Cutthroat Trout fry. Winter steelhead is the largest of these production programs and detailed information on how the hatchery staggers hatching and fry rearing was not available. According to the bioprogram information provided, steelhead would require 42 troughs to meet DI requirements, while kokanee and Cutthroat Trout would require 23 and 22 troughs each. These programs overlap production in March, which would require 86 total troughs. Current flows can maintain target FI levels.

Developing more early life stage rearing space would help the hatchery maintain its production goals during the period of overlapping production. To meet the volume and flow demands required for hatchery production goals, the hatchery should consider installing early life stage rearing units capable of incorporating water recirculation. These include circular, Cornell-style tanks with double drains that can use water more efficiently in partial recirculation systems. The use of partial reuse systems with additional equipment for cooling water and providing higher levels of oxygen with equipment may be needed to accommodate some species as the incoming water temperature increases over the next century as forecasted by NHC. Additionally, this would allow other equipment such as microscreen drum filters and UV sterilization to be utilized in a cost effective and efficient manner to provide biosecurity and water quality parameters more in line with the various species that are cultured at Kendall Creek Fish Hatchery.

6.4 Samish Hatchery

6.4.1 Climate Stressors

This section describes how each climate stressor will potentially impact operations at Samish hatchery. A summary of the climate stressors and their impacts can be found in Table 6-4.

The primary water source for the Samish hatchery is Friday Creek, while the adult holding ponds and fish ladder are supplied by the Samish River. Water demand for the hatchery is concentrated between February and May, and peaks during March and April (Table 4-22). Average monthly streamflow in Friday Creek is not projected to decrease during this period but will decrease significantly from June through September (Figure 5-7). Groundwater is not currently used for fish culture purposes at Samish or the adult holding ponds, determining feasibility and availability of groundwater should be a priority if WDFW is committed to raising fish at these sites in the future.

Significant increases in Friday Creek water temperatures will occur in August, with average daily temperatures near 65°F (Figure 5-11), which is beyond the optimal temperature maximum for salmon and will cause extreme stress and likely high mortality. Fortunately, all fish are released from the hatchery in May, which will experience some warming in Friday Creek but not as severe as the later summer months. Unfortunately, this means that the

Samish hatchery is a poor site to develop extended growth programs or other culture operations that would require year-round use of the facility. The current average August water temperatures of the Samish River are approximately 59°F; by the end of the century this will increase between 2.1° and 5.5°F to final temperatures of 61.8° and 65.1°F (Table 5-14). This will pose a serious risk of stress and mortality for adult Chinook salmon returning to spawn in September and October. Incorporating use of groundwater or mechanical chillers to temper adult holding ponds may become a necessity in the future.

Flood events that normally have a 2% probability of occurring in each year (50-year events) are more than four times as likely (9% probability, or 11-year events) to occur each year in Friday Creek by the end of the century (Table 5-12). High-flow events are more likely to increase in the months that the hatchery is in operation and will pose a moderate risk to hatchery production. It is vital that the Friday Creek intake is repaired and that there is safe, reliable access to it for staff and equipment as increased flooding will lead to increased needs for maintenance.

Extreme increases in the hottest days on record are likely to occur for the Samish hatchery, with the hottest days possibly being 20°F warmer than those currently experienced (Appendix C). This could lead to days nearing 100°F from June through August and present a risk to worker safety. Fortunately, these extremes will likely occur when no fish are on station. Workers will be able to take precautions and limit working outside in the extreme heat without concern for maintaining fish on-site. It is still possible that extremely warm days will be experienced in September which will be an issue for both workers and the fish returning to the adult ponds. Handling adult broodstock salmon is physically demanding, ensuring that there are safe, cool areas for staff to recover in will be necessary. Reducing handling and increasing the quality of recovery tanks and rearing areas for the fish will be vital to reduce pre-spawn mortalities.

The Samish hatchery is situated in a rain-dominated hydrologic regime currently. Snowfall and snow accumulation that typically occurs from January to March will decrease. This is not likely to drastically impact hatchery operations.

Table 6-4. Impact of climate stressors on Samish hatchery including the severity, likelihood, and overall risk to facility operations.

Climate Stressor	Severity	Likelihood of Occurrence	Risk to Operations
Water availability	Due to limited operations of the facility, decreases in water availability will not impact current operational schedule but will limit possibility of future expansion.	Likely	Low
Water quality and temperature	Increasing water temperatures in Friday Creek will not drastically impact current hatchery operations but will severely impact broodstock holding and egg collection. Temperatures will pose a major risk of increased stress and mortality for adult fish during September.	Likely	High
Flood events	Increased high water events on Friday Creek during months that the hatchery operates. The status of the intake and access to it is extremely poor and will need to be addressed immediately.	Likely	Moderate
Air temperature extremes	Most severe extremes could be 20°F warmer than current highs but will likely occur while no fish are on site (June-Aug). Some extremely hot days could occur during September and could potentially create unsafe conditions for staff and fish when adults return.	Possible	Moderate
Snowpack declines	Snowfall and accumulation from January to March will decrease. Samish is not currently in a snow-dominated region so this will have little impact on hatchery operations.	Likely	Low

6.4.2 Fish Health Impacts

Warming water temperatures will accelerate the life cycle of external parasites that infect fish at the Samish Hatchery. The change in the life cycle of parasites will lead to a faster progression of disease, from infection to outbreak, and increasing severity of disease as water temperatures increase from spring to summer and the lifecycle of the parasite is accelerated.

Prevalence of Costia infections has been shown to decrease as water temperatures increase, though Ich infections have the opposite trend (Karvonen et al. 2010). This may lead to a shift in the parasite community if water temperatures become more suited for parasites that cause Ich. Decreasing flows will reduce the water exchange rate and allow the presence of infective stages of the parasites in the rearing unit for longer, providing more infection opportunities.

6.4.3 Bioprogramming

The forecasted climate impacts include significant changes to precipitation and temperature profiles in the summer. However, since production at Samish Hatchery is limited to November through May, peak temperatures should not occur while fish are held onsite. Temperatures will still warm significantly relative to the current climate, and these changes will need to be addressed to meet production goals. Currently, egg incubation occurs at Kendall Creek hatchery due to water quality limitations at Samish. To return these operations to Samish would require the development of new wells or ability to treat incoming surface water through tempering, disinfection, and oxygenation.

To meet the density guidelines of 3 lbs/gpm and 0.35 lbs/ft^3 outlined in the HGMP for Chinook Salmon production at Samish hatchery, the facility will need to develop additional rearing space. Including the adult holding pond fed by the Samish River Intake, the facility has 162,609.50 ft^3 of production space. The volume requirement for 6.5 million fish at 80 fpp (81,250 lbs. total biomass) is 232,142.85 ft^3; therefore, a deficit of approximately 69,533 ft^3 exists. Replacement of the adult ponds is in the current WDFW Ten Year Capital Plan, with four 20-foot x 180-foot raceways taking their place. Even with the upgrades, rearing volume for the production goal of 6.5 million fish per year would still be limiting. There is also an issue with water flow; according to the HGMP, there is approximately 23 cfs of water rights for Friday Creek and 25 cfs for Samish River. The required flow to maintain a density of 3 lbs/gpm for the total target biomass is 60.34 cfs, a deficit of 12.34 cfs. The Friday Creek Intake structure is also on the list for replacement. To support the proposed expansion of production, WDFW should consider increasing the available water rights for Friday Creek and sizing the intake appropriately to accommodate the potential increase. Ultimately, the current requirements of the HGMP may be unrealistic or cost prohibitive for this facility without an entirely new construction.

6.5 Goldendale Hatchery

6.5.1 Climate Stressors

This section describes how each climate stressor will potentially impact operations at Goldendale hatchery. A summary of the climate stressors and their impacts can be found in Table 6-5.

Water availability at Goldendale hatchery is difficult to determine because of the unique water source it operates with—the Spring Creek artisan spring. The hatchery occasionally deals with variable flow rates and low oxygen levels during winter months, but overall staff has reported that there is no noticeable difference in water volume during drought years. The net surface water balance of the area near Goldendale hatchery is expected to increase except during summer months when precipitation will decrease (Appendix C). Overall, projections imply that the average annual infiltration rates will increase, which should sufficiently recharge the spring (Table 5-17). A major unknown variable is the number of new wells that may be added to the area. If enough well development occurs, it could jeopardize the Goldendale hatchery's only water source. This is concerning and should be addressed by WDFW with more detailed aquifer modeling and studies to determine the future viability of the water source. This will help the agency determine if other water sources or water recirculation technology needs to be incorporated into the facility to maintain operational consistency through the end of the century.

Water temperature increases were projected using available air temperature data. Groundwater temperatures are forecasted to increase between 1.4° and 3.2°F by the end of the century (Table 5-18), which will keep them within the optimal range for trout production. While determining the future viability of the spring as a consistent water source, WDFW may also want to perform a more in-depth analysis to determine if the water temperature will remain constant. Climate projections in this report relied on a limited amount of available data, and more information specific to the Spring Creek water source could support or negate the conclusions in this report.

Since the water source is an underground spring, flooding does not impact it. Precipitation projections show that moderate increases in daily precipitation may occur during the fall, winter, and spring (Appendix C). It is possible that Spring Creek could flood, and water levels could increase enough to flow into the abatement pond at the hatchery and cause them to be out of compliance with their NPDES permit requirements, but this is unlikely given the current projections.

Compared to the other facilities in this report, Goldendale will experience the least extreme air temperature increases. Projections indicate that the hottest days on record from June through August may only be 15°F warmer by the end of the century than the current records. This would bring air temperatures to nearly 90°F for the most extreme projections (Appendix C). More optimistic projections using the RCP4.5 climate scenario show extreme temperatures near 80°F (Appendix C). Though not as drastic of an increase relative to other hatcheries in this report, these temperatures are still cause for concern for the safety of staff working outside.

Snowmelt and accumulation will likely decrease as temperatures warm, and precipitation falls as rain. This is not likely to significantly impact hatchery operations as rain will also recharge the aquifer supplying the hatchery.

Table 6-5. Impact of climate stressors on Goldendale hatchery including the severity, likelihood, and overall risk to facility operations.

Climate Stressor	Severity	Likelihood of Occurrence	Risk to Operations
Water availability	Projections indicate that the spring source should remain sufficiently charged. However, more information is needed to determine the future viability of the spring. Population growth and agricultural development can potentially decrease water availability.	Possible	Moderate
Water quality and temperature	Water temperatures are projected to increase slightly by the end of the century, but will be in the optimal range for trout production.	Likely	Low
Flood events	Possible flooding of Spring Creek into the effluent abatement pond would trigger an NPDES violation.	Not Likely	Low
Air temperature extremes	Extreme temperatures near 90°F may be experienced on some days.	Possible	Low
Snowpack declines	Snowfall and snow accumulation will decline as temperatures warm, and precipitation falls as rain. This will still recharge the source aquifer.	Possible	Low

6.5.2 Fish Health Impacts

Unlike other surface water sources, the spring water used at Goldendale will not experience a temperature increase significant enough to reduce the viability of *F. psychrophilum*, the causative agent of BCWD. Therefore, instances of disease will likely increase in response to climate change. The most susceptible life stage (fry), immediately prior to or after transition to outdoor raceways, will likely remain affected by the disease. Timing the transition of fry to the raceways must be balanced between allowing sufficient immune development before handling and avoiding high densities that promote disease. This creates a challenging situation for the hatchery staff tasked with managing BCWD. Fish most susceptible to BCWD are reared on well water; therefore, warming temperatures due to climate change should not have severe impacts on fish growth rate or bacterial loads during this production stage. However, the transition of these fish from well water to surface water in raceways will continue to be a stressful event that promotes disease. Differences in water quality and temperature between ground and surface water may lead to increased stress levels during transfer, further promoting disease.

6.5.3 Bioprogramming

Due to the difficulty of modeling changes for the unique spring water source for Goldendale, strategies to quantify the climate change impacts used for other hatcheries were not available. An important projection for the spring supplying Goldendale is that precipitation infiltration rates should increase in the areas surrounding Spring Creek. This may provide the facility with spring water for the rest of the century. However, water temperature will likely increase as air temperatures rise in the future. This may require further water tempering and treatment in the future to maintain a high-quality rearing environment.

Based on review of the provided information, it appears that the hatchery is currently exceeding the allowable total flow from the spring than is licensed. Increasing efficiency of the water usage throughout the hatchery by incorporating Partial Recirculating Aquaculture System (PRAS) technology will benefit all Goldendale Hatchery production programs. Water recirculation strategies may also require changes to the water process. Elevation from the spring source to the hatchery provides very little head height, piping may be compromised, and this will likely be a limiting factor with the water supply system to the hatchery.

7.0 Alternatives Development (Technologies)

This section outlines technology that has the potential to mitigate impacts of climate change for hatchery production. This includes several different options of technology or combinations of technology that could be utilized and are incorporated into the evaluations at each specific hatchery.

7.1 Oxygenation

7.1.1 Low Head Oxygenators

Low head oxygenators (LHOs) are named because of their ability to use minimal hydraulic head for operation and efficient gas transfer. LHOs provide high (90–95%) gas transfer efficiency with low energy use and, because of the low head requirements, can readily adapt to changes in flow.

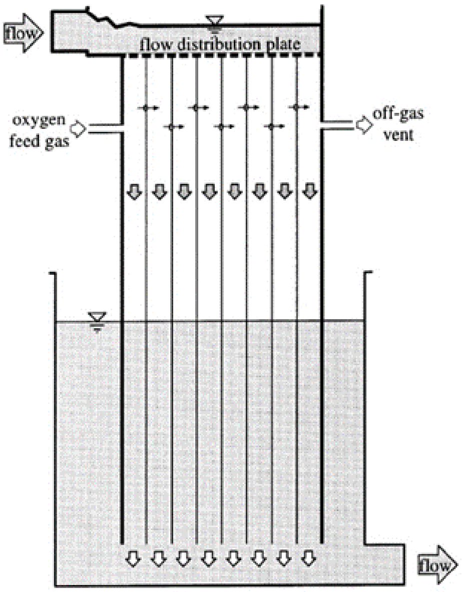


Figure 7-1. Low Head Oxygenator (LHO) Unit

LHO configurations (Figure 7-1) consist of water inflow onto a perforated distribution plate that covers multiple chambers which the water flows into. These chambers are the site of gas-liquid interface required for mixing and efficient oxygen transfer. Pure oxygen gas is introduced into the outermost chamber where it meets water flowing through the distribution plate. As the gas is transferred in a chamber, oxygen concentration decreases, and gas passes through holes to the next chamber repeating the process.

7.1.2 Hyper InfusiO_2n™

Hyper InfusiO_2n™ is a new oxygenation technology developed by Merck Animal Health. Traditional oxygenation strategies rely on diffusion, which introduces oxygen gas to the water. Any oxygen that is not dissolved is released into the atmosphere. Infusion technology replaces existing dissolved gases, such as nitrogen, with dissolved oxygen that is stable within the water. This eliminates the potential for wasted oxygen gas and provides oxygen that is immediately available for fish respiration. This technology can be used to supersaturate water with dissolved oxygen and increase concentrations up to 450% saturation without impacting the total gas pressure (TGP). Other oxygenation technology is capable of supersaturation, but without gas stripping there is a potential for increased TGP that can cause fish stress and mortality due to gas bubble disease (GBD). This technology is in the experimental stages and may not be suitable for conservation hatcheries.

7.1.3 Oxygenation Cones

Oxygenation (Speece) cones, or downflow bubble-contactors, use differences in water velocity within different diameter pipes to achieve gas transfer efficiencies up to 100% (Figure 7-2). Water, at a high velocity, and pure oxygen enter the top of the cone. Oxygen bubbles are forced downward by the high velocity water. As the diameter of the cone increases, downward water velocity decreases. When the downward velocity of the water is equivalent to the upward velocity of the bubbles, bubbles are held in suspension until oxygen completely diffuses into the water. Undissolved bubbles continue circulating toward the top of the cone so that only water without bubbles exits from the bottom.

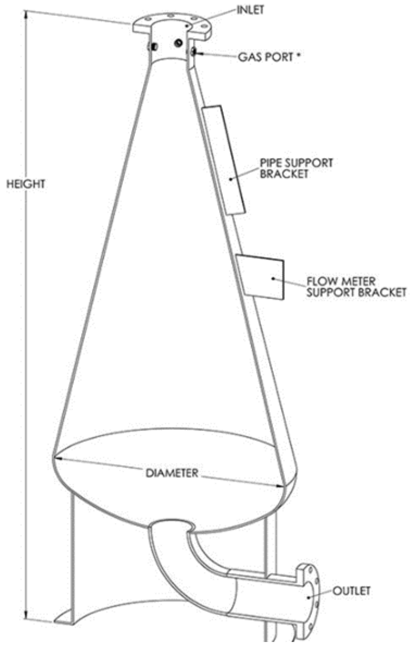


Figure 7-2. Oxygenation (Speece) Cone

7.1.4 Pressurized Packed Column

Pressurized packed columns (PPCs) are designed to dissolve oxygen across an increased surface area. Columns are packed with media with a high surface area, and oxygen gas is introduced and generally travels counter to the water flow. Gas transfer efficiencies of over 90% can be reached, with outflow concentrations exceeding 100 mg/L. This allows for smaller volumes of oxygenated water to bring the culture system water to adequate DO levels. These systems can be centralized for use with multiple tanks or can be assigned one PPC per tank. Installation is relatively easy and can be done with minimal disruption to operation. The main disadvantages are the energy requirements necessary to pressurize the system and the potential for biofouling of the media within the column.

7.1.5 U-Tube Aerator

U-tube aerators operate on the principle of increasing gas pressure to increase the total gas transfer rate. The system consists of two concentric pipes, or two pipes in a vertical shaft, 30 to 150 feet long. Oxygen is introduced on the top end of the down-leg in the system. As the water and oxygen move down, an increase in hydrostatic pressure increases the oxygen transfer rate. Gas transfer efficiency is a function of the total length of the U-tube, incoming gas concentration and flow rate, water velocity, and diffuser depth. Effluent water can reach DO concentrations of 20 to 40 mg/L. However, overall gas transfer efficiency is limited to 30 to 50%; recycling the off-gas can raise total transfer efficiency to 55 to 80%.

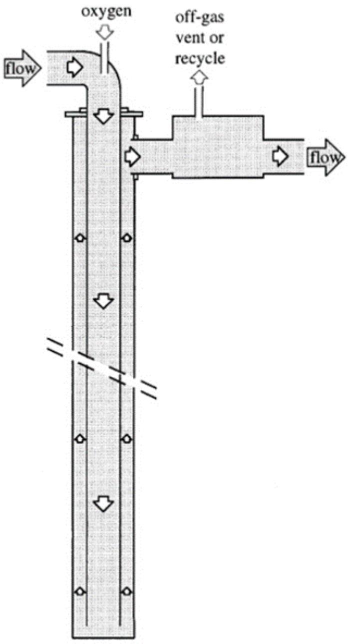


Figure 7-3. U-Tube Aerator

Advantages of this system are the low hydraulic head requirements, eliminating the need for external power if adequate head is available. It can also be used with water sources containing high levels of particulates or organics without risk of equipment fouling. Disadvantages include the inability to efficiently strip other gases, including nitrogen and carbon dioxide, from the water. Construction costs can be high, particularly if obstacles, such as the presence of bedrock, are encountered while drilling and placing deep pipes.

7.2 Tempering

Temperature is one of the most important factors impacting the development and growth rate of fish. The ability for a facility to maintain the optimal temperature will create an environment for continuous, stable fish development and growth, allowing for a more predictable cycle to achieve production targets relative to fish size and schedules. It should be noted that optimal temperatures for species may differ among life stages and depend on hatchery goals and production schedules. To mitigate climate change’s impacts on hatchery production, facilities must have the ability to increase their water tempering capacity in response to temperature changes.

7.2.1 Chillers

Chillers will aid in the effort to mitigate impacts of climate change on hatchery operations as temperatures rise and flows are reduced in summer months. Air-cooled chillers do not require an external water source for operation, making them advantageous when processed water is limited. Alternatively, water-cooled chillers use more water for operation, but are generally less expensive to purchase and operate more efficiently. Chillers are generally rated by the ton for aquaculture facilities; 1 ton chilling capacity is equal to 12,000 BTUs per hour, or 3.516 kW. Chillers are a major energy cost of facility operation, but energy recovery systems can help offset this.

7.2.2 Energy Recovery

Energy recovery systems can reduce the required sizes of water tempering equipment such as chillers and boilers. Treated, or tempered, effluent from a culture system is captured and routed back to the water tempering system. Heat is exchanged between the used effluent and the fresh inflow, reducing the tempering requirements of the system. For instance, incoming water is chilled and used for production. The chilled effluent is then captured and pumped through the chilled water heat exchanger. The countercurrent exchange of heat reduces the temperature of the fresh incoming water before it reaches the chiller, reducing the total load of the chiller and reducing energy costs. After effluent water goes through the heat exchange, it is discharged into the main hatchery drain system.

7.3 Water Reuse Systems

Maintaining hatchery productivity while conserving water for natural ecosystems in the face of climate change will require conscious efforts to use water efficiently. Process water reuse system design should consider seasonality of fish production and water quality and availability. Renovations should provide flexibility to adapt to future changes of water quality and availability in response to climate change, as well as increases in fish production goals.

7.3.1 Partial Recirculating Aquaculture Systems

Partial recirculating aquaculture systems (PRAS) are designed to reuse up to 75% of water within the system. Incorporating water reuse into a system requires several design components as described in this section.

7.3.1.1 Solids Removal

Waste generated from feed and fish is typically removed using microscreen drum filters. Water enters the center of the drum and filters through the microscreen. As solids accumulate on the screen, the drum rotates, and the buildup is backwashed into a separate waste collection for effluent discharge. During backwashing, solids are continuously filtered through the clean section of screen. The recommended filter pore size is 50 µm in recirculating systems (Timmons, Guerdat, and Vinci, 2018). Filter pore sizes are dependent upon fish species and targeted TSS as well. Drum sizes are determined by the total amount of waste generated, which is a function of the amount of feed inputs to the system as well as total process flow through the system.

7.3.1.2 Degassing/Aeration Chamber

After solids removal, water is passed to a degassing/aeration chamber where carbon dioxide, produced by fish, is removed and oxygen is replaced. The most common methods of gas stripping in PRAS are packed columns or aeration basins. In packed columns, water is pumped to the top of the column and sprayed downward over the packing media as air is pumped upward through the column. The large air to water surface interface allows for the transfer of carbon dioxide out of the water that is then carried up and out of the column by the blown air. Aeration basins are an alternative to packed columns that collect water and remove carbon dioxide using diffusers. These should be adequately ventilated to avoid increasing carbon dioxide concentrations in the building, enough that it later diffuses back into the process water. Packed columns are more efficient at gas removal than aeration basins, allowing for greater rearing densities, but require significant vertical space in a building and are more expensive for comparable stripping efficiencies. Aeration basins are typically within the floor in vaults and may be difficult to install within existing infrastructure. Evaluation of both types of systems will determine the most cost-effective approach for a specific facility's requirements for aeration basins. After carbon dioxide is stripped, the water flows into an LHO (Figure 7-1), or some other oxygen supplementation system, to return oxygen to appropriate fish production levels.

7.3.1.3 Pump Station

Pump stations are required to keep the reused water in the process flow. They can be placed before or after the aeration chamber depending on the design. These will generally include a sump from which the reused water will be pumped through treatment processes to a head tank before returning to the rearing vessel. The order of pumps, water treatments, and makeup water inflow may differ among designs. Pump capacity must be sized for the maximum reuse for full operation. If future upgrades to a higher water reuse percentage are being considered, the pumps and sump should be sized to accommodate these improvements.

7.3.1.4 Water Disinfection

Prior to returning to culture tanks, water needs to be disinfected to decrease pathogen load within the system. The main strategies for this are ultraviolet (UV) irradiation and ozonation. It is important that this is the final step in water treatment and uses the cleanest water, as suspended solids can decrease the efficacy of disinfection. UV treatment works by irradiating DNA in organisms, and its efficiency requires water with low total suspended solids content. It is suggested that prior to UV treatment, water is passed through a 50-μm filter to remove organic and inorganic compounds. UV treatment is generally less costly and complex to implement in a system and does not produce any toxic byproducts. Ozonation has been used in the past and is an effective disinfectant; however, it must be generated onsite and is toxic to both fish and humans.

7.3.2 Raceway Reuse Systems

If a transition from linear raceways to circular tanks is not feasible due to space or funding limitations, water reuse can be incorporated into existing raceway systems. Implementation will depend on existing plumbing, structures, and available space, but generally a reuse sump would be located on the downstream end of the raceway system. This sump would collect the overflow from the raceways where it could be pumped back to the head end of the raceways. Reused water would require oxygenation. A microscreen filter and UV disinfection could be included depending on the level of reuse and existing water quality. These systems can be relatively simple to implement depending on the facility and do not require the large investments of transitioning to a traditional dual drain circular tank reuse system.

7.3.3 Egg Incubation Reuse Systems

Recirculation can be a simple way to reduce the requirement of high-quality water for egg incubation. These systems are typically smaller scale, with lower flow requirements, and can operate without microscreen or bio-filtration (Figure 7-4). If formalin treatments are used, there must be a bypass to allow the treatment dose to flow out of the recirculation system to avoid prolonged contact with the eggs.

Figure 7-4. An Example of a Recirculating Egg Incubation System Designed by Aqua Logic that includes 4 half-stacks, chiller, UV disinfection, water mixing sump, pump, and controls.

7.3.4 Airlift Systems

Airlift technology works by injecting air into the bottom of a water column. The air/water mixture is less dense than the water around it and the mixture rises to the top of the column. Airlift pumps can move large volumes of water with relatively low energy inputs compared to other pumps. They also have the added benefit of simple aeration and carbon dioxide stripping because air is introduced for pumping. Airlift systems can be used to design a decentralized PRAS that can reduce makeup water requirements by 50 to 75%. These systems were developed and improved by the Freshwater Fisheries Society (FFS) of British Columbia. Airlift systems can be incorporated into raceway or circular tank systems, providing extra flow and aeration at a fraction of the cost of traditional pumps (Figure 7-5).

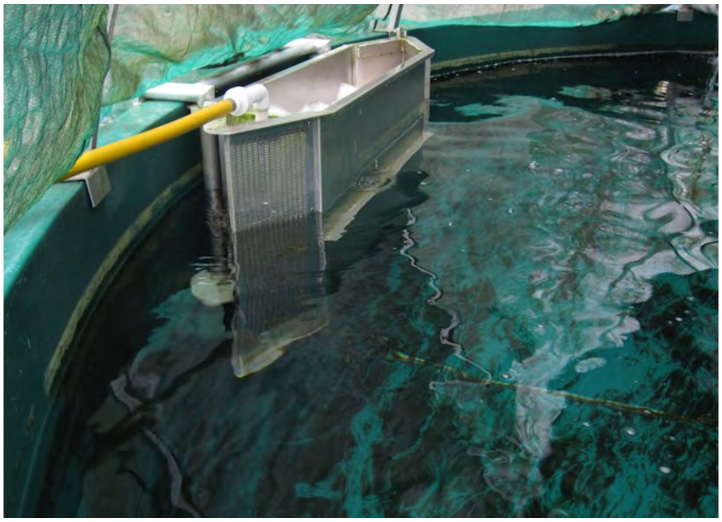


Figure 7-5. Airlift System in a Circular Tank.

7.3.5 Full Recirculating Aquaculture Systems

Recirculating aquaculture systems (RAS) are designed to reuse a higher percentage of water compared to PRAS, with up to a 99% reuse rate. Water treatment equipment must be sized to accommodate the amount of reuse flow. The addition of a biofilter to convert toxic ammonia produced by fish into less toxic nitrate is necessary and several types of biofilters are described below. It is important to note that bacterial activity in the biofilter increases oxygen consumption. If DO levels in water leaving the biofilter are not high enough, then downstream oxygenation equipment may not return oxygen to high enough levels for the fish. Full RAS has the benefit of reducing total water demand and reducing the demand of water tempering equipment because energy is kept within the system. Disadvantages include increased amount of equipment, operating complexity, and operating costs.

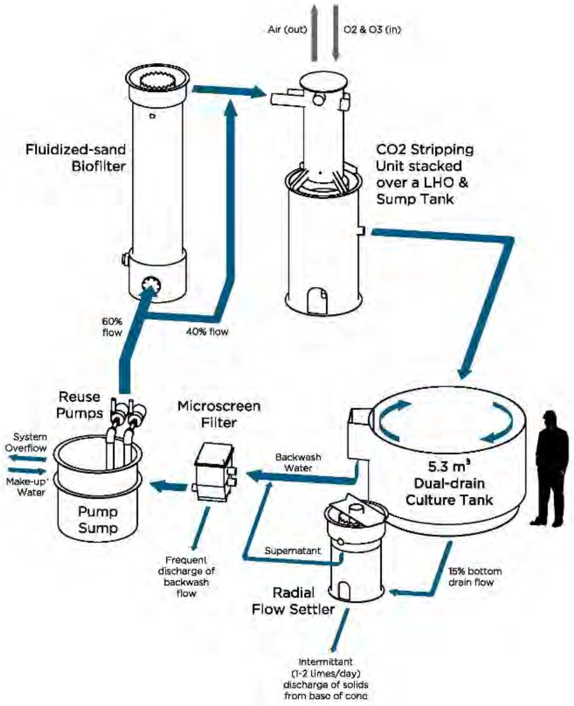


Figure 7-6. RAS Process Flow Example from Conservation Fund Freshwater Institute

7.3.5.1 Rotating Biological Contactors

Rotating biological contactors (RBC), also known as biodisc filters, are a set of circular plates on a central axle. The axle rotates slowly, exposing the media to both recirculated water and the air, providing oxygen to the bacteria. The advantages of these are that they are self-aerating and gas stripping, do not require a large hydraulic head, and have low operating costs. However, they are less efficient in terms of cost per unit of nitrification compared to other filters.

7.3.5.2 Trickling Biofilters

Trickling biofilters are made of a column filled with fixed media that recirculated water trickles down over. These continuously oxygenate the water and at the same time strip dissolved carbon dioxide. Trickling filters are simple to construct and have moderate operating costs. Filter media is prone to clogging and must be cleaned out occasionally. The use of vertical or cross flow media makes this process easier compared to random media such as loose plastic balls. These filters become less efficient at lower water temperatures and therefore are not often used in large-scale cold-water systems. Small hatcheries with low, variable loads have used them with success.

Emergent biofilters, such as RBC or trickling, tend to be favored when the limiting factor of nitrification is oxygen availability for bacteria colonies. With the progression of gas transfer and solids removal techniques in RAS, nitrification is now primarily limited by ammonia diffusion. As such, the industry has shifted toward using submerged biofilters such as fluidized bed or bead filters.

7.3.5.3 Fluidized Bed Biofilters

Fluidized bed biofilters are created by a bed of sand that is continuously suspended by an upwelling water current. The sand within the bed has a very high surface area for biofilm to adhere. These filters have the highest ammonia conversion rate per unit of media and can be designed as large as needed for a facility.

Pumping water to keep the media fluidized is a major operating cost for these filters. For efficient ammonia conversion, sand must remain suspended and circulating. Therefore, proper sizing and design of the water injectors under the sand bed are crucial. Pumping water to fluidize the media can also be a major expense. The Cyclo-Bio™, developed by Marine Biotech Inc., is one way to reduce these costs. It is a specific kind of fluidized bed filter design that introduces water tangentially into the biofilter through a slot at the base. This creates a rotation of the water and eventually the media bed. This system expands the media bed using much lower water pressures compared to traditional water injectors, lowering the operation costs of the filter.

7.3.5.4 Floating Bead Biofilters

Floating bead filters are also referred to as bioclarifiers because they remove suspended solids as well as provide a site for nitrification. Small beads (3 to 5 mm) specifically manufactured to be slightly buoyant in a pressurized chamber provide the surface area for bacterial colonization. These are resistant to biofouling and do not require large amounts of water for backwashing. Backwashing is simple and consists of using either a mixing motor and propellor or pressurized air to disrupt the beads. Solids are released from the beads and concentrate on the bottom of the chamber where they can be drained. These filter types are compact and easy to install while providing similar nitrification rates as fluidized beds. They are less expensive to operate and water loss from backwashing can be negligible.

7.3.5.5 Microbead Biofilters

Microbead biofilters use smaller (1 to 3 mm) highly buoyant beads for bacterial colonization. Microbeads are much less expensive than floating beads because they do not have special density requirements for operation. The operating costs associated with microbeads are also dramatically less than fluidized bed filters because they use low head, high volume pumps for circulation. Water flows down over the top of the media bed, trickling down before flowing out of the reactor. They do not offer solids capture, but depending on how water is delivered to the media bed, they can provide some gas stripping.

7.3.5.6 Moving Bed Bioreactors

Moving bed bioreactors (MBBR) use larger plastic media (6 to 13 mm) compared to floating or microbead filters. Media is placed in a tank that air is constantly pumped into, slowly moving the media. The significant amount of air required to maintain movement also contributes to gas stripping and aeration. MBBRs are less expensive and simpler to operate compared to fluidized sand biofilters, but the total nitrification capacity of an MBBR is only 50% of that of fluidized sand beds. This leads to MBBRs requiring a much larger footprint to achieve the same nitrification levels of a smaller fluidized sand bed.

7.4 Pathogen Treatments

7.4.1 Ultraviolet Irradiation

UV irradiation is a common way to treat bacterial and viral pathogens in the incoming water of aquaculture facilities by disrupting the DNA of the pathogens, eliminating their ability to multiply or infect hosts. A major advantage of UV treatment is that it does not produce any toxic byproducts that require removal. The limiting factor of UV treatment success is the UV light’s ability to penetrate the incoming water. More turbid water reduces the transmission distance of UV and therefore reduces the total amount of water that can be treated. Pre-filtering incoming water with a 50-µm pore size (or finer) drum filter prior to UV treatment is required to increase the effectiveness of water treatment. Doses will also depend on the specific pathogens being targeted; infectious pancreatic necrosis virus (IPNv) is one of the most UV-resistant fish pathogens. For many salmonid aquaculture facilities in the West, *Flavobacterium psychrophilum*, the causative agent of bacterial cold-water disease (BCWD), can be a persistent issue. A UV treatment dose of 126 mJ/cm^2 is required for significant reductions in bacterial load. Infectious hematopoietic necrosis virus (IHNv) is another common pathogen in salmon and trout, but only requires a 10 mJ/cm^2 UV dose for control. It is important to establish the lowest expected transmittance of the UV light to correctly size the bulb for the desired dose and flow rate of the system. UV filters are commonly designed as a pressurized unit. The bulbs are contained in quartz sleeves that retain heat and output strength of the bulb. The quartz shields must be regularly cleaned to maintain the desired dose, and bulbs should be changed annually.

7.4.2 Formalin

Formalin is commonly used to treat external parasites on wild adult salmonids being held in facilities prior to spawning, and as a fungicide to reduce *Saprolegnia* growth during egg incubation. Formalin is available under the trade name Parasite-S from Syndel Laboratories Int. as an aqueous solution containing 37% formaldehyde. Doses for external parasite treatments depend on water temperature; the maximum dose for water above 50°F is 170 µL/L for 60 minutes. Below 50°F, the dose can be increased to 250 µL per liter for 60 minutes. For fungus control of eggs, the target dose is 1,000–2,000 µL/L for 15 minutes. Formalin is most often used in a flow-through treatment. This requires an initial delivery of formalin to reach the target concentration and constant delivery to maintain the concentration for the required duration. Drip systems for this delivery can use gravity and head pressure to deliver the treatment, or more complex systems may contain timers and pumps. Formalin should be used with caution in RAS. If formalin concentrations greater than 37 mg/L reach the biofilter, it may kill the nitrifying bacteria and cause lasting damage to the filter's performance (Fredricks et al. 2018). RAS should be converted to a flow-through system during treatments to avoid recirculating formalin and potentially overdosing fish.

A safe formalin discharge that poses no adverse environmental effects requires a 1:10 dilution for up to a 250-µL/L dose and a 1:1000 dilution for a 2000-µL/L dose according to manufacturer's guidelines. If adults and eggs require treatment at the same time, treatments should be staggered to avoid overloading the discharge system with formalin without enough available untreated water for dilution. For facilities that regularly treat with formalin, the discharge system should be evaluated to ensure appropriate mixing and dilution.

7.4.3 Hydrogen Peroxide

Hydrogen peroxide is another common chemical used to control fungal growth in fish eggs. It is available as 35% PEROX-AID®, a 35% solution provided by Syndel Laboratories Int. Treatment doses for eggs are 500–1000 milligrams per liter for 15 minutes for a flow-through treatment. Unlike Parasite-S, which is 100% active ingredient, PEROX-AID® is only 35% active ingredient. This factor must be accounted for when calculating amounts used for treatments. Hydrogen peroxide should still be handled with appropriate protective gear such as gloves and eyewear. Hydrogen peroxide is highly reactive and rapidly degrades in sunlight and water. Typically, discharge does not require special consideration for mixing and diluting the treatment flow. Hydrogen peroxide breaks down in sunlight and may be disposed of easier than Formalin. The FDA has set acute water quality benchmarks at 0.7 mg/L on a short-term basis.

8.0 Management Actions (Adaptive Management)

This section provides a list of potential management actions WDFW could take to provide operational consistency at these facilities as they experience worsening effects of climate change. This includes general recommendations that are applicable to all four hatcheries in this report and potentially other hatcheries operated by WDFW. Each hatchery also has proposed actions specific to its production goals and facility constraints.

It is important to note that the actions proposed are not an exhaustive list. Situations and conditions at each facility may experience changes that are not addressed in this report. Water reuse systems play a large role in these proposed actions in part because the time horizon for this report extends to the end of the century. Flow through systems may be more ideal from a biosecurity, fish health, and cost standpoint; however, securing a consistent supply of cold, clean water for fish rearing will become increasingly difficult as the effects of climate change worsen in the coming decades. Technologies reviewed in Section 7.0 include cutting edge aquaculture equipment, but future innovation may provide strategies better suited to address the warming water temperatures and decreasing flows that are poised to negatively impact production at these facilities.

8.1 General Recommendations

8.1.1 Fish Health

Disease risks will always be present in an aquatic environment. Emphasis should be placed on limiting risks as much as possible to prevent disease. One of the simplest ways to decrease the risk of disease and maintain good fish health is to reduce stressful events and conditions. Regulating and maintaining consistent temperatures within the optimal range for salmonids will be important as the climate continues to change. Several factors influencing fish health (increased densities, increased pathogen growth and transmission, increased stress) are a direct result of warming water temperatures due to climate change. Keeping rearing densities low and flows high for particularly sensitive species and life stages is advised. Use of shade cloth or other material to provide cover for fish can also reduce stress. Coverings may reduce bursts of fish avoidance behavior as work is performed in adjacent areas and may disperse fish if they currently crowd into shaded sections. Limiting handling and movement of fish, when possible, will reduce stressful events and therefore reduce the risk of disease outbreaks. When fish are handled or stressed, judicious use of therapeutants such as salt will assist recovery and reduce delayed mortalities. Salt is relatively inexpensive and is readily available, is an effective parasiticide, and is safe for use when properly administered.

Maintaining a clean environment and having good biosecurity practices are also important. Treatment of surface water with filtration and UV disinfection will help decrease harmful levels of TSS and pathogens. This is especially important if surface water is used for sensitive life stages such as eggs, fry, and pre-spawn adults. UV irradiation effectively reduces viral and bacterial pathogen loads of water without producing toxic byproducts. To reduce *F. psychrophilum* levels by 99%, a treatment dose of 126 mJmWs/cm^2 for 5 minutes is required (Hedrick et al. 2000), while all other pathogens of concern for the listed facilities would require lower doses to achieve a similar reduction. TSS can be reduced by using microscreen filters or a settling pond to treat incoming water. Microscreen drum filters would have a smaller footprint than settling ponds, but also require a consistent power supply. Cost would depend on available space, construction access, and existing infrastructure that could incorporate a filtration system. Keeping the surfaces of rearing units such as tanks and raceways clean is also important. Concrete raceways and ponds may require resurfacing, smoothing, and sealing to create a surface that hatchery staff is able to keep clean. When concrete is pitted and aggregate is exposed, it provides more surface area and protected spaces for microbes, plants, and algae to colonize, making it extremely difficult to keep clean and posing a potential hazard for fish health. Additionally, removing mortalities frequently should be a priority because dead fish act as reservoirs that shed large amounts of pathogens, putting healthy fish at greater risk of infection.

As climate change continues to shift equilibrium in favor of pathogens and disease, other preventative measures such as vaccines will become more important. Though vaccines are not currently used at these facilities, they may provide a much-needed advantage for the most susceptible species and life stages as conditions deteriorate. Autogenous vaccines can be developed for specific hatcheries if specific pathogens consistently cause issues. Availability of general purpose, large-scale vaccines for fish is limited, but advancements are being made. In terms of environmental changes, Washington may experience increased instances of thiamine deficiency in returning adult salmon and their eggs. Due to changes in adult salmon diets in the ocean, thiamine is not being absorbed in adult fish and therefore cannot be transferred to their offspring. This is currently an issue in the Central Valley region of California. Preventative thiamine injections and egg baths are used to control this disease, but treatments may evolve in the future. Facility managers and their fish health specialists should monitor available options as climate change alters environmental conditions.

Formalin is used by all hatcheries in this analysis to treat disease. Two major concerns with formalin treatments regarding climate change are its increased toxicity at warmer temperatures and the removal of dissolved oxygen during treatments. If formalin is being used at temperatures significantly warmer than normal, a test treatment on a small batch of fish is advised. Doses should be decreased and tested on small groups of fish if temperatures exceed

68°F. Dissolved oxygen should also be measured prior to and during treatment. Climate change may lead to increased densities and warmer water, which would negatively impact dissolved oxygen concentrations. Hydrogen peroxide (35% PEROX-AID®) also treats external bacteria and parasites with an effectiveness comparable to formalin but breaks down into oxygen and water. As with formalin, toxicity increases with water temperatures, but dissolved oxygen concentration will increase for a brief period during treatment. Other therapeutants, chemicals, and vaccines may become available for aquaculture. Hatcheries should regularly check with fish health specialists to ensure that treatment programs are up to date.

8.1.2 Raceway Rehabilitation

Pitted, chipped, and leaking concrete raceways can lead to algal growth and bacterial biofilm adhesion. These issues can negatively impact fish health and make it difficult or impossible for hatchery staff to keep surfaces clean. To prepare for worsening water quality conditions caused by climate change, improvement of raceways is recommended to prevent unwanted microbe proliferation.

Depending on surface condition, rehabilitation may include surface preparation (such as sand blasting), skim coating, or painting with sealants such as epoxy or polyurethane. Recommendations on the specific requirements for each raceway can only be made with more detailed information and a site visit to evaluate current concrete conditions.

8.1.3 Covering Outdoor Rearing Areas

Both air and water temperatures are projected to continue to increase in the future. To help reduce the compounding effect of rising water and air temperatures, we recommend covering outdoor production raceways where feasible. This will limit the amount of solar radiation that increases water temperatures onsite.

An added benefit of covering raceways is the potential to also add enclosures to prevent predators or other unwanted wildlife from accessing the raceways and improve biosecurity. As temperatures rise and rearing environments are pushed to the edge of their acceptable ranges, limiting potential pathogen vectors such as wildlife will be an important aspect of fish health strategies. Coverings will also benefit fish health by reducing stress.

8.1.4 Evaluation of Power Requirements

As flows are expected to decrease and water temperatures increase, water recirculation will become an important part of hatchery operations. Recirculation will allow for more fish production with less water and provide significant energy savings by reusing already chilled or treated water. However, as more recirculation technologies are required in the future, hatcheries should evaluate their current power availability and backup generator capacity. We have assumed that there is sufficient power available to the hatcheries to incorporate the proposals outlined below. Future detailed designs will confirm or deny this assumption and determine if current backup power generation is able to meet these demands.

8.1.5 Riparian Area Rehabilitation

Surface water sources that use small streams, such as Friday Creek at the Samish Hatchery, would benefit from increased tree coverage in their riparian areas. Denser foliage will reduce solar radiation and water warming, as well as decrease the evaporative losses. This would be simple to implement but may require considerable effort to achieve grassroots support from property owners along these streams.

8.1.6 Operational Schedule Changes

Climate change will have a variety of impacts on wild fish populations, many of which cannot be accurately forecasted based on available information. Changes to wild populations of returning adult salmon will undoubtedly affect the hatcheries in this report, excluding Goldendale, but exactly how hatchery operations will change is uncertain. With decreasing streamflows and increasing water temperatures, hatcheries should prepare for rearing and stocking schedules to shift in the future. Decreasing stream flows in the summer months may require hatcheries to release fish earlier in the season to take advantage of high-flow periods. Increasing water temperatures will likely impact the timing of adult returns depending on the species and the current run timing. These issues are important to keep in mind while considering future management actions.

8.2 Marblemount Hatchery

The following management actions are recommended for Marblemount Hatchery:

- Fish health recommendations
- Cascade River intake replacement to meet NMFS standards, optimize flow control to the hatchery, and address flood control needs
- Well rehabilitation for the five existing wells
- Incorporation of a PRAS system for yearling spring Chinook rearing to be located at one of the existing channel ponds
- Incorporation of a PRAS system for early life stage spring Chinook rearing in a newly constructed building

- Incorporation of a PRAS system for Coho rearing to be located at one of the existing channel ponds
- Transitioning to full Heath stack incubators and incorporation of PRAS modules for incubation
- Installation of pollution abatement (PA) ponds for effluent treatment
- Development of instrumentation and controls to minimize water usage

Details for these systems are provided in the following sections.

8.2.1 Fish Health

Use of therapeutants, including salt, on returning adult salmon may help prevent or delay severe cases of furunculosis or columnaris disease. If water conditions become unsuitable for formalin treatment due to low dissolved oxygen, extra-label prescription of hydrogen peroxide may be a viable alternative. Hydrogen peroxide is a strong oxidizer and would increase DO concentrations in the water as it breaks down. Its effectiveness as a parasiticide and bactericide is comparable to that of formalin. Vaccines are only effective when administered several weeks before the disease normally presents itself; their use would depend on how long fish are held prior to spawning and how soon after their arrival signs of disease occur.

The causative agent of BKD, *R. salmoninarum*, is essentially always present in aquatic environments that contain susceptible species. Control and prevention will be limited by actions taken to reduce stressful events and to increase rearing environment quality. This may require lower initial stocking densities and splitting of fish sooner than in the current production process. If disease becomes a severe, chronic issue over multiple years as climate change progresses, vaccination strategies or changes to the egg culling thresholds may be considered to decrease mortalities and reliance on antibiotic use.

8.2.2 Intake Replacement

WDFW has requested funds within the 2021–2023 biennium capital budget to replace both the Cascade River Intake and the Clark Creek Intake to meet current federal and state fish screening and fish passage criteria. The current facilities are outdated and inadequate to handle current hatchery programs and production efforts. Intake replacement is also recommended as a management action for this assessment so that the future structures will be appropriately robust for a higher variation in flood conditions and to optimize flow control and availability to the hatchery. With limited information on the intake condition, an intake replacement cost is not included in the cost estimate for this project. Replacement costs are also already provided within the WDFW requested capital budget and could be escalated from 3 to 4% per year to the estimated date of implementation. If there are existing designs in progress for these replacements, the design flows should be compared to the peak flow increases identified in this document.

8.2.3 Well Rehabilitation

The five wells at Marblemount Hatchery are filling with sand and at a minimum need to be re-developed to provide a consistent robust water supply. The hatchery staff note that the well infrastructure is in good condition but well development is needed. It is recommended that a thorough condition assessment, including inspection of the mechanical and electrical equipment, be performed for each well every 10 years (at a minimum) to determine what improvements may be needed. If well supply declines significantly, a well inspection by video camera should be performed to determine the condition of the casing. The hatchery staff also reported that the wells were steady but that they had to be turned down in the summertime to prevent them from sucking air. WDFW might consider consulting with a local geologist or driller on the optimal depth for water supply within the aquifer to determine if there would be any benefit to drilling to a different depth.

The cost for each well to be re-developed is included in the cost estimate evaluation described in Section 9.4.

8.2.4 Yearling Spring Chinook Salmon Recirculating System

As the largest program, by biomass, at the Marblemount Hatchery, incorporating water reuse into the production will provide significant water savings throughout the hatchery. In the future, as hatchery programs and goals change, a large reuse system such as this may prove to be a valuable resource to produce other fish with efficient water use.

This program produces 400,000 7-inch fish each year for a total biomass of approximately 50,000 lbs. To maintain a DI below 0.2, the required volume is approximately 35,715 ft^3 (Table 4-6); to maintain an FI below 1.2, a conservative threshold used by McMillen biologists, the total required flow is approximately 6,000 gpm. The current program uses a single channel pond for production, which has sufficient volume but not enough flow (2,040 gpm) to maintain a high-quality rearing environment. In the future, a more detailed design could incorporate a transfer schedule for fish throughout the circular tanks during the production cycle, but this effort is outside the scope of the current analysis.

8.2.4.1 Required Equipment

The following equipment is necessary for the Marblemount Hatchery:

- Set up 20 circular tanks, each 20 feet in diameter with an operating water depth of 6 feet. Each tank would have a volume of 1,885 ft^3 for a total volume of 37,700 ft^3.
- Provide a water treatment system capable of processing up to 4,500 gpm in a 75% reuse scenario, with flexibility for greater capacity in the future (i.e., tighter water reuse and biofilter incorporation). The following should be included with the system:
  - Microscreen drum filter (if needed)
  - Counter current pressurized packed column for degassing
  - An LHO for oxygenation
  - UV disinfection
  - Circulation pumps and VFDs

To meet the total flow requirement of approximately 6,000 gpm for this program, based on the percentage of reuse, the following is required:

- For 50% reuse, at least 3,000 gpm of fresh makeup water entering the reuse system mixed with 3,000 gpm of recycled water is needed.
- For 75% reuse, at least 1,500 gpm of fresh makeup water entering the reuse system mixed with 4,500 gpm of recycled water is needed.

To provide flexibility for future operational changes and changes throughout the production cycle, it is recommended that this partial recirculating system be designed in modules. For this specific program, a design of four modules, each with five tanks and its own water treatment system, would provide flexibility and increased biosecurity. Additional space would be included in the design to add a biofilter for flexibility in the future if higher reuse rates were needed.

8.2.5 Early Life-Stage Spring Chinook Rearing

There is currently a lack of sufficient rearing volume in the intermediate troughs to maintain the target DI of 0.2 for the early life stages of the spring Chinook Salmon program (Table 4-6). There are currently 16 troughs available, each with an approximate volume of 111 ft^3 for a total rearing volume of 1,776 ft^3, but 4,263 ft^3 is required. Targeting an FI of 1.2 would require approximately 715 gpm. We propose the addition of a new building to house a reuse system capable of handling the volume and flow requirements for this program to produce, growing fish up to the 1.3-inch transfer size. The building size proposed will allow for space to outfit egg incubation capabilities, discussed in Section 8.2.7, to completely house the hatching and fry rearing stages for this species.

8.2.5.1 Required Equipment and Upgrades

The following equipment and upgrades are necessary for the Marblemount Hatchery:

- Construct a new building with an estimated size of 35 feet x 85 feet.
- Set up 44 circular tanks, each 6 feet in diameter, with an operating water depth of 3 feet. This would provide a total rearing volume of 4,354.25 ft^3.
- Provide a water treatment system capable of processing up to 536.25 gpm. The following should be included with the system:
  - Microscreen drum filter
  - Degassing and oxygenation
  - UV disinfection
  - Circulation pumps and VFDs

To meet the total flow requirement of 715 gpm for this program, based on the percentage of reuse, the following is required:

- For 50% reuse, at least 357.5 gpm of fresh makeup water entering the reuse system mixed with 357.5 gpm of recycled water is needed.
- For 75% reuse, at least 178.75 gpm of fresh makeup water entering the reuse system mixed with 536.25 gpm of recycled water is needed.

To provide flexibility for future operational changes and changes throughout the production cycle, it is recommended that this recirculating system be designed in modules. We propose setting up two modules, each with 22 tanks, for this production system.

8.2.6 Coho Salmon Recirculating System

Another unused channel pond could accommodate the pre-release production of Coho Salmon at Marblemount. It would only require 10 of the previously mentioned 20-foot-diameter circular tanks (18,850 ft^3 total rearing volume) to provide enough space required by the Coho Salmon program's pre-release stage (17,825 ft^3, Table 4-8). The total flow requirements using an FI of 1.2 for this stage of the program is approximately 4,500 gpm. For a 50% reuse system, this would require 2,250 gpm of fresh makeup water mixed with 2,250 gpm of recycled water.

For a 75% reuse system, 1,125 gpm of fresh makeup water would be mixed with 3,375 gpm of recycled water. Currently, Coho Salmon are transferred from raceways to the channel ponds for yearling production once they reach a length of 4.7 inches. This proposed system would be able to accommodate both sub-yearling and yearling production, eliminating the need for an extra fish transfer.

8.2.6.1 Required Equipment

The following equipment is necessary for the Marblemount Hatchery:

- Set up 10 circular tanks, each 20 feet in diameter with an operating water depth of 6 feet. Each tank would have a volume of 1,885 ft^3 for a total volume of 18,850 ft^3.
- Provide a water treatment system capable of processing up to 3,375 gpm of recycled water with flexibility for greater capacity in the future (i.e., tighter water reuse and biofilter incorporation). The following should be included with the system:
  - Microscreen drum filter
  - Counter current packed column for degassing
  - An LHO for oxygenation
  - UV disinfection
  - Circulation pumps and VFDs

To provide flexibility and to increase biosecurity during disease outbreaks, it is recommended that the recirculating system be designed with two separate modules, each with five tanks.

8.2.7 Egg Incubation

Climate analysis has forecasted a significant increase in water temperatures in the future for the Marblemount Hatchery. To maintain temperatures suitable for egg development, water will need to be tempered. Implementing a recirculating incubation system will provide savings on energy costs associated with chilling or heating incoming water.

Currently, the hatchery has 132 Heath incubator half-stacks with 1,056 trays. Supplying each stack with 5 gpm would require a total flow rate of 660 gpm. To provide more water savings, we propose the use of full stacks, each with 16 trays, requiring only 66 stacks and a total flow rate of 330 gpm. A recirculating system for egg incubation requirements could be designed using 11 total modules, each containing 6 full stacks and requiring 30 gpm of flow. By reusing 50% of the water, each module would need 15 gpm of fresh makeup water; a 75% reuse system would require 7.5 gpm of makeup water. If additional flexibility is required in the future, additional equipment including pumps, chillers, and mixing sumps could be added or removed to create different sized modules.

8.2.7.1 Required Equipment

The following equipment is necessary for the hatchery:

- Set up 11 incubation recirculation modules each able to process up to 22.5 gpm of recycled flow, and each with the following:
  - A head tank or sump to mix reused and makeup water
  - UV disinfection system
  - Packed column for degassing and aeration
  - Pumps with VFD

8.2.8 Marblemount Summary

Based on the recommendations made above for Marblemount Hatchery, the facility would reduce overall water use by more than 1,300 gpm from November to January. Over the course of a full year, water savings would exceed 10,000 gpm while also significantly improving the current FIs for spring Chinook and Coho production, creating a healthier environment for the fish.

8.3 Kendall Creek Hatchery

The following management actions are recommended for Kendall Creek Hatchery:

- Fish health recommendations
- Kendall Creek intake replacement to meet NMFS standards, optimize flow control to the hatchery, and address flood control needs
- Well improvements
  - Well rehabilitation for existing Wells 1 through 5
  - New well pump for Well 1
  - Additional aeration for wells
- Addition of a new hatchery building to include the following:
  - Incorporation of a PRAS for winter steelhead early rearing
  - Incorporation of multiple PRAS systems for incubation

- Incorporation of a reuse system for raceways

Details for these systems are provided in the following sections.

8.3.1 Fish Health

In the future, decreasing initial fry stocking densities will lead to a less stressful state when fish are split into new tanks. Alternatively, not allowing densities to reach critical levels associated with BCWD outbreaks by splitting fish sooner should decrease instances and severity of disease. The same strategies will be useful in limiting severity of BKD. If these diseases persist and worsen in response to climate change, vaccines may become an important preventative measure for maintaining fish health.

8.3.2 Kendall Creek Intake Replacement

WDFW has requested funds within the 2021–2023 biennium capital budget to rebuild the intake screens and baffles at Kendall Creek Hatchery to meet current federal and state fish screening and fish passage criteria. The intake infrastructure condition is deteriorating and the intake needs replacement. Intake replacement is also recommended as a management action in this assessment in order for the structure to be appropriately robust for a wider future variation in flood conditions and to optimize flow control and availability to the hatchery. With limited information on the intake condition, an intake replacement cost is not included in the cost estimate for this project. Replacement costs are also already provided within the capital budget and could be escalated from 3 to 4% per year to the estimated date of implementation. If there are existing designs in progress for these replacements, the design flows should be compared to the flow increases identified in this document.

8.3.3 Well Improvements

There are five wells at Kendall Creek Hatchery used for groundwater supply. The hatchery staff note that all five wells are only producing a fraction of their original design. They also indicated that Wells 1 and 2 are an infiltration trench and production varies depending on river level. It is recommended that a thorough condition assessment, including inspection of the mechanical and electrical equipment, be performed now for each well, as well as every 10 years (at a minimum), to determine what improvements may be needed. Well inspections by video camera should also be performed to determine the condition of the well casings. If additional improvements do not result in the desired well capacity, WDFW might consider drilling new wells or consulting with a local geologist or driller on the optimal depth for water supply within the aquifer to determine if there would be any benefit to drilling to a different depth for existing wells.

The cost for each well to be re-developed is included in the cost estimate evaluation described in Section 9.4.

8.3.4 Winter Steelhead Early Rearing Partial Recirculating System

The winter steelhead production program is an important program that is limited in both water and space at the Kendall Creek Hatchery. Providing a new early rearing building for fry and fingerling culture would solve several issues at Kendall Creek. Incorporating water reuse into the production and adding more rearing tanks would provide significant water savings throughout the rest of the hatchery while providing lower DIs for producing quality fish.

This program produces 190,000 fry and 180,500 juveniles each year for a total biomass of approximately 903 lbs. To maintain a DI below 0.3, the required volume is approximately 280.34 ft^3; to maintain an FI below 1.2, a conservative threshold for the total required flow is 200 gpm (Table 4-15). The current program uses multiple small fry tanks for production, and there is not enough space or flow to meet the required DI and FI. Adding rearing units will provide space for the correct DI, and adding in a partial recirculation component will provide adequate water flow to combat the future effects of climate change.

Another benefit of implementing this reuse system would be the additional space freed up in raceways if winter steelhead juveniles were grown in the circular tanks. In the future, a more detailed design could incorporate a transfer schedule for fish throughout the circular tanks during the production cycle, but this effort is outside the scope of the current analysis.

8.3.4.1 Required Equipment and Upgrades

The following equipment and upgrades are required for this system:

- Construct a new building with an estimated size of 45 feet x 30 feet.
- Set up 24 circular tanks, each 4 feet in diameter with fry inserts with an operating water depth of 3.6 feet. Each tank would have a volume of 44.1 cubic ft for a total of 1058.4 cubic feet. Insert tanks operated at a depth of 1 foot would have a volume of 12.6 cubic feet.
- Provide a water treatment system capable of processing up to 200 gpm, with flexibility for greater capacity in the future (i.e., tighter water reuse and biofilter incorporation). The following should be included with the system:
  - Microscreen drum filter
  - Degassing and oxygenation
  - UV disinfection

- Circulation pumps and VFDs

To meet the total flow requirement of approximately 200 gpm for this program, based on the percentage of reuse, the following is required:

- For 50% reuse, at least 100 gpm of fresh makeup water entering the reuse system mixed with 100 gpm of recycled water leading to a total flow of 200 gpm is needed.
- For 75% reuse, at least 50 gpm of fresh makeup water entering the reuse system mixed with 150 gpm of recycled water is needed.

To provide flexibility for future operational changes and changes throughout the production cycle, it is recommended that this recirculating system be designed in modules. For this specific program, a design of two modules, each with 12 tanks and its own water treatment system, would provide enough flexibility and allow for isolation of some units if a disease outbreak were to occur.

8.3.5 Egg Incubation

Presently Kendall Creek Hatchery is utilizing 37 Heath-style incubators that have double stacks for an estimated 592 egg trays. Because it has been forecasted that Kendall Creek Hatchery will experience significantly elevated water temperatures in the future, we propose a recirculating egg incubation system that would provide savings on energy costs associated with chilling or heating water for eggs. A recirculating incubation system could be designed in modules with each containing 4 full stacks with 16 trays for a total of 64 trays. The standard flow rate for each stack is 5 gpm, meaning each module with 4 half-stacks would require 20 gpm of total flow. Reusing 50% of the water would require 10 gpm of fresh makeup water; 75% reuse would require 5 gpm of makeup water. If more flexibility is required in the future, more pumps and chillers could be added to create smaller or larger modules as needed for the various programs and for different biosecurity needs. This modification would require additional information and discussion with hatchery staff to meet the specific needs of their programs.

8.3.6 Partial Reuse for Raceways

Depending on the configuration and fish species reared, it appears that there are some options available to institute a PRAS system of some type for the outdoor raceways at Kendall Creek Hatchery. Utilizing a PRAS system in the raceways would help alleviate some of the issues with limited water in other locations at the hatchery. Additionally, this may allow various treatments of the water if the temperature or fish pathogens become problematic. Exact sizing of systems and equipment would need to be done on specific raceways at a later time.

8.3.6.1 Required Equipment

A water treatment system capable of processing effluent water from raceways is required. The following should be included with the system:

- Microscreen drum filter
- Degassing and oxygenation
- UV disinfection
- Chillers (if needed)
- Circulation pumps and VFDs
- Raceway cover with shade cloth

8.3.7 Kendall Summary

Based on the recommendations made for the Kendall Hatchery, the hatchery may increase the well water availability from 6,500 gpm to as high as 15,000 gpm by rehabilitating the well water supplies. This partial ground source water (Wells 1 and 2 are from the infiltration trench and output will vary depending upon river levels) would increase water availability. With rising temperatures, the cooler groundwater supply would provide protection against temperature extremes and decrease the risk of disease and parasite issues that would be expected to increase with rising water temperatures. Incorporation of packed columns/aeration tower to mechanically increase oxygen from the wells would provide an abundance of cold, oxygen-saturated water.

The winter steelhead partial reuse system addresses the shortfall in rearing space to achieve densities. This system allows these fish to be reared in half the water—100 gpm assuming a 50% PRAS with the flexibility to further reduce water consumption by reusing up to a 75% PRAS. The system would have flexibility to address years where the higher level of PRAS was necessary to maintain healthy water temperatures.

Partial reuse for raceways, depending upon which species were being reared in the raceways, along with a design that prioritized biosecurity, would enable the raceways to be operated on less water. Raceways could be designed with a pump-back system for each raceway with water savings ranging from 50 to 75%.

8.4 Samish Hatchery

The following management actions are recommended for Samish Hatchery:

- Fish health recommendations
- Friday Creek intake replacement to meet NMFS standards, optimize flow control to the hatchery, and address flood control needs
- Upgrades for Samish intake to resolve mechanical issues
- Addition of a new well system and associated infrastructure
- Improvements to incubation (new and existing):
    - Incorporation of a new incubation module
    - One additional headtank and 12 full-stacks (or 35 half-stacks) for incubation
    - Retrofitting existing incubation modules for water reuse
- Water reuse systems for raceways
    - Incorporation of a raceway reuse system for ponds 1-8 for fall Chinook
    - Renovation of Ponds 9–12 for a circular tank and reuse system
    - Renovation of Pond 13 for circular tanks and reuse system

Details for these systems are provided in the following sections.

8.4.1 Fish Health

The Samish Hatchery relies exclusively on surface water and currently has issues with increased turbidity of incoming water during some periods. Higher levels of TSS associated with increased turbidity can damage fish gills and skin, leaving fish more susceptible to external parasitic infections. Filtration to reduce TSS levels for fish rearing is recommended; this can be accomplished with a settling pond or microscreen filtration. This may be coupled with a UV disinfection system to deal with the possible increase in virulent pathogens that thrive in warming waters such as *F. columnare* and *A. salmonicida*.

8.4.2 Friday Creek Intake

WDFW has current plans to request funding for the design (FY 2023–2025) and construction (FY 2025–2027) to provide an intake that meets current state and federal standards for fish passage and screening of intakes. As described in the 2021–2023 Capital Budget Request by WDFW, the need for the request is multifold:

- The current fishway is undersized and the resulting turbulence does not provide passage within the range of flows required.
- The water surface drops over the weirs exceed WDFW fish passage criteria.
- The screens do meet criteria due to channel geometry and bypass location.
- The spillway and bypass outfall splash directly onto a concrete apron. The concern stated being that entrained juveniles could hit the apron and potentially be injured.
- Road improvements and bank stabilization are needed to protect against high flows.

As described in Section 6.4.3, the high-flow events will become more frequent and the low-flow events will slowly become earlier in the year. The preliminary design of a new intake is beyond the scope of this report; however, the contents of this report related to climatic changes (i.e., more low-flow periods and more frequent flood events in Friday Creek) should be considered during the design phase. The design of the new intake structure should have the capacity to accommodate these wider ranges of flow as well as the greater variability of the flows. The wider range and greater variability will directly affect the design of the fishway and screen structures.

8.4.3 New Well System

The feasibility of installing a well system capable of supplying 420 gpm of high-quality water to be used as makeup water for incubation should be investigated; see Section 8.4.4 below. An onsite or near onsite well system would allow egg incubation activities to return to Samish Hatchery (incubation currently takes place at Kendall Creek Hatchery).

8.4.4 Egg Incubation

The egg-take goal of the Samish and Whatcom Creek fall Chinook Salmon programs is 7.6 million, but according to the HGMP, up to 8.6 million eggs have been collected as recently as 2018 to supply other fall Chinook Salmon hatchery programs. For this analysis, we assume a maximum egg take of 9 million for the Samish Hatchery to accommodate potential future increases in egg collection. Currently, eggs are incubated offsite at the Kendall Creek Hatchery due to the lack of high-quality, clean water available at the Samish Hatchery. Once eggs reach the eyed stage they are transferred back to the Samish Hatchery for hatching, grow-out, and release.

The infrastructure at Samish Hatchery includes 1,008 Heath trays organized in 144 half-stacks that are in turn divided into groups of 24 stacks per head tank. The loading density of the Heath trays is approximately 7,200 eggs per tray. To meet a maximum demand of 9 million eggs, 1,250 trays are needed, which would require an additional 35 half-stacks with 7 trays each (245 trays total) and at least one additional head tank for the new trays.

To increase water savings and reduce operating costs of the egg incubation system, we propose that the facility transition to using full stacks of Heath trays. The feasibility of retrofitting the existing system to full stacks would depend on the ceiling height and available space in the current egg incubation building. The Samish Hatchery uses 7 out of 8 available trays in a half-stack for egg incubation; a full stack would use 15 trays with 1 tray left for mixing and/or cleaning purposes. Retrofitting the existing 144 half-stacks into 72 full stacks would provide 1,080 usable trays. An additional 12 full stacks (180 operational trays) would be required as well as an additional head tank. Existing head tanks and plumbing would also require retrofitting to accommodate the increased height of the full stacks.

A total of 7 modules would be needed, with each module including 12 full stacks. Each stack would require 5 gpm of flow or 60 gpm per module. To incorporate 50% or 75% water reuse for each incubation module, fresh makeup water requirements would be reduced to 30 and 15 gpm, respectively. The total flow requirement without recirculation for all 7 modules would be 420 gpm, less than half the water use for a half-stack system. The total required makeup flow for a recirculation system would be 210 (50%) or 105 gpm (75%). This would significantly reduce the groundwater requirements for egg incubation and the number of wells to be developed.

8.4.4.1 Required Equipment and Upgrades

The following equipment and upgrades are necessary for the Samish Hatchery:

- Develop wells to provide a total flow of 105 gpm for a 75% reuse system.
- Provide egg incubation recirculating modules, each capable of recirculating up to 36 gpm for a 75% reuse system.
    - A new module would include the following:
        - 12 full stacks
        - Head tank
    - All modules existing and new (7 total) would include the following:
        - UV disinfection system
        - Microscreen drum filter (for eggshell removal)
        - Packed column for degassing and aeration
        - Pumps and VFDs

8.4.5 Water Reuse Systems for Raceways and Ponds

Friday Creek is expected to experience worsening, prolonged periods of low flow from August through October in the future. Fortunately, production at Samish Hatchery occurs in November through March, which should somewhat insulate operations from drastic changes in the next several decades. The scope of this analysis does not include accounting for changes in behavior of the returning adult fish, which may have a major impact on hatchery operations.

To increase realized flow of the facility without relying on diminishing water availability in Friday Creek, we propose incorporating a partial recirculation system into Ponds 1–8. This would include two modules, each with four raceways. To maintain a DI of 0.3 and an FI of 1.2, the flow requirements for a fully stocked system would be approximately 9,500 gpm. This could be accomplished with only 2,375 gpm of fresh makeup water in a 75% recirculation system, leaving 825 gpm extra for use in other areas.

We also recommend renovating Ponds 9–12 by removing the center walls and adding 16-foot-diameter circular tanks. Each pond would be able to accommodate four tanks, for a total of 16 circular tanks in the current area of Ponds 9–12. These 16-foot circular tanks would also incorporate water reuse technology. The required flow for density thresholds would be approximately 2,800 gpm. This could be achieved with only 700 gpm of fresh makeup water in a 75% recirculation system, leaving up to 1,300 gpm extra flow for use in other areas.

Pond 13 is currently supplied with serial reuse water from Ponds 1–12. With the water savings achieved by installing PRAS technology, 2,125 gpm of fresh water would be available to supply Pond 13. To further capitalize on this makeup water, an additional PRAS setup could be added to Pond 13. The large area allows for multiple potential configurations. In the interest of simplicity, we propose the addition of 36 of the same 16-foot-diameter tanks that are suggested for Ponds 9–12. These would be designed in four tank modules that would allow for the same water processing equipment (UV, filters, etc.) to be used in both the Pond 9–12 system and the Pond 13 system. The 36 tanks would provide enough volume for the remaining fish not stocked into the other areas (currently Ponds 1–12) and would only require 5,904 gpm of flow. A recirculation rate of 75% would only require 1,475 gpm of fresh makeup water, less than the 2,125 gpm of fresh water that would become available when PRAS was implemented for Ponds 1–12, providing more flexibility for operations.

Table 8-1. Theoretical Use of Various Rearing Units at Samish Hatchery for the Production Goal of 6.5 Million Fish at 80 fpp.

Existing Rearing System	Existing Water Supply (gpm)	Proposed Update	Proposed Makeup Flow (75% reuse; gpm)	Process Flow with Recirculation (gpm)
Ponds 1–8	3,200	Raceway Reuse	2,375	9,500
Ponds 9–12	2,000	16 circular tank reuse system	700	2,800
Pond 13	0*	36 circular tank reuse system	1,475	5,904
Total	5,200		4,550	18,204

*Pond 13 is currently supplied with only serial reuse water from Ponds 1–12.

8.4.5.1 Required Equipment and Upgrades

The following equipment and upgrades are necessary for the Samish Hatchery:

- For Ponds 1–8, provide a water treatment capable of processing effluent that includes the following:
  - Microscreen drum filter *
  - Degassing and oxygenation
  - UV disinfection**
  - Chillers***
  - Circulation pumps and VFDs
  - Raceway cover with shade cloth
- For Ponds 9–12, the following should be renovated or provided:
  - Remove the center concrete wall.
  - Set up 16 circular tanks that are each 16 feet in diameter.
  - Provide a water treatment system capable of processing effluent that includes the following:
    - Microscreen drum filter*
    - Circulation pumps and VFD

    - Degassing and oxygenation
    - UV disinfection**
    - Chillers***
  - Cover the raceways with shade cloth.
- For the Pond 13, the following should be renovated or provided:
  - Set up 36 circular tanks that are 16 feet in diameter.
  - Provide a water treatment system capable of processing effluent that includes the following:
    - Microscreen drum filter*
    - Circulation pumps and VFD
    - Degassing and oxygenation
    - UV disinfection**
    - Chillers***
  - Cover the raceway with shade cloth.

* Analysis of feed rates required to determine necessity.

** Optional addition of UV disinfectant if disease loads increase due to climate changes.

*** It is possible to include chillers in water reuse systems, but due to high cost of operation it is recommended to go to a higher recirculation rate system which would include additional equipment such as bio filters, drum filter, and UV disinfection.

8.4.6 Summary

The Samish Hatchery is severely limited by its rearing volume and available flows from Friday Creek. To meet production goals with the existing infrastructure, it must incorporate significant amounts of water reuse technology. Ultimately, the addition of the large PRAS setups proposed in this section may not be as desirable as a full facility rebuild. WDFW may also consider implementing the proposed PRAS setups on the Samish River property instead of at the current facility to ensure a more consistent water source for future operation.

8.5 Goldendale Hatchery

The following management actions are recommended for Goldendale Hatchery:

- Fish health recommendations
- Incorporation of a recirculating egg incubation system
- Partial reuse system for raceways

- Outdoor rearing area coverage
- Water supply improvements
    - Repair the cistern and dam boards for collection of spring water.
    - Maintain and/or update piping runs from spring to hatchery to maximize water collection.

Details for these systems are provided in the following sections.

8.5.1 Fish Health

Like BCWD issues at Kendall Creek, Goldendale currently deals with the disease during the early fry stage. However, the disease is more often seen after fish are moved into raceways. The stress event of handling and transfer is the likely outbreak catalyst. This event is unavoidable, but increasing immunocompetence of fry before their transition outdoors to surface water can be addressed. Implementing a system that incorporates some surface water to indoor fry several weeks prior to splitting can expose them to low levels of pathogens and allow for immune development. Signs of BCWD will still be present after transition, but water mixing may reduce the severity and length of the outbreak.

Ensuring raceways are thoroughly cleaned and disinfected will also help in reducing disease. Currently, raceways are chipped and have plant growth throughout the year. If raceways are deteriorated to the point that water seeps through the walls, larger fish in one raceway can shed significant amounts of pathogen that can infiltrate a neighboring raceway. Other facilities have altered their fish movements to limit stocking young, immunocompromised fish in raceways next to older fish; this has led to a decrease in total mortalities and reduction in antibiotic use (David Burbank, Fish Pathologist, IDFG, personal communication). Another suggestion would be to resurface and seal existing raceways to prevent seepage and reduce the ability of plants and algae to adhere. However, production in the raceway would stop and this process can take over a week, depending on the products used and the current condition of the concrete.

8.5.2 Egg Incubation

Because Goldendale Hatchery will experience significantly elevated water temperatures in the future, we propose a recirculating egg incubation system that would provide savings on energy costs associated with chilling water for eggs. For example, a recirculating incubation system could be designed in modules with each containing 4 stacks with 16 trays for a total of 64 trays. The standard flow rate for each half-stack is 5 gpm, meaning each module with 4 half-stacks would require 20 gpm of total flow. Reusing 50% of the water would require 10 gpm of fresh makeup water while 75% reuse would require 5 gpm of makeup water. If more flexibility is required in the future, more pumps and chillers could be added to create smaller or larger modules as needed for the various programs and for different biosecurity needs.

8.5.2.1 Required Equipment

A recirculating egg incubation module with 64 trays is needed. Each module can recirculate up to 15 gpm for a 75% reuse system. This system would be capable of incubating 5,000–10,000 eggs per tray depending on fish species.

8.5.3 Partial Reuse for Raceways

Depending on the configuration and fish species reared, it appears there are some options available to institute a PRAS system of some type for the outdoor raceways at Goldendale Hatchery. Utilizing a PRAS system in the raceways would help to alleviate some of the issues with limited water in other locations at the hatchery. Additionally, this may allow various treatments of the water if the temperature or fish pathogens become problematic. Exact sizing of systems and equipment would need to be done on specific raceways at a later time.

Specifically, we envision utilizing the existing two adult rearing ponds for Rainbow Trout, and outfitting the ponds with the necessary equipment to provide reuse capabilities. A collection box could be added at the rear of the raceways where effluent flow is combined and solids are separated. Pumps would then move fairly clean water back to the heads of the raceways into a degassing/aeration column outfitted with an LHO to achieve a 50–70% reuse rate of water. This would increase the flows available for the raceways while providing some reduction of water usage, which would benefit other parts of the hatchery. A microscreen drum filter and UV disinfection would be utilized to provide cleaner reuse water. Fresh water would be mixed with the flow from the degassing/aeration column at the correct ratio to achieve the desired reuse rate.

Another option considered was utilizing the remaining 10 outdoor raceways and combining them into two groups, one of six raceways and one of four raceways (depending on species reared), and outfitting them with equipment similar to that described above to reuse water and reduce total water needed with these raceways.

More discussion with hatchery staff is needed to completely identify whether these options would work within their production schemes for the various species of fish reared at the facility.

8.5.3.1 Required Equipment

A water treatment system capable of processing effluent water from raceways is needed that includes the following:

- Microscreen drum filter
- Degassing/aeration and oxygenation
- UV disinfection
- Circulation pumps and VFDs
- Collection boxes

8.5.4 Cover Outdoor Rearing Areas

Replacing the existing bird screen/netting over the raceways with shade cloth and incorporating either bird netting or shade cloth around the periphery should be considered; see general recommendations above in Section 8.1.3. The current bird netting is 2 1/2-inch x 2 1/2-inch polyethylene over a 17,437 ft^2 area (185.5 ft x 94 ft). The perimeter is 559 feet. Netting frames are 18.25 feet tall. Structural supports, counterweights, and anchors would need to be evaluated for capacity prior to installing shade cloth.

8.5.5 Water Supply Improvements

Limited information was provided regarding the condition of the spring water collection structure. It was reported that the cistern has leaks and that dam boards need replacement. Given the limited head available to drive flows to the hatchery, it is vital that existing head be preserved. Hatchery personnel have reported difficulties in obtaining sufficient flows at certain times during the year. Sealing leaks in the cistern and replacing the dam boards with a dual leaf gate to ensure that the maximum head is available at the spring collection structure is recommended.

Limited information was provided regarding the main supply pipe type and diameter. As-built drawing H115531c002.tif shows a short section of 24-inch transit pipe that supplies a head box where a 20-inch inside diameter (ID) pipe of unspecified material type continues to the hatchery. A preliminary investigation shows that surface roughness is a key factor in determining whether the pipe can supply the full 10 cfs of the water rights. Cast iron and concrete pipes may not be able to supply the entire 10 cfs. Steel and plastic pipe appear to be able to supply the 10 cfs, provided that the pipes are maintained and fouling is kept to a minimum. It is recommended that regular maintenance of the pipe over its life span be required and possibly increasing its size when replacement is necessary.

8.5.6 Goldendale Hatchery Summary

Based on the recommendations for the Goldendale Hatchery, an incubation reuse system would provide protection for the incubation stage against future warm water associated with climate change and would allow the incubation system to operate on as little as 5 gpm reuse.

Partial reuse for raceways per the conceptual design would enable the raceways to be operated on 50% of the water, and partitioning the reuse system into multiple systems would allow for biosecurity to accommodate rearing multiple species without cross-contamination. This would have a water savings up to 2,100 gpm or more depending on the time of year and if a higher level of reuse was needed in the future.

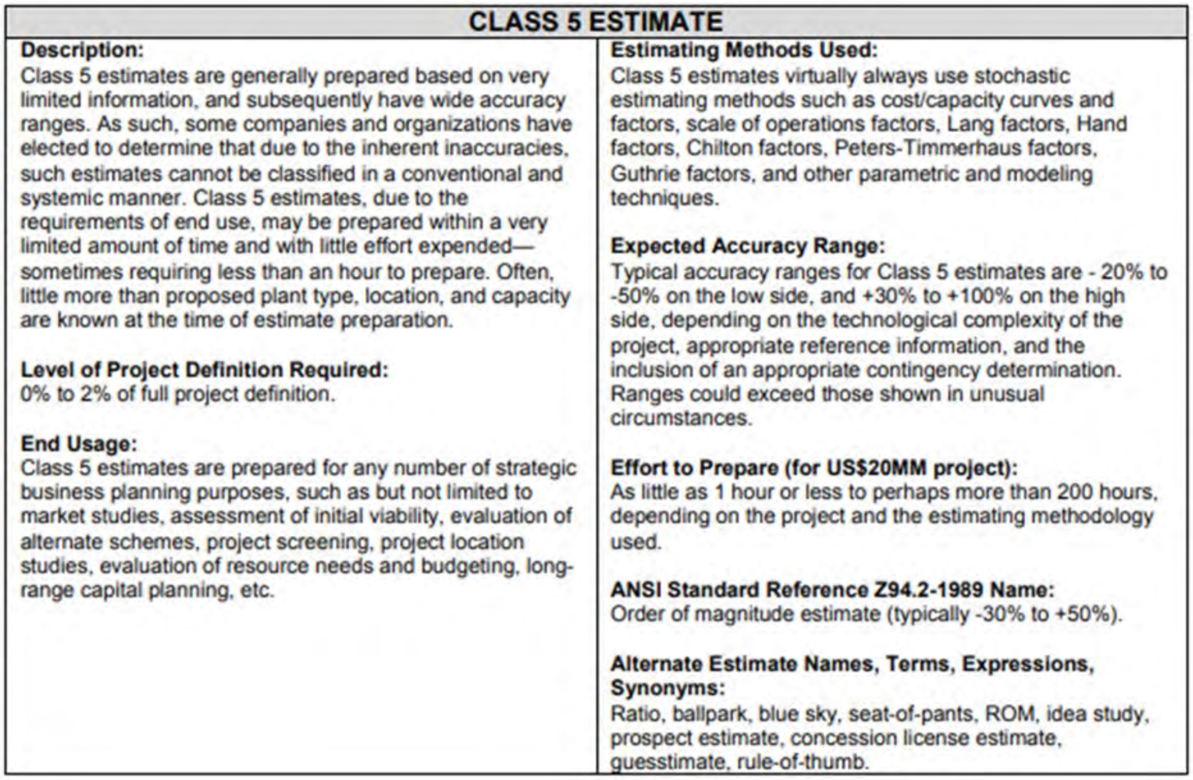
9.0 Opinion of Probable Construction Costs

9.1 Introduction

McMillen has utilized historical costs as a self-performing general contractor in the performance of similarly technical projects, as the basis of our Preliminary Concept Planning – Opinion of Probable Construction Cost (OPCC) estimate for this Project. Additionally, McMillen has solicited pricing or utilized recently received material quotes for similar materials and equipment or components. An application of appropriate overhead and profit markups have been included in presented project pricing.

9.2 Estimate Classification

This OPCC estimate is consistent with a Class 5 estimate as defined by the AACE classification system, as shown in the Figure 9-1 below. For purposes of this project, McMillen has utilized an accuracy range of -30% to +50% in the estimates presented in Section 9.4 below.



CLASS 5 ESTIMATE

Description:
Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systemic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with little effort expended—sometimes requiring less than an hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation.

Level of Project Definition Required:
0% to 2% of full project definition.

End Usage:
Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.

Estimating Methods Used:
Class 5 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques.

Expected Accuracy Range:
Typical accuracy ranges for Class 5 estimates are - 20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.

Effort to Prepare (for US$20MM project):
As little as 1 hour or less to perhaps more than 200 hours, depending on the project and the estimating methodology used.

ANSI Standard Reference Z94.2-1989 Name:
Order of magnitude estimate (typically -30% to +50%).

Alternate Estimate Names, Terms, Expressions, Synonyms:
Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of-thumb.

Figure 9-1. AACE Class 5 Estimate Description

9.3 Cost Evaluation Assumptions

The following assumptions were made while developing the Class 5 cost estimates for this alternatives analysis:

- No asphalt paving has been included in this cost estimate. All exterior improvement areas have been assumed as placement and compaction of a 6-Inch layer of aggregate base course gravel.
- The quantities and descriptions with the detailed cost report included in the appendices of this document constitute the assumed scope and quantification of the work associated with this project.
- The new buildings are assumed to be Pre-Engineered Metal Buildings (PEMB) with minor architectural interior/exterior elements. Hatchery buildings to be slab on grade with floor trenches for pipe runs.
- Site geotechnical properties have not been evaluated but are assumed to be good for construction at the hatcheries.
- All concrete process structures assumed to have 12” walls and 12” slabs. Concrete strength assumed at 4,000-4,500 psi.
- Site pipe to be C900/C905. Interior pipe assumed to be Sched 80 PVC.
- Simple HVAC system is included with humidity control for the new hatchery buildings.
- 25% contingency is applied to the Class 5 Cost Estimate as an average contingency for this level of cost estimate.
- All costs are presented in 2023 dollars and will need to be escalated as appropriate for future construction years.

9.4 Hatchery Cost Estimates

The Opinion of Probable Construction Costs for the hatchery improvements for each facility are provided in Appendix E. Since the exact time of construction for each of the proposed improvements is unknown, these construction costs are illustrated in today’s dollars. If WDFW decides to move forward with the improvements and has identified an approximate timeframe, it is recommended that the costs be escalated 3 to 4% per year to the anticipated year of construction. The construction costs for each of the hatcheries is identified below in Table 9-1.

Table 9-1. Climate Resiliency Proposed Modifications

Description	Marblemount	Kendall Creek	Samish	Goldendale
Base Construction Costs	**$10,999,000**	**$3,773,000**	**$10,467,000**	**$2,227,000**
Contingency (Const Cost 25%)	$2,750,000	$944,000	$2,617,000	$557,000
Overhead (7%)	$962,000	$330,000	$916,000	$195,000
Profit (8%)	$1,100,000	$377,000	$1,047,000	$223,000
Bond Rate (Approximate 1%)	$137,000	$47,000	$131,000	$28,000
Total Base Construction Price	**$15,948,000**	**$5,471,000**	**$15,178,000**	**$3,230,000**
Design, Permitting, Construction Assistance	$2,392,000	$821,000	$2,277,000	$485,000
Total Project Cost - Base Bid	**$18,340,000**	**$6,292,000**	**$17,455,000**	**$3,715,000**
Accuracy Range 30%	$12,838,000	$4,404,000	$12,219,000	$2,601,000
+50%	$27,510,000	$9,438,000	$26,183,000	$5,573,000

10.0 Conclusions and Recommendations

This report provides valuable information on how climate change could impact the operations of four WDFW hatcheries and describes options that can be taken to increase the resiliency of these facilities. NHC has performed an in-depth analysis of available hydrologic data and applicable projections to forecast changes at each facility. In general, surface water temperatures will increase at a faster rate than groundwater sources, and air temperatures will be warmer during the normal winter season, leading to longer and drier summer periods.

The hatchery that is positioned to experience the most drastic shift relative to its current climate is Marblemount as it transitions from a snow-dominated to a rainfall-dominated precipitation regime. This will shift the current pattern of low and peak flows, creating more high-flow events in the winter and extreme low-flow periods becoming more frequent in late summer and early fall.

For Kendall Creek, water temperatures will increase, and flows will decrease significantly in August at the beginning of the spring Chinook egg-take season. Periods of low creek flows will also become more common in the late winter and early spring, which will cause issues in March when hatchery water use peaks.

The Samish Hatchery is mainly active from November through May, and periods of low flow in Friday Creek will become increasingly common in April and May as staff prepare for fish releases. Projected temperature increases in Friday Creek are expected to be larger, by approximately 0.5°F, than those for the Samish River for the same time horizon.

Finally, Goldendale’s unique water source makes climate projections difficult, but the facility is forecasted to experience a smaller increase in air temperature compared to the other facilities, which should correspond to a smaller increase in the water temperature of the spring. The spring should also remain a consistent source of water for the hatchery since water infiltration in the surrounding area is expected to increase and should recharge the source aquifer.

To meet WDFW’s goal of maintaining a healthy environment for fish and wildlife while supporting conservation and sport fisheries goals, increasing the resiliency of hatchery facilities in the face of climate change will be vital in the near and distant future.

Some recommendations that would help achieve this goal include

- maintaining and repairing existing concrete rearing structures to provide a better environment for the fish and staff,

- covering outdoor rearing areas to reduce thermal radiation and decrease predation and disease transmission
- evaluating existing power availability and considering upgrades and expansion as needed, and
- remaining on the leading edge of fish health through strong biosecurity measures and adoption of new therapeutants and drugs as they become available.

Priority should be placed on incorporating water recirculation systems to provide a buffer against reduced flows, as well as to reduce energy costs associated with expanded water treatment technologies (e.g., chilling and oxygenation) that may be required to offset climate impacts. These include general recommendations such as adding recirculating egg incubation systems, incorporating partial recirculation aquaculture systems overall, and developing more specific systems for large fish production programs including Kendall Creek's winter steelhead and Marblemount's spring Chinook.

Future discussions about prioritizing funds and improvement projects will be important when determining WDFW's management direction in the near future. A review meeting is scheduled with WDFW, McMillen, and NHC to discuss the current report. Recommendations proposed in this report are subject to change depending on feedback from WDFW, and recommendations will be finalized after a follow-up meeting. Based on the results from the climate change impacts analysis described in this report, and review of existing conditions at each facility, it is necessary to address the potential impacts from climate change through the proposed recommendations in this report to ensure that hatchery operations continue to provide valuable resources for the State of Washington and its citizens.

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Appendix A. Interview Documentation

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McMillen

		Job No.	23-034	No.	
Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
Subject	Marblemount Hatchery	Checked		Date	
Task	Questionnaire - Data Collection	Sheet	1	Of	1

The following questionnaire spreadsheet is for the collection of data for the subject Fish Hatchery Climate Change Vulnerability Assessment Project. This sheet contains the general information and data required for the project. Place a check mark next to the info that has been uploaded to the SharePoint site.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ____________________ Date: __________
Name: ____________________ Date: __________
Name: ____________________ Date: __________

Hatchery Name: Marblemount Fish Hatchery
Address: 8319 Fish Hatchery Road Marblemount WA 98267
Year Built: 1946

Data Collection: Collection

- ________ As-Built Drawings or most recent drawings of the facility.
- ________ Geotechnical Report/ information
- ________ Well Information
  - ________ Drillers Logs
  - ________ Well Capacity Tests

- ________ Water Right Information
- ________ Groundwater table records (if applicable)
- ________ Production Reports - Species, numbers, biomass, feed rates, etc.
- ________ Production Goals - If not meeting production, or future goals
- ________ Descriptions of Hatchery Water Sources - Location, pump/gravity, flow, treatment required, etc.
  Ground water, springs, surface water, treated city water?
- ________ Hatchery Water Quality Reports
- ________ Hatchery Water Yearly Temperature data
- ________ Any Streamflow records (if available)
- ________ Air temperature records (if available)
- ________ Hatchery Effluent Treatment Reports/Requirements? NPDES Permit?
- ________ Monthly water use report or schedule. Water usage by area per month for a year.
  Or fill out the tab "Water Budget"
- ________ Water Treatment equipment, cut sheets, performance info, etc.
- ________ Pump list with pump curves, production rates, etc.
- ________ Power
  - ________ Utilitiy: ____________________
  - ________ Transformer Size: ____________________
  - ________ Backup Power: ____________________
  - ________ ATS: ____________________
  - ________ Power Usage (12 months worth, utility bills)
  - ________ Solar?

McMillen

		Job No.	23-034	No.	
Project	WDFW Climate Change Sensitivity Assessment	Computed		Date	
Subject	Marblemount Hatchery	Checked		Date	
Task	Questionnaire - Process Flow	Sheet	1	Of	1

Please provide information on the process flow through the hatchery.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ____________________ Date: ____________
Name: ____________________ Date: ____________
Name: ____________________ Date: ____________

Water Supply

Please provide a narrative of the water sources for the facility and which take priority? (Include seasonal changes)

Cascade River Intake provides surface water for the facility year round. Clark creek intake provides surface water until it begins to dru up in the Summer. Jordan creek intake provides gravity fed surface water almost year round, but also drys up during the summer. Jordan and Cascade get very leafy during the fall months and cause clogged intakes frequently. Wells 1 - 5 provide steady well water for the incubation room and raceways 1 - 3 to hold broodstock salmon. They attempted to drill well 6, and failed due to the amount of clay sediment in the hole.

Water Rights	CFS/GPM	Amount currently used
Well		
Surface		
Spring		

Wells	A		gpm production rates
	B		gpm production rates
	C		gpm production rates

Please provide any seasonal observations for the water supply with regards to flooding /drought events/areas of erosion

In the summertime, Jordan and Clark creek tend to dry up a bit, and we turn them off. In the fall, Cascade and Jordan get a lot of leafy debris and cause issues. The wells are steady, but we do have to turn them down during the summer to prevent them from sucking air. In the summer we put sandbags on the existing infastructure that diverts the creek into our intake in order for the intake and the fish ladder to function propperly.

Please provide a description of the exisitng condition of the intake and/or well infrastructure

Jordan creek infastructure is in good condition. Cascade intake structure has a loose screen on the far left side (it is in the works to get this repaired). Clark creek infastructure is in good condition. All the wells could use a rehab, but the infastructure is in good condition.

Water Delivery system

Please provide a narrative of how the water flows through the facility and any water treatment along the way.

Jordan creek is gravity fed and runs through a pipeline that meets up with a common pipeline that combines all 3 surface water sources. Cascade intakes runs from the intake to the settling pond, and from the settling pond to the pumphouse where it runs into the common pipeline. Clark creek runs from the clark creek intakes to the clark creek pumphouse and into the common pipeline. The wells all run together into the well tower and to the incubation room and raceways 1 - 3.

What issues do you currently have with the water distribution system?

infrastructure somewhat dated

on capital budget for rebuild for the full hatchery - 6 to 8 years from breaking ground

Effluent Discharge and Treatment

Please provide a narrative of where the water is discharged from the hatchery and any existing issues with the effluent.

All of the effluent water flows into clark creek above the intake and either flows through the adult pond, through the old steelhead channel, or into the release channel. From there is will go through the attraction channel and settle out before making it to the river.

We can also divert the effluent flow from 1-12 straight into the attraction channel.

Please describe any existing or planned effluent treatment for the facility

assuming PA ponds for rebuild

are under general permit….does not have the oxygen or temp impairment that samish had, kendall has temperature

testing for dissolved and total settleable solids

McMillen		Job No. 23-034	No.
Project	WDFW Climate Change Vulnerability Assessment	Computed	Date
Subject	Marblemount Hatchery	Checked	Date
Task	Questionnaire - Rearing Facilities	Sheet 1	Of 1

Please provide information on the rearing facilities and add any additonal notes on the sysetms or issues with the systems.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ______________________ Date: ____________

Name: ______________________ Date: ____________

1 Incubation: Describe the incubation space and any special requirements.

Inubator Types:

Number of Incubators:

Flow Rate:

Standard loading eggs/incubator

Rearing: Identify all of different types of rearing vessels. Copy and Insert additional types of rearing units as needed for the full hatchery.

Rearing A: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Standard Raceways (21), 3 only receive well water, an additional 3 that could have a small amount of well water, otherwise surface water

	Linear		Circular	
Length (ft)		ft, OR		ft Diameter
Width (ft)		ft		
Wall Height (ft)		ft		ft
Operating Depth		ft		ft
Number of units				
Flow Rate		gpm per rearing unit		

Rearing B: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

16'-dia Circular tanks (3)

	Linear		Circular	
Length (ft)		ft, OR	16	ft Diameter
Width (ft)		ft		
Wall Height (ft)		ft		ft
Operating Depth		ft		ft
Number of units				
Flow Rate		gpm per rearing unit		

Rearing C: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Channel ponds (asphalt lined, 1/4 acre) (4)

	Linear		Circular	
Length (ft)		ft, OR		ft Diameter
Width (ft)		ft		
Wall Height (ft)		ft		ft
Operating Depth		ft		ft
Number of units				
Flow Rate		gpm per rearing unit		

Rearing D: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Adult pond (1/4 acre)

	Linear		Circular	
Length (ft)	300	ft, OR		ft Diameter
Width (ft)	12	ft		
Wall Height (ft)		ft		ft
Operating Depth		ft		ft
Number of units				
Flow Rate		gpm per rearing unit		

Adult Holding/ Spawning: Description (Circulars, raceway, pond,...)

Troughs (16) 112 cu ft each

	Linear		Circular	
Length (ft)		ft, OR		ft Diameter
Width (ft)		ft		
Wall Height (ft)		ft		ft
Operating Depth		ft		ft
Number of units				
Flow Rate		gpm per rearing unit		

Please provide a description of the overall conidition of the rearing vessels.

infrastructure is old

channel ponds will be filled in and 200'X 20' raceways installed in their place (8)

McMillen

		Job No.		No.	23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
Subject	Marblemount Hatchery	Checked		Date	
Task	Questionnaire - Species A Production	Sheet	1	Of	1

Please provide information on the production goals for Species A. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ______________________ Date: ____________

Name: ______________________ Date: ____________

Name: ______________________ Date: ____________

1 Provide the following information on production for Species A.

Species: ____________

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = ____________

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = ____________

Final Production Goal

____________ # of fish

____________ Lbs of fish

# of Eggs Incubated

____

# of Fry ____________ % survival

____

Fry Rearing Tank ____________

Size at Transfer #1 ____________ FPP or ____________ inches

Biomass at Tranfer ____________

____________ % survival

# of Juveniles

____

Juv Rearing Tank ____________

Size at Transfer 2 ____________ FPP or ____________ inches

Biomass at Tranfer ____________

____________ % survival

# of Adults/Outplants

____

Adult Rearing Tank ____________

Size at Outplant ____________ FPP or ____________ inches

Biomass at Outplant ____________

McMillen		Job No.	No. 23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed	Date
Subject	Marblemount Hatchery	Checked	Date
Task	Questionnaire - Species B Production	Sheet 1	Of 1

Please provide information on the production goals for Species B. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ______________ Date: ______________

Name: ______________ Date: ______________

Name: ______________ Date: ______________

1 Provide the following information on production for Species B.

Species: ______________

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = ______

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = ______

Final Production Goal

______ # of fish

______ Lbs of fish

# of Eggs Incubated

______

# of Fry ______ % survival

______

Fry Rearing Tank ______

Size at Transfer #1 ______ FPP or ______ inches

Biomass at Tranfer ______

______ % survival

# of Juveniles

______

Juv Rearing Tank ______

Size at Transfer 2 ______ FPP or ______ inches

Biomass at Tranfer ______

______ % survival

# of Adults/Outplants

______

Adult Rearing Tank ______

Size at Outplant ______ FPP or ______ inches

Biomass at Outplant ______

		Job No.	No. 23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed	Date
Subject	Marblemount Hatchery	Checked	Date
Task	Questionnaire - Species C Production	Sheet 1	Of 1

Please provide information on the production goals for Species C. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ______________________ Date: __________

Name: ______________________ Date: __________

Name: ______________________ Date: __________

1 Provide the following information on production for Species C.

Species: __________

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = __________

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = __________

Final Production Goal

__________ # of fish

__________ Lbs of fish

# of Eggs Incubated

____

# of Fry __________ % survival

____

Fry Rearing Tank __________

Size at Transfer #1 __________ FPP or __________ inches

Biomass at Tranfer __________

__________ % survival

# of Juveniles

____

Juv Rearing Tank __________

Size at Transfer 2 __________ FPP or __________ inches

Biomass at Tranfer __________

__________ % survival

# of Adults/Outplants

____

Adult Rearing Tank __________

Size at Outplant __________ FPP or __________ inches

Biomass at Outplant __________

McMillen		Job No.	No. 23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed	Date
Subject	XXX State Hatchery	Checked JT	Date
Task	Questionnaire - Water Budget	Sheet 1	Of 1

The water budget will help to identify monthly usage of water by the hatchery production. Understanding how the water is distributed across each species and rearing vessel/life stage per month will support the evaluation and methods to improve water usage/conservation.

As some species have a longer rearing cycle at a hatchery than one year, please illustrate the water usage over a two year program. The example below provides context. Overwrite the Data per your program.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: David Dismore Date:
Name: Michelle Hoftell Date:
Name: Date:

Surface Well

		Rearing Vessel	Jan Flow Rate (gpm)	Feb Flow Rate (gpm)	Mar Flow Rate (gpm)	Apr Flow Rate (gpm)	May Flow Rate (gpm)	Jun Flow Rate (gpm)	Jul Flow Rate (gpm)	Aug Flow Rate (gpm)	Sep Flow Rate (gpm)	Oct Flow Rate (gpm)	Nov Flow Rate (gpm)	Dec Flow Rate (gpm)
Species A - Ross Lake Rainbow														
	Incubation	Heath Trays					18	22	22					
	Fry Rearing	Intermediate Troughs								165	165	165		
	Juvenile Rearing	Circulars	32	32	32	32								
	Outplan Rearing (Captive Brood)	Raceways	612	612	612	612	612	612	612	612	612	612	612	612
Species B - Spring Chinook														
	Incubation	Heath Trays							64	282	143	138	138	74
	Fry Rearing	Intermediate Troughs	375	375										150
	Juvenile Rearing	Raceways			1224	1224	1224	1224	561	561	561			
	Yearling Rearing	Channel Pond	2040	2040	2040				2040	2040	2040	2040	2040	2040
	Broodstock	Raceways						618	618	618				
Species C - Summer Chinook														
	Incubation	Heath Trays	15									20	20	15
	Fry Rearing	Intermediate Troughs		100	100									
	Juvenile Rearing	Raceways				306	306	306						
	Broodstock	Raceways								918	918	918		
Species D - Coho														
	Incubation	Freestyles										20	20	20
	Incubation	Heath Trays	105	33										72
	Fry Rearing	Raceways		612	918	918	918	918	3366	3366	3366	3366	3366	3366
	Yearling Rearing	Channel Pond	2040	2040	2040	2040				2040	2040	2040	2040	2040
Species D - Skagit Chum														
	Incubation	Heath Trays	227	82	67	67							193	227
	Fry Rearing	Intermediate Troughs			125	125	300							
	Juvenile Rearing													
	Broodstock	Raceways										612	612	612
		Total (gpm)	5446	5926	7158	5324	3378	3700	7283	10602	9845	9931	9041	9228
		Total (cfs)	12.1	13.2	15.9	11.9	7.5	8.2	16.2	23.6	21.9	22.1	20.1	20.6

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)
				18	22	22					
							165	165	165		
32	32	32	32								
612	612	612	612	612	612	612	612	612	612	612	612
						64	282	143	138	138	74
375	375										150
		1224	1224	1224	1224	561	561	561			
2040	2040	2040				2040	2040	2040	2040	2040	2040
					618	618	618				
15									20	20	15
	100	100									
			306	306	306						
							918	918	918		
									20	20	20
105	33										72
	612	918	918	918	918	3366	3366	3366	3366	3366	3366
2040	2040	2040	2040				2040	2040	2040	2040	2040
227	82	67	67							193	227
		125	125	300							
									612	612	612
5446	5926	7158	5324	3378	3700	7283	10602	9845	9931	9041	9228
12.1	13.2	15.9	11.9	7.5	8.2	16.2	23.6	21.9	22.1	20.1	20.6

McMillen		Job No.	23-034	No.	
Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
Subject	Marblemount Hatchery	Checked		Date	
Task	Questionnaire - Process Flow	Sheet	1	Of	1

Please provide information on the fish health at the hatchery.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ____________________ Date: __________

Name: ____________________ Date: __________

Name: ____________________ Date: __________

Water Supply

List the pathogens of concern for the facility:

low level BKD for chinook and yearling coho

bacterial cold water

costia and trichodine

skagit river is IHN positive system but has not been seen at Marblemount for ~ 10 years

cascade flows into skagit

Please provide any seasonal observations for the pathogens of concern at the facility

BKD in the winter and going into spring of the yearly chinook program

spring chinook adults - frunc and columnaris - late in brood cycle, near spawning. They are on well water at that time.

Please provide any existing treatments or mitigation measures to protect fish health

broodstock treated with formalin

juveniles can be treated with formalin or salt

McMillen

Project	WDFW Climate Change Vulnerability Assessment	Job No. 23-034 Computed	No. Date
Subject	Kendall Creek Hatchery	Checked	Date
Task	Questionnaire - Data Collection	Sheet 1	Of 1

The following questionnaire spreadsheet is for the collection of data for the subject Fish Hatchery Climate Change Vulnerability Assessment Project. This sheet contains the general information and data required for the project. Place a check mark next to the info that has been uploaded to the SharePoint site.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name:	Kristofer G. Flowers	Date:	16-Mar
Name:		Date:	
Name:		Date:	

Hatchery Name: Kendall Creek Hatchery
Address: 7100 Hatchery Road
Year Built: Current building 1952, original site 1897

Data Collection: Collection

- __________ As-Built Drawings or most recent drawings of the facility.
- __________ Geotechnical Report/ information
- __________ Well Information
    - __________ Drillers Logs
    - __________ Well Capacity Tests
- __________ Water Right Information
- __________ Groundwater table records (if applicable)
- __________ Production Reports - Species, numbers, biomass, feed rates, etc.
- __________ Production Goals - If not meeting production, or future goals
- __________ Descriptions of Hatchery Water Sources - Location, pump/gravity, flow, treatment required
    - Ground water, springs, surface water, treated city water?
- __________ Hatchery Water Quality Reports
- __________ Hatchery Water Yearly Temperature data
- __________ Any Streamflow records (if available)
- __________ Air temperature records (if available)
- __________ Hatchery Effluent Treatment Reports/Requirements? NPDES Permit?
- __________ Monthly water use report or schedule. Water usage by area per month for a year.
    - Or fill out the tab "Water Budget"
- __________ Water Treatment equipment, cut sheets, performance info, etc.
- __________ Pump list with pump curves, production rates, etc.
- __________ Power
    - __________ Utilitiy:
    - __________ Transformer Size:
    - __________ Backup Power:
    - __________ ATS:
    - __________ Power Usage (12 months worth, utility bills)
    - __________ Solar?

		Job No.	23-034	No.	
Project	WDFW Climate Change Sensitivity Assessment	Computed		Date	
Subject	Kendall Creek Hatchery	Checked		Date	
Task	Questionnaire - Process Flow	Sheet	1	Of	1

Please provide information on the process flow through the hatchery.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: Kristofer G. Flowers Date: 16-Mar

Name: Date:

Name: Date:

Water Supply

Please provide a narrative of the water sources for the facility and which take priority? (Include seasonal changes)

Kendall is supplied with water from 5 well sites and a gravity system from Kendall Creek.

Water Rights			CFS/GPM	Amount currently used
	Well	1,2	4950 GPM	2400 GPM
	Well	3,4,5	11000	4100 GPM
	Well	DOMESTIC	20 GPM	20 GPM
	Surface		22.36 CFS	8.06 CFS
	Spring		NDA	

Wells	A	1200	gpm production rates
	B	1200	gpm production rates
	C	300	gpm production rates
	D	2000	gpm production rates
	E	1800	gpm production rates

Please provide any seasonal observations for the water supply with regards to flooding /drought events/areas of erosion

Wells 1/2 are an infiltration trench and production varies depending on river level

multiple flooding events, major storm took out primary production wells, had to use surface water for everything during that time. When kendall creek floods, it jumps up and down very quickly. Water going down after 12 hours. Snowmelt can create flooding in north fork of nooksack.

Please provide a description of the exisitng condition of the intake and/or well infrastructure

Kendall Creek gravity intake is non-compliant. All wells are producing only a fraction of the original

Water Delivery system

Please provide a narrative of how the water flows through the facility and any water treatment along the way.

Well #1 currently has no pumps currently installed on it. Well #2 has 2 pumps that provide between

Two primary production wells (4 and 5) are out back by 1/4 acre ponds 1-3. Pumped to aeration tower and pumped from there to anywhere in facility. The 3 smaller production wells (1-3). 1 and 2 not routed through aeration tower. Mostly used for mixing, not directly on to population of fish since it has not been degassed and DO is low. Well 3, is adjacent to 1 and 2, does get routed through aeration tower and water can be used anywhere in the facility.

Old wood stave intake right on Kendall Creek. Improvements needed to bring to compliance. It serves screen box area where fish are screened out. Fish enter for about 100 yards and go back out at plunge pool. Surface water delivered to raceway series 4 (standard) and raceway series 8 (super raceways). No LHO's, oxygen etc.

What issues do you currently have with the water distribution system?

Many non-functioning valves and lack of production from aging pumps and infrastructure.

again 1 and 2 not going to aeration tower; this will be good water source for the PRAS system that will be in Pond 3. Typical PRAS equipment, no UV per initial budget but provisions for future installation.

Effluent Discharge and Treatment

Please provide a narrative of where the water is discharged from the hatchery and any existing issues with the effluent.

Seven discharge areas are located into Kendall Creek.

Existing issues - NDA

composite sample, so all outfalls monitored through NPDES

Please describe any exisitng or planned effluent treatment for the facility

Abatement pond

McMillen		Job No.	23-034	No.	
Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
Subject	Kendall Creek Hatchery	Checked		Date	
Task	Questionnaire - Rearing Facilities	Sheet	1	Of	1

Please provide information on the rearing facilities and add any additonal notes on the sysetms or issues with the systems.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name:	Kristofer G. Flowers	Date:	16-Mar
Name:		Date:	
Name:		Date:	

1 Incubation: Describe the incubation space and any special requirements.

3 rowsof double stacks - includes separate water supply for otolith marking

Inubator Types: Vertical stacks
Number of Incubators: 37
Flow Rate: 4 gpm
Standard loading 1 lb/gpm - regardless of egg/lb eggs/incubator

2 Incubation: Describe the incubation space and any special requirements.

5 rows of 4 free-styles - includes duel plumbing to "chill" water for otolith marking

Inubator Types: Free-style
Number of Incubators: 20
Flow Rate: 10 gpm
Standard loading 150k (only for eyed stage) eggs/incubator

3 Incubation: Describe the incubation space and any special requirements.

Shipping container incubation placed near asphalt ponds

Inubator Types: Redd-Zone container
Number of Incubators: 9
Flow Rate: 9 gpm
Standard loading 150k from green to swim-up eggs/incubator

Rearing: Identify all of different types of rearing vessels. Copy and Insert additional types of rearing units as needed for the full hatchery.

Rearing A: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Asphalt Pond

	Linear		Circular	
Length (ft)	220	ft, OR		ft Diameter
Width (ft)	70	ft		
Wall Height (ft)	6	ft		ft
Operating Depth	3.5	ft		ft
Number of units	2			
Flow Rate	1500	gpm per rearing unit		

Rearing B: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Concrete raceways

	Linear		Circular	
Length (ft)	96.5	ft, OR		ft Diameter
Width (ft)	10	ft		
Wall Height (ft)	4	ft		ft
Operating Depth	3.25	ft		ft
Number of units	12			
Flow Rate	200	gpm per rearing unit		

Rearing C: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Concrete "super" raceways

	Linear		Circular	
Length (ft)	128.5	ft, OR		ft Diameter
Width (ft)	20	ft		
Wall Height (ft)	6	ft		ft
Operating Depth	4.5	ft		ft
Number of units	3			
Flow Rate	1200	gpm per rearing unit		

Rearing C: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Modified Adult pond

	Linear		Circular	
Length (ft)	120	ft, OR		ft Diameter
Width (ft)	20	ft		
Wall Height (ft)	8	ft		ft
Operating Depth	4.5	ft		ft
Number of units	2			
Flow Rate	1200	gpm per rearing unit		

Rearing D: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Fiberglass circular ponds (2)

	Linear		Circular	
Length (ft)		ft, OR	20	ft Diameter
Width (ft)		ft		
Wall Height (ft)		ft	4	ft
Operating Depth		ft	3.5	ft
Number of units	2			
Flow Rate	125	gpm per rearing unit		

Rearing E: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Fiberglass circular ponds (8)

	Linear		Circular	
Length (ft)		ft, OR	16	ft Diameter
Width (ft)		ft		
Wall Height (ft)		ft	4	ft
Operating Depth		ft	3.5	ft
Number of units	8			
Flow Rate	125	gpm per rearing unit		

Rearing F: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Fiberglass circular ponds

	Linear		Circular	
Length (ft)		ft, OR	6	ft Diameter
Width (ft)		ft		
Wall Height (ft)		ft	3	ft
Operating Depth		ft	2.5	ft
Number of units	4			
Flow Rate	75	gpm per rearing unit		

Rearing G: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Aluminum Capilano troughs

	Linear		Circular	
Length (ft)	20	ft, OR		ft Diameter
Width (ft)	3	ft		
Wall Height (ft)	2	ft		ft
Operating Depth	1.5	ft		ft
Number of units	10			
Flow Rate	75	gpm per rearing unit		

Rearing H: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Fiberglass intermediate troughs

	Linear		Circular	
Length (ft)	11	ft, OR		ft Diameter
Width (ft)	3	ft		
Wall Height (ft)	3	ft		ft
Operating Depth	2.5	ft		ft
Number of units	6			
Flow Rate	75	gpm per rearing unit		

Rearing I: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Fiberglass shallow troughs

	Linear		Circular	
Length (ft)	1.17	ft, OR		ft Diameter
Width (ft)	1	ft		
Wall Height (ft)	0.67	ft		ft
Operating Depth	0.58	ft		ft
Number of units	34			
Flow Rate	10	gpm per rearing unit		

Rearing J: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Fiberglass shallow troughs

	Linear		Circular	
Length (ft)	1.17	ft, OR		ft Diameter
Width (ft)	1	ft		
Wall Height (ft)	0.67	ft		ft
Operating Depth	0.58	ft		ft
Number of units	34			
Flow Rate	10	gpm per rearing unit		

Adult Holding/ Spawning: Description (Circulars, raceway, pond,…)

	Linear		Circular	
Length (ft)		ft, OR		ft Diameter
Width (ft)		ft		
Wall Height (ft)		ft		ft
Operating Depth		ft		ft
Number of units				
Flow Rate		gpm per rearing unit		

Please provide a description of the overall conidition of the rearing vessels.

McMillen

		Job No.		No.	23-034
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Task	Questionnaire - Species A Production	Sheet	1	Of	1

Please provide information on the production goals for Species A. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name:	Kristofer G. Flowers	Date:	16-Mar
Name:		Date:	
Name:		Date:	

1 Provide the following information on production for Species A.

Species: Spring Chinook

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = 0.2

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = 1.91

Final Production Goal

1200000 # of fish

13000 Lbs of fish

# of Eggs Incubated

2000000

96.2 % survival

# of Fry

1424000

Fry Rearing Tank: concrete raceway

Size at Transfer #1: 1101.328 FPP or 1.4465 inches

Biomass at Tranfer: 1292.98

98 % survival

# of Juveniles

1400000

Juv Rearing Tank: concrete raceway

Size at Transfer 2: 250.005 FPP or 2.3712 inches

Biomass at Tranfer: 5599.89

98.6 % survival

# of Adults/Outplants

1100000

Adult Rearing Tank: Modified adult pond

Size at Outplant: 100 FPP or 3.2183 inches

Biomass at Outplant: 11,000.00

# of Adults/Outplants

400000

Adult Rearing Tank: Modified adult pond

Size at Outplant: 80 FPP or 5.6245 inches

Biomass at Outplant: 5,000.00

If there are more than 2 fish moves prior to outplant, add corresponding intermediate move by copying the "# of Juveniles" section down.

McMillen

		Job No.		No.	23-034
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Task	Questionnaire - Species B Production	Sheet	1	Of	1

Please provide information on the production goals for Species B. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name:	Kristofer G. Flowers	Date:	18-Mar
Name:		Date:	
Name:		Date:	

1 Provide the following information on production for Species B.

Species: Kendall Creek Coho

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = 0.3

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = 1.91

Final Production Goal

500000 # of fish

29411.76 Lbs of fish

# of Eggs Incubated

575000

# of Fry			95	% survival
546250				
Fry Rearing Tank	concrete raceway			
Size at Transfer #1	1201.929	FPP or	1.3346	inches
Biomass at Tranfer	454.48			
			95	% survival
# of Juveniles				
518938				
Juv Rearing Tank	concrete "super" raceway			
Size at Transfer 2	200	FPP or	2.426	inches
Biomass at Tranfer	2594.69			
			95	% survival
# of Adults/Outplants				
500000				
Adult Rearing Tank	concrete "super" raceway			
Size at Outplant	17	FPP or	5.5	inches
Biomass at Outplant	29411.76			

If there are more than 2 fish moves prior to outplant, add corresponding intermediate move by copying the "# of Juveniles" section down.

McMillen

		Job No.		No.	23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
Subject	Kendall Creek Hatchery	Checked		Date	
Task	Questionnaire - Species C Production	Sheet	1	Of	1

Please provide information on the production goals for Species C. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: Kristofer G. Flowers Date: 18-Mar
Name: Date:
Name: Date:

1 Provide the following information on production for Species C.

Species: NF Nooksack River Fall Chum

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = 0.3

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = 2.865

Final Production Goal

5000000 # of fish
8333.33 Lbs of fish

# of Eggs Incubated

5600000

97 % survival

# of Fry

5092500

Fry Rearing Tank Asphalt Pond
Size at Transfer #1 1201.929 FPP or 1.3346 inches
Biomass at Tranfer 25219.26

98 % survival

# of Juveniles

5000000

Juv Rearing Tank Asphalt pond
Size at Transfer 2 400 FPP or 1.94 inches
Biomass at Tranfer 12500

98 % survival

# of Adults/Outplants

5000000

Adult Rearing Tank Asphalt pond
Size at Outplant 400 FPP or 1.94 inches
Biomass at Outplant 12500

If there are more than 2 fish moves prior to outplant, add corresponding intermediate move by copying the "# of Juveniles" section down.

McMillen		Job No.		No.	23-034
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Task	Questionnaire - Species C Production	Sheet	1	Of	1

Please provide information on the production goals for Species D. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name:	Kristofer G. Flowers	Date:	18-Mar
Name:		Date:	
Name:		Date:	

1 Provide the following information on production for Species C.

Species: Kendall Creek Winter Steelhead Hatchery Program

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = 0.3

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = 1.91

Final Production Goal

150000 # of fish

30000 Lbs of fish

# of Eggs Incubated

200000

95 % survival

# of Fry

190000

Fry Rearing Tank	Fiberglass shallow trough		
Size at Transfer #1	2000 FPP or	1.13	inches
Biomass at Tranfer	95		

95 % survival

# of Juveniles

180500

Juv Rearing Tank	concrete raceway		
Size at Transfer 2	200 FPP or	2.426	inches
Biomass at Tranfer	902.5		

83.4 % survival

# of Adults/Outplants

150000

Adult Rearing Tank	concrete "super" raceway		
Size at Outplant	5 FPP or	8.76	inches
Biomass at Outplant	30000		

If there are more than 2 fish moves prior to outplant, add corresponding intermediate move by copying the "# of Juveniles" section down.

McMillen

		Job No.	No. 23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed	Date
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Task	Questionnaire - Species C Production	Sheet 1	Of 1

Please provide information on the production goals for Species E. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: Kristofer G. Flowers Date: 18-Mar
Name: Date:
Name: Date:

1 Provide the following information on production for Species C.

Species: Goldendale Rainbow Trout

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = 0.5

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = 1.91

Final Production Goal

51000 # of fish
25500 Lbs of fish

# of Eggs Incubated
160000

# of Fry 80 % survival
128000
Fry Rearing Tank Fiberglass shallow trough
Size at Transfer #1 2500 FPP or 1 inches
Biomass at Tranfer 51.2

90 % survival

# of Juveniles
115200
Juv Rearing Tank concrete raceway
Size at Transfer 2 400 FPP or 1.8 inches
Biomass at Tranfer 288

90 % survival

# of Juveniles
103680
Juv Rearing Tank concrete "super" raceway
Size at Transfer 2 100 FPP or 2.92 inches
Biomass at Tranfer 1300

95 % survival

# of Adults/Outplants
37000
Adult Rearing Tank concrete "super" raceway
Size at Outplant 37 FPP or 4.07 inches
Biomass at Outplant 1000

# of Adults/Outplants
43000
Adult Rearing Tank concrete "super" raceway
Size at Outplant 0.5 FPP or 10 inches
Biomass at Outplant 21500

# of Adults/Outplants
8000
Adult Rearing Tank Fiberglass circular pond
Size at Outplant 1 FPP or 18 inches
Biomass at Outplant 8000

McMillen

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Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
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Task	Questionnaire - Species C Production	Sheet	1	Of	1

Please provide information on the production goals for Species F. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name:	Kristofer G. Flowers	Date:	18-Mar
Name:		Date:	
Name:		Date:	

1 Provide the following information on production for Species C.

Species: Ford hatchery Brown trout

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = 0.5

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = 1.91

Final Production Goal

32000 # of fish

533.33 Lbs of fish

# of Eggs Incubated

90000

65 % survival

# of Fry

58500

Fry Rearing Tank	Fiberglass shallow trough			
Size at Transfer #1	2500	FPP or	1	inches
Biomass at Tranfer	23.4			

80 % survival

# of Juveniles

46800

Juv Rearing Tank	concrete raceway			
Size at Transfer 2	400	FPP or	1.8	inches
Biomass at Tranfer	117			

80 % survival

# of Adults/Outplants

32000

Adult Rearing Tank	concrete raceway			
Size at Outplant	60	FPP or	3.45	inches
Biomass at Outplant	533.33			

McMillen

		Job No.	No. 23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed	Date
Subject	Kendall Creek Hatchery	Checked	Date
Task	Questionnaire - Species C Production	Sheet 1	Of 1

Please provide information on the production goals for Species G. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: Kristofer G. Flowers Date: 18-Mar
Name: Date:
Name: Date:

1 Provide the following information on production for Species C.

Species: Eels Springs hatchery Cutthroat

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = 0.3

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = 1.91

Final Production Goal

77000 # of fish
900 Lbs of fish

# of Eggs Incubated

160000

70 % survival

# of Fry

112000

Fry Rearing Tank: Fiberglass shallow trough
Size at Transfer #1: 2500 FPP or 1 inches
Biomass at Tranfer: 44.8

85 % survival

# of Juveniles

95200

Juv Rearing Tank: concrete raceway
Size at Transfer 2: 400 FPP or 1.8 inches
Biomass at Tranfer: 238

85 % survival

# of Adults/Outplants

5000

Adult Rearing Tank: concrete raceway
Size at Outplant: 400 FPP or 1.8 inches
Biomass at Outplant: 12.5

# of Adults/Outplants

72000

Adult Rearing Tank: concrete raceway
Size at Outplant: 80 FPP or 3.46 inches
Biomass at Outplant: 900

McMillen

		Job No.		No.	23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
Subject	Kendall Creek Hatchery	Checked		Date	
Task	Questionnaire - Species C Production	Sheet	1	Of	1

Please provide information on the production goals for Species H. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name:	Kristofer G. Flowers	Date:	18-Mar
Name:		Date:	
Name:		Date:	

1 Provide the following information on production for Species C.

Species: Lake Whatcom Kokanee

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = 0.3

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = 1.91

Final Production Goal

100000 # of fish

1000 Lbs of fish

# of Eggs Incubated

120000

# of Fry 95 % survival

114000

Fry Rearing Tank	Fiberglass shallow trough		
Size at Transfer #1	2500 FPP or	1	inches
Biomass at Tranfer	45.6		

95 % survival

# of Juveniles

108300

Juv Rearing Tank	concrete raceway		
Size at Transfer 2	400 FPP or	1.8	inches
Biomass at Tranfer	270.75		

95 % survival

# of Adults/Outplants

100000

Adult Rearing Tank	concrete raceway		
Size at Outplant	100 FPP or	2.92	inches
Biomass at Outplant	1000		

McMillen		Job No.		No.	23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
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Task	Questionnaire - Species C Production	Sheet	1	Of	1

Please provide information on the production goals for Species I. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: Kristofer G. Flowers Date: 18-Mar
Name: Date:
Name: Date:

1 Provide the following information on production for Species C.

Species: Skookum Creek hatchery Coho

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = 0.3

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = 2.865

Final Production Goal

1000000 # of fish
28571.43 Lbs of fish

# of Eggs Incubated
1200000

# of Fry
95 % survival
1140000

Fry Rearing Tank: Asphalt pond
Size at Transfer #1: 1201.929 FPP or 1.3346 inches
Biomass at Tranfer: 948.48

95 % survival

# of Juveniles
1083000

Juv Rearing Tank: Asphalt pond
Size at Transfer 2: 200 FPP or 2.426 inches
Biomass at Tranfer: 5415

95 % survival

# of Adults/Outplants
1000000

Adult Rearing Tank: Asphalt pond
Size at Outplant: 35 FPP or 4.32 inches
Biomass at Outplant: 28571.43

		Job No.	No. 23-034
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Subject	Kendall Creek Hatchery	Checked	Date
Task	Questionnaire - Species C Production	Sheet 1	Of 1

Please provide information on the production goals for Species C. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: Kristofer Flowers Date: 18-Mar
Name: Date:
Name: Date:

1 Provide the following information on production for Species C.

Species: Samish hatchery Fall Chinook

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = NDA

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = NDA

Final Production Goal

NDA # of fish
NDA Lbs of fish

# of Eggs Incubated

9000000

# of Fry % survival

Fry Rearing Tank
Size at Transfer #1 FPP or inches
Biomass at Tranfer

% survival

# of Juveniles

Juv Rearing Tank
Size at Transfer 2 FPP or inches
Biomass at Tranfer

% survival

# of Adults/Outplants

Adult Rearing Tank
Size at Outplant FPP or inches
Biomass at Outplant

McMillen		Job No.	No. 23-034
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Task	Questionnaire - Species C Production	Sheet 1	Of 1

Please provide information on the production goals for Species C. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: Kristofer Flowers Date: 18-Mar

Name: Date:

Name: Date:

1 Provide the following information on production for Species C.

Species: Kendall Hatchery Captive brood Steelhead

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI =

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI =

Final Production Goal

\# of fish

Lbs of fish

\# of Eggs Incubated

\# of Fry % survival

Fry Rearing Tank

Size at Transfer #1 FPP or inches

Biomass at Tranfer

% survival

\# of Juveniles

Juv Rearing Tank

Size at Transfer 2 FPP or inches

Biomass at Tranfer

% survival

\# of Adults/Outplants

Adult Rearing Tank

Size at Outplant FPP or inches

Biomass at Outplant

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Rearing Vessel	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)
Species A														
	Incubation	Vertical stacks / Freestyle								60	60	100	100	
	Fry Rearing	Concrete raceways	1800											1100
	Juvenile Rearing	Concrete raceways		2400	1200	600	300							
	Outplan Rearing	Modified adult pond			2000	900	750							
Species B														
	Incubation	Vertical stacks	20	20	20									
	Fry Rearing	Concrete raceways			100									
	Juvenile Rearing	Concrete raceways				150	200							
	Outplan Rearing	Concrete "super" raceway	1000	1200	1200	1500	1500	500	500	750	750	750	750	1000
Species C														
	Incubation	Freestyle	60										60	60
	Incubation	Redd-Zone Container		100	100									
	Fry Rearing	Asphalt pond				500	750							
	Outplan Rearing	Asphalt pond												
Species D														
	Incubation	Fiberglass shallow trough	20	20										
	Fry Rearing	Fiberglass shallow trough			20	20								
	Juvenile Rearing	Concrete raceway					100	150	150					
	Outplan Rearing	Concrete "super" raceway	750	1200	1500	1500				350	350	350	350	500
Species E														
	Incubation	Fiberglass shallow trough	80											
	Fry Rearing	Aluminum Capilano		80	80									
	Juvenile Rearing	Concrete raceway				100	150	150	150					
	Outplan Rearing	Concrete "super" raceway								250	250	350	350	500
	Outplan Rearing	Fiberglass round pond												
Species F														
	Incubation	Fiberglass shallow trough	40	40										
	Fry Rearing	Aluminum Capilano			40									
	Juvenile Rearing	Concrete raceway				100	150	150						
	Outplan Rearing	Concrete raceway							150	150	200	200		
Species G														
	Incubation	Fiberglass shallow trough	40	40										
	Fry Rearing	Fiberglass shallow trough			40									
	Juvenile Rearing	Concrete raceway				100	150	150						
	Outplan Rearing	Concrete raceway							150	150	200	200		
Species H														
	Incubation	Fiberglass shallow trough	40	40										
	Fry Rearing	Fiberglass shallow trough			40									
	Juvenile Rearing	Concrete raceway				100	150	150						
	Outplan Rearing	Concrete raceway							150	150	200	200		
Species I														
	Incubation	Redd-Zone Container	100											100
	Fry Rearing	Asphalt pond		150	150	150	200							
	Juvenile Rearing	Asphalt pond						300	500	500	500	750	750	750
	Outplan Rearing	Asphalt pond	1800	1800	1800									
Species J														
	Incubation	Free-style incubators									60	60		

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)
							60	60	100	100	
1800											1100
	2400	1200	600	300							
		2000	900	750							
20	20	20									
		100									
			150	200							
1000	1200	1200	1500	1500	500	500	750	750	750	750	1000
60										60	60
	100	100									
			500	750							
20	20										
		20	20								
				100	150	150					
750	1200	1500	1500				350	350	350	350	500
80											
	80	80									
			100	150	150	150					
							250	250	350	350	500
40	40										
		40									
			100	150	150						
						150	150	200	200		
40	40										
		40									
			100	150	150						
						150	150	200	200		
40	40										
		40									
			100	150	150						
						150	150	200	200		
100											100
	150	150	150	200							
					300	500	500	500	750	750	750
1800	1800	1800									
								60	60		

McMillen		Job No. 23-034	No.
Project	WDFW Climate Change Vulnerability Assessment	Computed	Date
Subject	Kendall Creek Hatchery	Checked	Date
Task	Questionnaire - Process Flow	Sheet 1	Of 1

Please provide information on the fish health at the hatchery.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ______________________ Date: __________

Name: ______________________ Date: __________

Name: ______________________ Date: __________

Water Supply

List the pathogens of concern for the facility:

BKD - not a huge concern, one raceway

cold water disease - primarily in steelhead, some in coho, generally able to catch it and treat it, generally in the eggs/small fry stage

furncolsis

Please provide any seasonal observations for the pathogens of concern at the facility

No, when creek at more elevated water temperature (55-56), not using it.

Please provide any existing treatments or mitigation measures to protect fish health

no prophylactic for BKD currently

haven't had to order medicated feed in a long time, that is how they would normally deal with it. Decreasing fish stress. Don't sample every week, use projections, good biosecurity etc.

formalin in incubation only

McMillen		Job No.	23-034	No.	
Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
Subject	Samish Hatchery	Checked		Date	
Task	Questionnaire - Data Collection	Sheet	1	Of	1

The following questionnaire spreadsheet is for the collection of data for the subject Fish Hatchery Climate Change Vulnerability Assessment Project. This sheet contains the general information and data required for the project. Place a check mark next to the info that has been uploaded to the SharePoint site.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: Date:
Name: Date:
Name: Date:

Hatchery Name Samish Hatchery
Address 5585 Old Hwy 99 N Burlington WA 98233
Year Built 1895

Data Collection: Collection

- As-Built Drawings or most recent drawings of the facility.
- Geotechnical Report/ information
- Well Information
  - Drillers Logs
  - Well Capacity Tests

- Water Right Information
- Groundwater table records (if applicable)
- Production Reports - Species, numbers, biomass, feed rates, etc.
- Production Goals - If not meeting production, or future goals
- Descriptions of Hatchery Water Sources - Location, pump/gravity, flow, treatment required,
  Ground water, springs, surface water, treated city water?
- Hatchery Water Quality Reports
- Hatchery Water Yearly Temperature data
- Any Streamflow records (if available)
- Air temperature records (if available)
- Hatchery Effluent Treatment Reports/Requirements? NPDES Permit?
- Monthly water use report or schedule. Water usage by area per month for a year.
  Or fill out the tab "Water Budget"
- Water Treatment equipment, cut sheets, performance info, etc.
- Pump list with pump curves, production rates, etc.
- Power
  - Utilitiy: Puget Sound Enery
  - Transformer Size: NDA
  - Backup Power: Standby Generator at Adult Pond
  - ATS: NDA
  - Power Usage (12 months worth, utility bills)
  - Solar?

McMillen

		Job No.	23-034	No.	
Project	WDFW Climate Change Sensitivity Assessment	Computed		Date	
Subject	Samish Hatchery	Checked		Date	
Task	Questionnaire - Process Flow	Sheet	1	Of	1

Please provide information on the process flow through the hatchery.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: Date:
Name: Date:
Name: Date:

Water Supply

Please provide a narrative of the water sources for the facility and which take priority? (Include seasonal changes)

Only source of water for Samish Hatchery is Friday Creek gravity intake.

Only source of water for Samish River adult pond is pump station on the Samish River.

Water Rights		CFS/GPM	Amount currently used
	Well	628 gpm	28 gpm
	Surface	40 cfs	36 cfs
	Spring		

Wells	A		gpm production rates
	B		gpm production rates
	C		gpm production rates

Please provide any seasonal observations for the water supply with regards to flooding /drought events/areas of erosion

Possible flooding November - February for both Friday Ccreek and Samish River. Low flows in Friday Creek beginning in May. Flows as low as 2 cfs in late summer. Temperature increases as flows decrease up to 70 degrees Fahrenheit. Samish River sees low flows (20 cfs) from August into October.

Please provide a description of the exisitng condition of the intake and/or well infrastructure

Samish River - New intake and obermeyer dam completed in 2021.
Friday Creek intake on capital budget list for replacement.
Intake not in compliance with current requirements.

Water Delivery system

Please provide a narrative of how the water flows through the facility and any water treatment along the way.

Water flows down underground pipeline to hatchery. Pipeline delivers water to 3 banks of ponds - Ponds 1-8, Ponds 9-12, and Pond 13. Water also goes to tower that feeds incubation room.
Samish River pump station pumps water from intake to head of pond.

What issues do you currently have with the water distribution system?

Friday Creek - Intake screens become plugged during high water events that stop flow of water to hatchery.
Samish River intake - Mechanical issues.

Effluent Discharge and Treatment

Please provide a narrative of where the water is discharged from the hatchery and any existing issues with the effluent.

Hatchery - 3 outlets
1) Ponds 9-12
2) Ponds 1-8, incubation room
3) Pond 13
Outflow from Ponds 1-8 and incubation room can be diverted into Pond 13.

Please describe any exisitng or planned effluent treatment for the facility

Hatchery has abatement pond for ponds 1-12.

		Job No.	23-034	No.	
Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
Subject	Samish Hatchery	Checked		Date	
Task	Questionnaire - Rearing Facilities	Sheet	1	Of	1

Please provide information on the rearing facilities and add any additonal notes on the sysetms or issues with the systems.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ______________________ Date: ____________

Name: ______________________ Date: ____________

Name: ______________________ Date: ____________

1 Incubation: Describe the incubation space and any special requirements.

6 Head troughs, 24 stacks per head trough

Inubator Types:	Mari source Vertical stacks	
Number of Incubators:	1008	
Flow Rate:	4 gpm per half stack	
Standard loading	7400	eggs/incubator

Rearing: Identify all of different types of rearing vessels. Copy and Insert additional types of rearing units as needed for the full hatchery.

Rearing A: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Concrete raceway ponds 1-8

	Linear		Circular	
Length (ft)	100	ft, OR		ft Diameter
Width (ft)	10	ft		
Wall Height (ft)	4	ft		ft
Operating Depth	3.3	ft		ft
Number of units	8			
Flow Rate	400	gpm per rearing unit		

Rearing B: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Concrete raceway ponds 9-12

	Linear		Circular	
Length (ft)	80	ft, OR		ft Diameter
Width (ft)	20	ft		
Wall Height (ft)	4	ft		ft
Operating Depth	3.5	ft		ft
Number of units	4			
Flow Rate	500	gpm per rearing unit		

Rearing C: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

1/4 acre asphalt pond Pond 13

	Linear		Circular		
Length (ft)	120	ft, OR		ft Diameter	
Width (ft)	60	ft			
Wall Height (ft)	5	ft		ft	
Operating Depth	4.5	ft		ft	
Number of units	1				
Flow Rate	3000	gpm per rearing unit			all serial reuse from Ponds 1-12

Rearing D: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

	Linear		Circular	
Length (ft)		ft, OR		ft Diameter
Width (ft)		ft		
Wall Height (ft)		ft		ft
Operating Depth		ft		ft
Number of units				
Flow Rate		gpm per rearing unit		

Adult Holding/ Spawning: Description (Circulars, raceway, pond,...)

Adult Holding / Spawning Rearing Pond 14

	Linear		Circular	
Length (ft)	229	ft, OR		ft Diameter
Width (ft)	79	ft		
Wall Height (ft)	5	ft		ft
Operating Depth	4.5	ft		ft
Number of units	1			
Flow Rate	6000	gpm per rearing unit		

Please provide a description of the overall conidition of the rearing vessels.

Adult pond built in earlly 1980s. No updates to asphalt bottom. Steel walls replaced wood pickets in 2005. On capital list for replacement. Poor condition. Ponds 9-12 built ?? Concrete worn, ponds have minor leaks on outside wall but otherwise good condition. Ponds 1-8 built in 2002. Good condition. Pond 13 asphalt has cracks throughout pond. Manifold has rust holes. Not enough screen area for water discharge. Poor condition.

McMillen		Job No.	No. 23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed	Date
Subject	Samish Hatchery	Checked	Date
Task	Questionnaire - Species A Production	Sheet 1	Of 1

Please provide information on the production goals for Species A. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ______________________ Date: __________

Name: ______________________ Date: __________

Name: ______________________ Date: __________

1 Provide the following information on production for Species A.

Species: Samish River Fall Chinook

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = 1.7

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = 1.41

Final Production Goal

5,200,000 # of fish

61,200 Lbs of fish

# of Eggs Incubated

5,720,000

90 % survival

# of Fry

5,500,000

Fry Rearing Tank: Ponds 1-12

Size at Transfer #1: 1300 FPP or ______ inches

Biomass at Tranfer: 4231

95 % survival

# of Juveniles

5,200,000

Juv Rearing Tank: Ponds 1-14

Size at Transfer 2: 200 FPP or ______ inches

Biomass at Tranfer: 26,000

100 % survival

# of Adults/Outplants

5,200,000

Adult Rearing Tank: Ponds 1-8, 13, 14

Size at Outplant: 90 FPP or ______ inches

Biomass at Outplant: 57,777

		Job No.		No.	23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
Subject	Samish Hatchery	Checked		Date	
Task	Questionnaire - Species B Production	Sheet	1	Of	1

Please provide information on the production goals for Species B. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ______ Date: ______
Name: ______ Date: ______
Name: ______ Date: ______

1 Provide the following information on production for Species B.

Species: ______

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = ______

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = ______

Final Production Goal

______ # of fish
______ Lbs of fish

# of Eggs Incubated

______

# of Fry ______ % survival

______

Fry Rearing Tank ______
Size at Transfer #1 ______ FPP or ______ inches
Biomass at Tranfer ______

______ % survival

# of Juveniles

______

Juv Rearing Tank ______
Size at Transfer 2 ______ FPP or ______ inches
Biomass at Tranfer ______

______ % survival

# of Adults/Outplants

______

Adult Rearing Tank ______
Size at Outplant ______ FPP or ______ inches
Biomass at Outplant ______

		Job No.	No. 23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed	Date
Subject	Samish Hatchery	Checked	Date
Task	Questionnaire - Species C Production	Sheet 1	Of 1

Please provide information on the production goals for Species C. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ____________________ Date: __________
Name: ____________________ Date: __________
Name: ____________________ Date: __________

1 Provide the following information on production for Species C.

Species: __________

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = ______

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = ______

Final Production Goal

______ # of fish
______ Lbs of fish

# of Eggs Incubated

______

# of Fry ______ % survival

______

Fry Rearing Tank ______
Size at Transfer #1 ______ FPP or ______ inches
Biomass at Tranfer ______

______ % survival

# of Juveniles

______

Juv Rearing Tank ______
Size at Transfer 2 ______ FPP or ______ inches
Biomass at Tranfer ______

______ % survival

# of Adults/Outplants

______

Adult Rearing Tank ______
Size at Outplant ______ FPP or ______ inches
Biomass at Outplant ______

McMillen

		Job No.	No. 23-034
Project	WDFW Climate Change Vulnerability Assessment	Computed	Date
Subject	Samish Hatchery	Checked	Date
Task	Questionnaire - Water Budget	Sheet 1	Of 1

The water budget will help to identify monthly usage of water by the hatchery production. Understanding how the water is distributed across each species and rearing vessel/life stage per month will support the evaluation and methods to improve water usage/conservation.

As some species have a longer rearing cycle at a hatchery than one year, please illustrate the water usage over a two year program. The example below provides context. Overwrite the Data per your program.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ________________ Date: __________
Name: ________________ Date: __________
Name: ________________ Date: __________

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Rearing Vessel	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)
Species A													
Incubation		780	650	130								780	780
Ponds 1-8			2000	2,400	3,200	3,400							
Pond 9			400	500	500								
Pond 10				500	500								
Pond 11				500									
Pond 12				500									
Pond 13 (reuse from 1-12)				2,400	3,200	3,200							
Pond 14 (Adult holding)					3,000	4,000				3,000	3,000		
Fish Ladder		1,500	1,500	1,000	600	600	900	900	900	900	900	1,000	1,500
Species B	Total (gpm)	1500	3900	7800	11000	11200	900	900	900	3900	3900	1000	1500
Incubation	Total (cfs)	3.3	8.7	17.4	24.5	25.0	2.0	2.0	2.0	8.7	8.7	2.2	3.3
Fry Rearing													
Juvenile Rearing													
Outplan Rearing													

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)
780	650	130									
	2000	2,400	3,200	3,400							
	400	500	500								
		500	500								
		500									
		500									
		2,400	3,200	3,200							
1,500	1,500	1,000	600	600	900	900	900	900	900	1,000	1,500
1500	3900	7800	8000	7200	900	900	900	900	900	1000	1500
3.3	8.7	17.4	17.8	16.0	2.0	2.0	2.0	2.0	2.0	2.2	3.3

McMillen

		Job No.	23-034	No.	
Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
Subject	XXX State Hatchery	Checked	JT	Date	
Task	Questionnaire - Process Flow	Sheet	1	Of	1

Please provide information on the fish health at the hatchery.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: Date:
Name: Date:
Name: Date:

Water Supply

List the pathogens of concern for the facility:

Ichthyophirius multifilis (ICH), Costia

Please provide any seasonal observations for the pathogens of concern at the facility

Diseases present when water temperatures increase in the spring.

Please provide any existing treatments or mitigation measures to protect fish health

Formalin treatments

		Job No. 23-034	No.
Project	WDFW Climate Change Vulnerability Assessment	Computed	Date
Subject	Goldendale Hatchery	Checked	Date
Task	Questionnaire - Data Collection	Sheet 1	Of 1

The following questionnaire spreadsheet is for the collection of data for the subject Fish Hatchery Climate Change Vulnerability Assessment Project. This sheet contains the general information and data required for the project. Place a check mark next to the info that has been uploaded to the SharePoint site.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ____________ Date: ____________
Name: ____________ Date: ____________
Name: ____________ Date: ____________

Hatchery Name	Goldendale Trout Hatchery
Address	130 Fish Hatchery rd. Goldendale, WA 98620
Year Built	Hatchery built 1938. New incubation and office built in 1995

Data Collection: Collection

As- Built Picture	As-Built Drawings or most recent drawings of the facility.
NDA	Geotechnical Report/ information
NDA	Well Information
	NDA Drillers Logs
	NDA Well Capacity Tests
Water Rights File	Water Right Information
NDA	Groundwater table records (if applicable)
Loadings File	Production Reports - Species, numbers, biomass, feed rates, etc.
Future Brood file	Production Goals - If not meeting production, or future goals
Spring water	Descriptions of Hatchery Water Sources - Location, pump/gravity, flow, treatment required, Ground water, springs, surface water, treated city water?
NPDES File	Hatchery Water Quality Reports
51.3 constant	Hatchery Water Yearly Temperature data
NDA	Any Streamflow records (if available)
NDA	Air temperature records (if available)
NPDES File	Hatchery Effluent Treatment Reports/Requirements? NPDES Permit?
Water Budget Tab	Monthly water use report or schedule. Water usage by area per month for a year. Or fill out the tab "Water Budget"

NDA	Water Treatment equipment, cut sheets, performance info, etc.		
NDA	Pump list with pump curves, production rates, etc.		
$17,000/ year	Power		
		Utilitiy:	Klickitat county PUD
		Transformer Size:	
		Backup Power:	Emergency Propane generator
		ATS:	
		Power Usage (12 months worth, utility bills)	
	N/A	Solar?	

McMillen

		Job No.	23-034	No.	
Project	WDFW Climate Change Sensitivity Assessment	Computed		Date	
Subject	Goldendale Hatchery	Checked		Date	
Task	Questionnaire - Process Flow	Sheet	1	Of	1

Please provide information on the process flow through the hatchery.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ____________________ Date: ____________
Name: ____________________ Date: ____________
Name: ____________________ Date: ____________

Water Supply

Please provide a narrative of the water sources for the facility and which take priority? (Include seasonal changes)

Spring Creek: artisian spring. 10 CFS. Only water source

Water Rights		CFS/GPM	Amount currently used
	Well	0	0
	Surface	0	0
	Spring	10 CFS	10 CFS

Wells	A		gpm production rates
	B		gpm production rates
	C		gpm production rates

Please provide any seasonal observations for the water supply with regards to flooding /drought events/areas of erosion

Water gets turbid late fall/spring. No flooding due to water coming from underground spring

No noticable different in water volume during drought year

Please provide a description of the exisitng condition of the intake and/or well infrastructure

Intake is in good condition. Dam boards were replaced 2019

Water Delivery system

Please provide a narrative of how the water flows through the facility and any water treatment along the way.

Water is gravity fed via 100 meter pipe line. Water is not treated before reaching raceway headboxes.

Water is pumped to degassing tower to remove radon before entering incubation room

What issues do you currently have with the water distribution system?

Uneven flow rates and low oxgyen satuation levels in late fall through early spring during lower spring output period/ high fish density in rearing vessels

Effluent Discharge and Treatment

Please provide a narrative of where the water is discharged from the hatchery and any existing issues with the effluent.

Water is discharged into abatement pond for soilds to settle out. Water will then over flow into spring creek

Please describe any exisitng or planned effluent treatment for the facility

NA

		Job No.	23-034	No.	
Project	WDFW Climate Change Vulnerability Assessment	Computed		Date	
Subject	Goldendale Hatchery	Checked		Date	
Task	Questionnaire - Rearing Facilities	Sheet	1	Of	1

Please provide information on the rearing facilities and add any additonal notes on the sysetms or issues with the systems.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ______________________ Date: __________
Name: ______________________ Date: __________
Name: ______________________ Date: __________

1 Incubation: Describe the incubation space and any special requirements.

Incubation room is made up of 32 concrete troughs and 3 plastic troughs used for

Inubator Types: Troughs
Number of Incubators: 16 troughs
Flow Rate: 7 GPM
Standard loading 25,000 eggs/incubator

Rearing: Identify all of different types of rearing vessels. Copy and Insert additional types of rearing units as needed for the full hatchery.

Rearing A: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Troughs

	Linear		Circular	
Length (ft)	13.9	ft, OR		ft Diameter
Width (ft)	1	ft		
Wall Height (ft)	1	ft		ft
Operating Depth	0.75	ft		ft
Number of units	38			
Flow Rate	10	gpm per rearing unit		

Rearing B: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Intermediate Raceways

	Linear		Circular	
Length (ft)	28.75	ft, OR		ft Diameter
Width (ft)	4	ft		
Wall Height (ft)	2	ft		ft
Operating Depth	17.5	ft		ft
Number of units	3			

Flow Rate	60	gpm per rearing unit

Rearing C: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

Concrete Raceways

	Linear		Circular	
Length (ft)	80	ft, OR		ft Diameter
Width (ft)	10	ft		
Wall Height (ft)	3.5	ft		ft
Operating Depth	2.2	ft		ft
Number of units	10			
Flow Rate	380	gpm per rearing unit		

Rearing D: Description (ie, concrete raceways, circular tanks, foster lucas ponds, 8x80s

	Linear		Circular	
Length (ft)		ft, OR		ft Diameter
Width (ft)		ft		
Wall Height (ft)		ft		ft
Operating Depth		ft		ft
Number of units				
Flow Rate		gpm per rearing unit		

Adult Holding/ Spawning: Description (Circulars, raceway, pond,...)

Concrete Adult Raceways

	Linear		Circular	
Length (ft)	80	ft, OR		ft Diameter
Width (ft)	15	ft		
Wall Height (ft)	5	ft		ft
Operating Depth	4	ft		ft
Number of units	2			
Flow Rate	489	gpm per rearing unit		

Please provide a description of the overall conidition of the rearing vessels.

Concrete raceways are weathered, chipped, and have plant growth on wall throughout the year.

RW's 1-10 have dam boards that build up water in a head box that will spill over into raceways via PVC piping. RW's 11 and 12 have upwells.

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Task	Questionnaire - Species A Production	Sheet	1	Of	1

Please provide information on the production goals for Species A. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ____________________ Date: __________

Name: ____________________ Date: __________

Name: ____________________ Date: __________

1 Provide the following information on production for Species A.

Species: Trout

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = ______

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = ______

Final Production Goal

150000 # of fish

83000 Lbs of fish

# of Eggs Incubated

6,250,000

# of Fry 65 % survival

220000

Fry Rearing Tank 19

Size at Transfer #1 250 FPP or ______ inches

Biomass at Tranfer 880

90 % survival

# of Juveni # of Juveni # of Juveni # of Juvenile # of Juveni # of Juveniles

200,000

Juv Rearing Tank 5

Size at Transfer 2 25 FPP or ______ inches

Biomass at Tranfer 8000

0.005 % survival

# of Juveni	# of Juveni	# of Juveni	# of Juvenile	# of Juveni	# of Juveniles
	155,000				
	Juv Rearing Tank		7		

McMillen

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Task	Questionnaire - Species B Production	Sheet	1	Of	1

Please provide information on the production goals for Species B. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: __________ Date: __________
Name: __________ Date: __________
Name: __________ Date: __________

1 Provide the following information on production for Species B.

Species: Ford Stock Brown Trout

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = ______

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = ______

Final Production Goal

9000 # of fish
180 Lbs of fish

# of Eggs Incubated

22000

60 % survival

# of Fry

11000

Fry Rearing Tank 4
Size at Transfer #1 300 FPP or ______ inches
Biomass at Tranfer 37

80 % survival

# of Juveniles

9000

Juv Rearing Tank 1
Size at Transfer 2 100 FPP or ______ inches
Biomass at Tranfer 90

99 % survival

# of Adults/Outplants

______

Adult Rearing Tank ______

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Task	Questionnaire - Species C Production	Sheet	1	Of	1

Please provide information on the production goals for Species C. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ________ Date: ________
Name: ________ Date: ________
Name: ________ Date: ________

1 Provide the following information on production for Species C.

Species: Tiger Trout

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = ________

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = ________

Final Production Goal

10000 # of fish
200 Lbs of fish

# of Eggs Incubated

20000

# of Fry 60 % survival

12000

Fry Rearing Tank 4
Size at Transfer #1 300 FPP or ________ inches
Biomass at Tranfer 44

90 % survival

# of Juveniles

10800

Juv Rearing Tank 1
Size at Transfer 2 100 FPP or ________ inches
Biomass at Tranfer 100

90 % survival

# of Adults/Outplants

____

Adult Rearing Tank ________

McMillen		Job No.	No. 23-034
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Task	Questionnaire - Species C Production	Sheet 1	Of 1

Please provide information on the production goals for Species C. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ______________________ Date: __________

Name: ______________________ Date: __________

Name: ______________________ Date: __________

1 Provide the following information on production for Species C.

Species: Eastern Brook Trout Ford Stock

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = ______

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = ______

Final Production Goal

16000 # of fish

320 Lbs of fish

# of Eggs Incubated

32000

# of Fry — 60 % survival

19000

Fry Rearing Tank: 4

Size at Transfer #1: 300 FPP or ______ inches

Biomass at Tranfer: 44

90 % survival

# of Juveniles

17000

Juv Rearing Tank: 1

Size at Transfer 2: 100 FPP or ______ inches

Biomass at Tranfer: 100

90 % survival

# of Adults/Outplants

______

Adult Rearing Tank: ______

TABLE 8. FLOW INDEX RELATED TO WATER TEMPERATURE AND ELEVATION FOR TROUT AND SALMON, BASED ON AN OPTIMUM INDEX OF F = 1.5 AT 50°F AND 5,000 FEET ELEVATION. OXYGEN CONCENTRATION IS ASSUMED TO BE AT OR NEAR 100% SATURATION. (SOURCE: BRUCE B. CANNADY, UNPUBLISHED.)

WATER TEMPER-ATURE	ELEVATION (FEET)									
(°F)	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000
40	2.70	2.61	2.52	2.43	2.34	2.25	2.16	2.09	2.01	1.94
41	2.61	2.52	2.44	2.35	2.26	2.18	2.09	2.02	1.94	1.87
42	2.52	2.44	2.35	2.27	2.18	2.10	2.02	1.95	1.88	1.81
43	2.43	2.35	2.27	2.19	2.11	2.03	1.94	1.88	1.81	1.74
44	2.34	2.26	2.18	2.11	2.03	1.95	1.87	1.81	1.74	1.68
45	2.25	2.18	2.10	2.03	1.95	1.88	1.80	1.74	1.68	1.61
46	2.16	2.09	2.02	1.94	1.87	1.80	1.73	1.67	1.61	1.55
47	2.07	2.00	1.93	1.86	1.79	1.73	1.66	1.60	1.54	1.48
48	1.98	1.91	1.85	1.78	1.72	1.65	1.58	1.53	1.47	1.42
49	1.89	1.83	1.76	1.70	1.64	1.58	1.51	1.46	1.41	1.36
50	1.80	1.74	1.68	1.62	1.56	*1.50*	1.44	1.39	1.34	1.29
51	1.73	1.67	1.62	1.56	1.50	1.44	1.38	1.34	1.29	1.24
52	1.67	1.61	1.56	1.50	1.44	1.39	1.33	1.29	1.24	1.19
53	1.61	1.55	1.50	1.45	1.39	1.34	1.29	1.24	1.20	1.15
54	1.55	1.50	1.45	1.40	1.34	1.29	1.24	1.20	1.16	1.11
55	1.50	1.45	1.40	1.35	1.30	1.25	1.20	1.16	1.12	1.07
56	1.45	1.40	1.35	1.31	1.26	1.21	1.16	1.12	1.08	1.04
57	1.41	1.36	1.31	1.27	1.22	1.17	1.13	1.09	1.05	1.01
58	1.36	1.32	1.27	1.23	1.18	1.14	1.09	1.05	1.02	0.98
59	1.32	1.28	1.24	1.19	1.15	1.10	1.06	1.02	0.99	0.95
60	1.29	1.24	1.20	1.16	1.11	1.07	1.03	0.99	0.96	0.92
61	1.25	1.21	1.17	1.13	1.08	1.04	1.00	0.97	0.93	0.90
62	1.22	1.18	1.14	1.09	1.05	1.01	0.97	0.94	0.91	0.87
63	1.18	1.14	1.11	1.07	1.03	0.99	0.95	0.92	0.88	0.85
64	1.15	1.12	1.08	1.04	1.00	0.96	0.92	0.89	0.86	0.83

(1) The Flow Index (F) is 1.30 (Table 8, 4,000 feet elevation, 55°F temperature).

(2) We can now estimate the permissible weight of trout that can be held per gallon per minute, by the formula $W = F \times L \times I$, where $F = 1.30$, $L = 4$ inches, and $I = 1$ gallon per minute. Approximately 5.2 pounds of trout can be safely reared per gallon per minute water inflow ($1.30 \times 4 \times 1$).

The effect of water temperature on the Flow Index can readily be seen in the table. For instance, a hatchery at a 5,000-foot elevation having a water

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Task	Questionnaire - Species C Production	Sheet 1	Of	1

Please provide information on the production goals for Species C. Copy this tab for as many species that are reared at the facility.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ______ Date: ______
Name: ______ Date: ______
Name: ______ Date: ______

1 Provide the following information on production for Species C.

Species: King Lake Cutthrout

Rearing Density Index per Piper. Typically for salmonids 0.15 to 0.3.

DI = ______

Flow Index per Piper. See table from Piper (to right) if Flow index unknown

FI = ______

Final Production Goal

6800 # of fish
250 Lbs of fish

# of Eggs Incubated

20000

60 % survival

# of Fry

10000

Fry Rearing Tank 4
Size at Transfer #1 250 FPP or ______ inches
Biomass at Tranfer 40

90 % survival

# of Juveniles

______

Juv Rearing Tank ______
Size at Transfer 2 ______ FPP or ______ inches
Biomass at Tranfer ______

90 % survival

# of Adults/Outplants

______

Adult Rearing Tank ______

McMillen

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Task	Questionnaire - Water Budget	Shee 1	Of	1

The water budget will help to identify monthly usage of water by the hatchery production. Understanding how the water is distributed across each species and rearing vessel/life stage per month will support the evaluation and methods to improve water usage/conservation.

As some species have a longer rearing cycle at a hatchery than one year, please illustrate the water usage over a two year program. The example below provides context. Overwrite the Data per your program.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ______________________ Date: __________

Name: ______________________ Date: __________

Name: ______________________ Date: __________

		Rearing Vessel	Jan Flow Rate (gpm)	Feb Flow Rate (gpm)	Mar Flow Rate (gpm)	Apr Flow Rate (gpm)	May Flow Rate (gpm)	Jun Flow Rate (gpm)	Jul Flow Rate (gpm)	Aug Flow Rate (gpm)	Sep Flow Rate (gpm)	Oct Flow Rate (gpm)	Nov Flow Rate (gpm)	Dec Flow Rate (gpm)
Example														
	Incubation	Heath Trays	60								60	60	60	60
	Fry Rearing	3' dia circulars	120	120	120									120
	Juvenile Rearing	12' dia circulars			400	400	400	400	400	400	400			
	Outplan Rearing	30' dia circulars	1200	1200	1200	1200						1200	1200	1200
Species A														
	Incubation	Troughs	14	NA	NA	NA	NA	NA	NA	16	NA	NA	84	84
	Fry Rearing	Troughs/ Interm Raceways	159	246	222	228	177	171	171	20	16	16	NA	NA
	Juvenile Rearing	Regular Concrete Raceways	3096	3724	3343	3037	1041	2625	2317	2916	2986	2986	3459	3540
	Outplan Rearing	Brood Concrete Raceways	708	718	875	951	3227	975	947	947	812	812	547	415
		Totals	3977	4688	4440	4216	4445	3771	3435	3899	3814	3814	4090	4039
Species B		Water Rights	4488	4488	4488	4488	4488	4488	4488	4488	4488	4488	4488	4488
	Incubation		0	1	0	0	0	0	0	0	0	0	0	0
	Fry Rearing		5											
	Juvenile Rearing													
	Outplan Rearing													

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)	Flow Rate (gpm)
60								60	60	60	60
120	120	120									120
		400	400	400	400	400	400	400			
1200	1200	1200	1200						1200	1200	1200
14	NA	NA	NA	NA	5	NA	NA	NA	14	77	98
64	212	314	880	323	194	147	NA	NA	20	NA	119
3548	2881	3202	3143	3354	3167	3796	2918	3073	3394	3414	3697
647	1093	971	969	1072	1065	1050	1050	1111	851	851	813
4273	4186	4487	4992	4749	4431	4993	3968	4184	4279	4342	4727
4488	4488	4488	4488	4488	4488	4488	4488	4488	4488	4488	4488
0	0	0	1	1	0	1	0	0	0	0	1

min	max		Water right	
3435	4993	gpm	4488	gpm
7.7	11.1	cfs	10	cfs

McMillen		Job No. 23-034	No.
Project	WDFW Climate Change Vulnerability Assessment	Computed	Date
Subject	Goldendale Hatchery	Checked	Date
Task	Questionnaire - Process Flow	Sheet 1	Of 1

Please provide information on the fish health at the hatchery.

If there is not any data available, Place "NDA" next to the information listed.

Personnel Gathering Data

Name: ________________ Date: ________

Name: ________________ Date: ________

Name: ________________ Date: ________

Water Supply

List the pathogens of concern for the facility:

Bacterial cold water disease

Please provide any seasonal observations for the pathogens of concern at the facility

BCWD spikes in the spring/ summer time after small fry leave incubation room and get ponded into raceways

Please provide any existing treatments or mitigation measures to protect fish health

Formalin for BCWD upon veterinary approval

Meeting Minutes

To:	WDFW	Project	WDFW Hatchery Climate Change Vulnerability Assessment
From:	McMillen, Inc.	cc:	
Prepared by:	McMillen, Inc.	Job No.:	23-034
Date:	March 29, 2023		
Subject:	Hatchery Interview #1 – Kendall Creek Hatchery		

1.0 Introduction

1.1 Purpose

Vulnerability Assessment Interview - Hatchery Interview #1 – Kendall Creek Hatchery

2.0 Kendall Creek Hatchery Overview

- Kevin provided a brief overview of the hatchery. Kendall has excellent water quality. They could use more but what they do have is extremely good water. They can do a lot more than an average facility due to the water quality.
- The Kendall hatchery is the most diverse in production hatcheries in the entire state. It has surface water; ground water and the water movement are complicated.
  - Intake on Kendall Creek only utilizes creek water about 6 months out of the year starting late November through early June. It doesn't completely dry up but is very low flow. The ground water is the bread and butter at Kendall. The volumes are listed on the questionnaire.
  - Kendall is supplied with water from 5 well sites and a gravity system from Kendall Creek. Wells 4 and 5 are the primary production wells. Wells 1-3 are smaller and well 1 is currently offline.
  - 6 raceways, 8 series super raceways, 9 series, 8 more standard, new adult pond designed to conduct juvenile rearing. Three quarter acre ponds also' only two are utilized. The only program they typically have on surface water is Steelhead and

Coho. Trout must be on pathogen free ground water based on fish health policy to move fish out of the basin.

    - Spring Chinook only uses creek water when running out of water. The fish do not do as well on surface vs. ground water.

  - Rearing Facilities
    - 3 rows of double stacks - includes separate water supply for otolith marking.
    - 5 rows of 4 free-styles - includes dual plumbing to "chill" water for otolith marking.
    - Shipping container incubation placed near asphalt ponds.
      - The 4 series and 8 series raceways can receive creek water.
  - Species
    - Kendall Creek Coho - 1M Coho for Lemhi Tribe and transfers rear from egg down to C ponds. They start transferring those between 20-30 FPP.
    - Early Winter Steelhead – Release 150,000 yearling smolt annually directly into Kendall Creek.
    - Also, culture Rainbow Trout, Brown Trout, Cutthroat Trout, and kokanee.
- Mariza – What are the concerns with steam flows and water temperatures with Kendall Creek. Does in need to be tempered?
    - Kevin – It adjusts, but they really don’t have any concerns with the surface water at Kendall. As for the NPDS permit regarding temporal, there are no issues. They are putting out cooler water than they’re bringing in. As far as fish health, there are no seasonality issues with Kendall Creek water.
  - Mariza -Asked about the flood event that occurred 2 years ago.
    - Kevin – Multiple flooding events, major storm took out primary production wells, had to use surface water for everything during that time. When Kendall creek floods, it jumps up and down very quickly. Water going down after 12 hours. Snowmelt can create flooding issues. Utilized surface water was used until the wells were back online. No fish lost and no facility damaged. They did have sediment and clean up.
  - Water Supply
    - Kendall Creek gravity intake is non-compliant.
    - All wells produce only a fraction of the original design.
    - Old wood stave intake right on Kendall Creek. Improvements needed to bring to compliance. It serves a screen box area where fish are screened out. Fish enter for

about 100 yards and go back out at plunge pool. Surface water delivered to raceway series 4 (standard) and raceway series 8 (super raceways). No LHO's, oxygen etc.

- Water Delivery System
    - Well #1 currently has no pumps currently installed on it. Well #2 has 2 pumps that provide between 500gpm-1,200gpm depending on the season. These pumps do not pass through an aeration tower and provide low oxygen water. Pump#2 is currently non-functioning. Well #3 has a temporary submersible pump until a new one can be installed. Pump #3 passes through aeration tower #2. Pump 4 passes through aeration tower #2. Well #5 passes through aeration tower #1. Water can be reused throughout the facility or mixed with surface water.
    - Two primary production wells (4 and 5) are out back by 1/4-acre ponds 1-3. Pumped to aeration tower and pumped from there to anywhere in facility. The 3 smaller production wells (1-3). 1 and 2 not routed through aeration tower. Mostly used for mixing, not directly on to population of fish since it has not been degassed and DO is low. Well 3, is adjacent to 1 and 2, does get routed through aeration tower and water can be used anywhere in the facility,
    - Old wood stave intake right on Kendall Creek. Improvements needed to bring to compliance. It serves a screen box area where fish are screened out. Fish enter for about 100 yards and go back out at plunge pool. Surface water delivered to raceway series 4 (standard) and raceway series 8 (super raceways). No LHO's, oxygen etc.
    - Composite sample, so all outfalls monitored through NPDES
- Issues with the water delivery system?
    - Many non-functioning valves and lack of production from aging pumps and infrastructure.
    - 1 and 2 not going to aeration tower; this will be good water source for the PRAS system that will be in Pond 3. Typical PRAS equipment, no UV per initial budget but provisions for future installation.
- Effluent Discharge and Treatment
    - Seven discharge areas are in Kendall Creek.
    - Composite sample, so all outfalls monitored through NPDES
        - Kevin – Met with Ecology and as the PRAS system is implemented, ecology will be monitoring. It’s not 100% what additional monitoring will be required. Design is only at 65%.

    - Greg discussed double drain Cornell style tanks for flexibility
    - Randy – Currently now to (1) drum filter and the sediment coming out will go the abatement pond.
- Effluent treatment – Abatement Pond.
  - Kevin – Will provide McMillen with the hatchery schematic. **AI**
- Fish Health - Pathogen Concerns
  - Cold water is primarily in Steelhead and some in Coho.
  - BKD. Not a big concern.
  - A recent finding from fish health on site was furnculosis in coho. level.
  - Greg – Where are they seeing the cold-water disease? What state is it most prevalent?
    - Kevin – After swim up, early fry in the eggs. Typically, it's when any splits and are in the small fry stage.
  - Greg – Do they do any other chemical treatments, injections, or vaccinations etc.,
    - Kevin - No prophylactic for BKD currently. They have not had an outbreak which would require feed etc. They would use medicated feed to treat.
    - Their fish culture is trying to be methodical and not cause a stressful environment for the fish to open the door for BDK etc. He does not sample every week. They use projections vs. handling the fish. He reduces handling events where they can. A handling event is a stressful event. Good Bio security as well.
    - Formalin is used in the incubation room.
- Seasonal Observations:
  - Kevin – No issues. When the creek is elevated to 55 and 56, they're not using it.
- General Tab Discussion
  - As built, well and water right information and water use tables are all saved to SharePoint.
  - WDFW will note "see HGMP" if the information is referenced in the document vs. adding it to the "General tab".
  - Kevin/Chris to provide a file with as much information pertaining to the general.
- Mariza – Is currently not seeing the issues especially with Kendall regarding Climate Change issues.

- Kevin – The issue with Kendall is we need more water than they have. You could attribute it to the water table not being as charged as it used to be. The river channel moves from one side of the basin to the other and has seasonal flow. There has already been a climate impact to the water table. He's currently been requesting smaller production wells out in the drain field. This will assist with not being so reliant on the large production wells and more water for a growing program.
- Mariza – Declining trend, but perhaps can't be attributed to climate change. However, new wells are needed to supplement the water supply.

3.0 Summary of Action Items

- Kevin will provide McMillen with the hatchery schematic.
- WDFW to provide an arial view of the hatchery layout. This will include pond numbers and corresponding letters.
- WDFW will note "see HGMP" if the information is referenced in the document vs. adding it to the "General tab".
- Kevin/Chris to provide a file with as much information pertaining to the general's tabs.

4.0 Adjourn

Meeting Minutes

To:	WDFW	Project	WDFW Hatchery Climate Change Vulnerability Assessment
From:	McMillen, Inc.	cc:	
Prepared by:	McMillen, Inc.	Job No.:	23-034
Date:	March 29, 2023		
Subject:	Hatchery Interview #1 – Marblemount Hatchery		

1.0 Introduction

1.1 Purpose

Vulnerability Assessment Interview - Hatchery Interview #2 – Marblemount Hatchery

2.0 Marblemount Hatchery Overview

- Water Supply
  - Coho go straight from incubation to the raceways. Chum is raised in the well water.
    - Action item: provide flow minimum requirements for each water source or total flow as combined.
  - No water flow concerns for Cascade. Lower flow in Clark Creek late summer, early fall. Jordan starts having issues earlier in the summer and eventually has to be shut off completely. All the water supplies go into a combined pipe. The various sources are not metered. WDFW to provide total flow.
  - What led to three different intakes?
    - History unknown. Clark is the oldest (pumped), Cascade next (pumped), then Jordan 2018 (gravity fed) – added likely due to being gravity fed for emergency supply.
  - Are there known temperatures issues with the water sources?
    - Jordan and Clark Creek have temp issues in summer due to low flow.

    - Cascade is glacial fed, which regulates the temperatures of the water.

- Water Delivery System
  - Looking at the HGMP document, wells are sanding in and need to be redeveloped. True of all the wells?
    - Problems with them running low and dry and must turn them off.
    - Last rehabbed 2-4 years ago. Saw benefit initially but it did not last long.

  - What kind of flooding issues do you have with the intakes?
    - Intakes will plug up with debris and need to be tended to.
    - Jordan creek has its own water burst system that works well.
    - Cascade is manual – shut down and brush off the debris.
      - Sand removal every 2 – 3 years of the settling pond.
      - 500 cubic yards of sand removed. Noted in HPA excavate that out.
    - Clark creek – not much debris to create problems.

  - Are there specific concerns that may become more difficult or more critical because of warming in the future? Or trends that are starting to concern you?
    - They have a short window of experience on site to comment.
    - Issue going into the future with warming water temperatures. Cascade is cooler and less affected by the day-to-day trends. Without the snow pack every year it could change the course of the river.
    - Clark Creek – Slower low gradient well forested – should sustain through climate change.
    - Jordan – High gradient, high demand that would be needed from snowpack and water reserves.

  - Has there been any land cover changes?
    - Active logging in the area over the past 3 years.

  - What the temperatures are?
    - Readers located at Jordan, Cascade and Clark
    - Action Item: Download reader data for this project.

  - Any issues with the water delivery system itself?
    - The infrastructure is going downhill.
      - 6-8 years on full hatchery rebuild.
      - $40-$50M (preplanning beginning in 2 years)

  - Effluent Discharge and Treatment

        - Screens or UV
    - They are screened intakes but no UV or chemical treatment. Settling pond for Cascade to remove settling solids. All three intakes are screened.
        - Action Item: Provide a figure, besides as-builts, that illustrate the water process through the facility.
        - Action Item: provide any additional Intake information.

- Rearing Facilities: Refer to WDFW HCCVA Questionaire_Marblemount updated 3/20

- Water supply
    - Refer to WDFW HCCVA Questionaire Marblemount updated 3/2.
        - Action Item: Please provide what water supply looks like from each.

    - Would like to have more well water. Currently is sufficient for what they need.
    - Having more ground water would be important for continual growth.
        - Increasing in incubation and early rearing indoors that uses a lot of that well water.
- Species
    - Spring and summer chinook – surface water
    - Coho – surface water
    - Chum – well water
        - Only rear in fresh water for a few weeks before going to salt water.
        - As soon as they emerge from gravel, they can go straight to salt water - released at 2 weeks.
        - 60% release is off station.
        - 40% release is on station.
    - Rainbow – surface water

- Fish health: Refer to WDFW HCCA Questionnaire_Marblemount

- When do we predict we will get the data?
    - NHC hoping to see action items information and data in 1-2 weeks.
    - General tab needs filled out. Production reports for Greg Fischer needs:
        - Species A Species B worksheets
            - Biomass
            - Numbers
            - Production report items

3.0 Summary of Action Items

- Provide any additional Intake information.
- Flow minimum requirements for each water source or total flow as combined,
- Download reader data for surface temperatures and flow.
- Provide a figure, besides as-builts, for the water process through the facility.
- McMillen to provide Kevin and Dave access to SharePoint.

4.0 Adjourn

Meeting Minutes

To:	WDFW	Project	WDFW Hatchery Climate Change Vulnerability Assessment
From:	McMillen, Inc.	cc:	
Prepared by:	McMillen, Inc.	Job No.:	23-034
Date:	March 29, 2023		
Subject:	Hatchery Interview #1 – Samish Hatchery		

1.0 Introduction

1.1 Purpose

Vulnerability Assessment Interview - Hatchery Interview #1 – Samish Hatchery and Kendall Creek Hatchery

1.2 Attendance

2.0 Samish Hatchery Overview

- General Overview
  - Samish Hatchery is strictly a Fall Chinook fishery. Largest Chinook release in Northern Puget Sound. Creates the largest recreational and non-rec fishery in Northern Puget Sound. The annual goal is releasing 5.2 million Fall Chinook at 90 FPP in May. Have transferred 1/2 million to local Co-op. Walkum Creek Hatchery.
  - Two rearing facilities
    - Main Hatchery
      - Series of 12 standard raceways and ¼ acre pond. Raise 3.6 million at those facilities. Utilize an adult pond for juvenile rearing in the spring due to insufficient water or space at the main facility to meet the release goal. Transfer about 1.5 million down to the adult pond to rear, mark and released.

        - Release is into Friday Creek. Sometimes they have to stagger releases based on the amount of water they can pull from Friday Creek.
    - Water Supply
        - Friday Creek is the main water supply and is all gravity fed. No wells at this facility. Minimum supply for Friday Creek is 2 cfs.
    - Adult Pond
        - Located on North Green Road. on the Samish River itself.
        - Water supply is a pump station, so all surface water and pump directly out of the river.
        - Release from the adult pond to the Samish.
    - Two full-time employees, (2) non-permanent employees.
- Questions/Comments
    - Greg Fisher – How deep is the 1/4-acre pond? Is it lined?
            - ¼ acre pond is juvenile rearing pond.
            - It is approximately 4ft deep.
            - It is an asphalt pond.
    - Greg – The adult pond? What is the size of that pond?

      The adult pond is adjacent to the Samish, less than one mile from main hatchery. It is approximately ½ acre. See questionnaire for exact size.
    - Patty – How often do you not have sufficient water for releases into Friday Creek?
        - Almost annually. They had a few springs where they had more flow.
        - Headwaters of Friday Creek is Samish Lake. Kevin has a good working relationship with Samish Water District so if he has releases coming up, he can generally call them, and they will pull some damn boards to make it easier for juveniles to get down to the Samish.
        - Until about 8-9 years ago was that they had well water onsite. That allowed them to incubate longer at the facility and allowed them to warm the water some. As far as egg development, surface water is at the mercy of water temperatures.
    - Well Water – Situated in an agricultural area and no longer maintained by DFW but by the two private residences. They're looking for potential well locations by N. Green Road. If found, they would build incubation at that site near the adult pond. This would provide them with the ability to incubate a full cycle. They take all

unfertilized eggs, five females per bucket, bring 100 females at a time to Kendall Hatchery, which is 34 miles away, and fertilize everything there. Until eyed up, at which time, we ship them to Samish as eyed eggs in the incubation room serviced by Friday Creek. The development of eggs gets slowed up on surface water. They are desperately looking for well water to discontinue this practice.

- Greg Fisher – Asked if they have looked at surface water to chill.
  - Kevin – They need water that is warmer than the current temperature of the surface water to have egg development. They need more thermal units per day to get fish out of the building earlier. They've investigated heated situations to warm the water. The problem with that is that Friday Creek is a heavy sediment creek. Running water through a facility to cool or heat would be a difficult thing due to the high sediment load. They're looking for ground/well water for consistency. The ground water is between 47-50ºF year-around. If they could access 48-degree water year around and the entire program was on that water, they could get the fish out in 45 days. The cold water on Friday Creek creates a big bottleneck. Federally mandated to mark before release. 5.2 million Chinook is a huge program to mark…2-3 manual trailers and 1 automated trailer and employ up to 20 people to get this process done.
  - They're trying to find a solid ground water source for incubation purposes. They've received the funding and are currently looking for the wells. In the last 2 years gained some traction and sites are currently being tested. This will help this program be successful. Take away from this is Samish is looking for ground/well water would be a big improvement for the facility.
- Water Supply
  - There is flooding Nov – February.
    - They had flooding bad enough at Friday Creek that the adult pond was under 2-ft of water. The biggest issue is landslides that make the access road to the intake inaccessible. They now have 4 wheelers on station to get to the intake.
    - Samish – They have a brand new weir and intake at this site. They've had two big weather events and the design is working well. They have an Obermeyer weir now and can lower the weir when the big water is coming.

- Questions/Comments:
  - Mariza – What would they say is the problem with low flows?

        - Kevin – Biggest concern with duration with low flows is not having the volume of water for density of the fish on site. Not to be able to maintain the approx. flow index sufficient for production.
            - Low flows problematic for program is in the spring. Low flow means increased temps which Chinook are sensitive to.
            - Having enough water in the creek to be able to safely navigate the stream bed to the Samish due to predators.
            - Having enough water to maintain flow indexes.
    - Mariza – Stated that she will be looking at climate change, and a quantitative number would be helpful. She asked Kevin if he thought the increase in temp was associated with different land uses in the watershed. Or is this an effect of climate change without other causes?
        - Kevin – Yes. It's accumulative. Yes, we are experiencing climate change and especially with surface water facilities. He's been in Adaptive Management mode due to the variables that change year over year. Increased temp, lower flows. The Friday Creek, community that live on the lake are grandfathered in with expectations. Beaver Dams that manipulate flows.
        - Pathogens manifest better the warmer water. Anything above 55-56 due to the pathogen issues.
    - Kevin discussed heavy sediment load that is abrasive to gills.
        - Samish – Is in an Agricultural area which produces higher levels of coliform. This hasn't had a negative effect on fish culture. The Samish in the fall is so warm that it does make keeping adult Chinook alive difficult. Getting the ground water, you can manipulate water temps in the adult pond.
- Mariza – Flooding? Fall/Winter?
    - Kevin – Correct.
- Mariza – Sediment is that associated with high flows.
    - Kevin – One reason Overmeryer and intake was redesigned. The flooding was causing accumulation of sediment. Usually, the events occur with no production happening. No negative effect on fish, but rather on the facility.
- Mariza – CFS threshold numbers for both streams.
    - Kevin – Will provide this information to the team. AI

    - Joy – Friday Creek Intake the capital budget to meet requirements. Any specific items they're looking to include?
        - Kevin – Friday Creek will remain gravity fed system. The work that needs to be done regarding capital projects is around compliance issues (screens, fish passage). The idea there is to rebuild so they comply. For the right size screens, the actual footprint needs to be expanded. He's been told in habitat that the fish ladder is too short and would like it to be lengthened. No plans to pump water from Friday Creek.
        - Friday Creek – Most Capital Budget is for Armoring the road for access the intake. Higher priority.
    - Question - Landslide that resulted in a multi-day no access. Do they have an excavator?
        - Kevin – Typically it results down to the shop send those that would dig out a landslide.
- Water Delivery – Greg asked for a review of their system.
    - Series of 4 raceways, deeper and double wide. The older raceways onsite.
    - 1-8 – Std.
    - 9-12 – non-Std.
    - Pond 13 – asphalt pond.
    - No treatment or LHO coming right from the river from Friday Creek to the raceways and ponds. No filter.
    - They have an aeration tower that supplies the incubation room with surface water. Basically, all the water goes into the aeration tower and distributor to pond headers. 100% goes through aeration to de-gas. Aeration water goes through it for the entire system. No pump, but gravity.
        - Greg – Pumped oxygen on site?
            - Kevin – No.
- Incubation Room
    - Kevin – They use formalin. Not much treatment due to getting eggs back from Kendall when they are already hatching. They do have a formalin treatment in their incubation room.
    - Water treatment is aeration only.
    - Effluent Discharge and Treatment.

    - 3 outfalls at the main facility that discharge to Friday Creek. No issues.
    - Abatement Pond – Yes. That is used for any time vacuum venture system to remove solid waste and pumped into abatement and settled out. Every 3 years dewater and manually remove sediment load for removal offsite.
    - Greg – Dot they have any permitting issues for phosphorus or nitrogen loads?
      - Randy – Added phosphorus testing. NPDS permit, does require impairment for release. Dissolved oxygen impairment test. This is a requirement only in the past 2 years due to the NPDS permit change.
  - Greg – Do they use any low phosphorus feeds?
    - Randy – Not directed.
  - Greg – Have they seen any issues with fish production and limits? Are they getting close to limits. Will reduced water cause higher pollutants in the water. He's thinking effluent what is leaving. Could this potentially cause an issue?
    - Kevin – Yes. Ecology has them testing and monitoring. They've never been in violation.
    - Randy 13 hatcheries that have the requirement.
- Rearing
  - Raceways 9-12 updated to 500 gpm. AI Kevin to verify.
  - 3,000 gpm is reuse water (1-12 and redirected through 13. This is not in addition. Mostly reuse, they have a header and some fresh water in, but generally reuse running down 13).
  - Samish is the 2nd oldest hatchery in Washington, built 1891 and updated many times throughout. It's historic and difficult to update historical.
- Bio Programming – Greg Fisher will review the data provided and discuss it at a later time.
- Water Budget
  - Kevin will provide the data to Randy for distribution to the team. **AI**
  - Greg – How do they monitor temperature?
    - Kevin DMR's – Temp data gathered and turned into Ecology. Min/Max temp daily. Data available for the last 2 years.
  - Greg – Are birds an issue at Samish?

    - Kevin – Not an issue.
- Greg – Pulling from the rivers is there non target species that are carrying a potential disease into the water source?
    - Kevin- They've not experienced this. The biggest concern that utilizes surface water, Salmon has the ability is IHN. Not tested positive in all the years. He does know that is the number one concern.
- Greg – Do they have to deal with VHS?
    - Kevin – No, not yet.

3.0 Summary of Action Items

- WDFW – Will provide the threshold numbers for both streams.
- WDFW to provide Greg, at McMillen, with the diseases that are present when temperatures increase in the spring.
- Kevin will provide Randy with the information that needs to be distributed to the team.

4.0 Adjourn

Meeting Minutes

To:	WDFW	Project	WDFW Hatchery Climate Change Vulnerability Assessment
From:	McMillen, Inc.	cc:	
Prepared by:	McMillen, Inc.	Job No.:	23-034
Date:	March 29, 2023		
Subject:	Hatchery Interview – Goldendale Hatchery		

1.0 Introduction

1.1 Purpose

Vulnerability Assessment Interview - Hatchery Interview – Goldendale Hatchery

2.0 Goldendale Hatchery Overview

- General Overview
    - Spring water supply is approximately 4800 gallons per minute. They do lose some flow in the winter due to freezing temperatures in the mountains; approximately 500 gallons per minute lost.
    - Water is consistently 51⁰ F temperature year-round. Collect 100% Spring Creek to a settling pond.
    - They have 140,000 catchables and 12,000 fish raised for replacement for broodstock. Spawn 3-year-olds and 4-year-olds for the broodstock. They have 3,000 on hand of the 3-year-olds and only about 800 of the 4-year-olds. The have approximately 1500 males and 1500 females.
    - Also culture Eastern Brook Browns, Tigers, West Slope Cutthroat. These are small programs that are used for releasing in the mountains in the summer. Released around 100 FPP and raised just in the incubation room.

- Water Supply
  - Spring Creek is only a spring and is the only source of water year-round. Only water that continues beyond the hatchery in Spring Creek is the water discharged from the facility at the raceways.
  - Using a 36” pipe collected at the spring, it goes to the headwater to the hatchery.
  - Do they have concerns about the future continuity of the abundance of water from the spring? Do they notice any trends that concern them.
    - Spring water has been fairly consistent with just 500 gallon per minute decrease in the wintertime. But since it is a spring fed system, they are concerned about decreases in the overall volume of water over time due to climate change impacts.
    - The vicinity in general has been identified for a number of alternative energy projects and significant solar panel projects as well as general growth of residential systems. They do have an overall water availability concern.
    - There is a difference in water output from spring, according to past hatchery managers. The spring is an artesian spring from the nearby mountains. In the wintertime the flows are reduced due to less snow melt.
  - Water is consistently 51^0 F temperature year-round.
  - In the wintertime they get turbidity in the water after high snow melt, so in the spring or just after fresh snow.
  - Mariza – Asked WDFW if they have any time series data collected on the spring output?
    - Not that WDFW is aware of.
  - Greg – Do they use aeration or UV on the water before going into the rearing and incubation?
    - They use a packed column for the water going into incubation room. There is no aeration prior for the raceways. They do use aerators in the raceways themselves throughout the year to extend the amount of rearing.
  - Greg – What kind of DO are they seeing with the spring water? Is it at saturation?
    - It is saturated, typically about 10.5 mg/L. However, the outflow at some rearing capacities is low, especially just after feeding.

        - Aerators in the raceways are just mechanical rotation to agitate the water, no liquid oxygen addition. They do have some emergency oxygen on hand if needed.
    - Greg – Oxygen gets low in the winter. Is it due to holding fish over?
        - Yes, that is correct. They have a tight release schedule. Winter release is 27,000 catchable - Releasing in mid-December and can't finish planting them until 1st of March.
    - Joy – Asked if all the rearing was flow-through in raceways.
        - Yes, that is correct. There is also 500 gallons that supplies the incubation room.
    - Joy – What is the low DO on average?
        - WDFW – It can be in the 4's and 5's.

- Water Delivery System
    - The concrete cistern and collection pipe are in good condition and were inspected a few years back. It's currently operational. Only 1 to 2' of head difference between the spring and the hatchery.
    - Joy – Any capital improvement projects and requested funding for this site?
        - This site is an inland broodstock station and produces close to 70% of catchables for region 5. They have 2 different capital project requests in for this facility but not prioritized. There were two versions 1) Augment existing facilities to use some limited recirc/LHO's and 2) Complete remodel ground up on PRAS or full recirc with modern technology. The water source is fantastic and there is a lot of potential. However, from an agency perspective, a lot of resources (funds) are going into the Spokane facility for the inland program currently, so any funding for this facility would be in que for future capital improvements.
    - Greg – It appears they are using all the space and water for their current facility.
        - If they could increase the volume of quality water through some of the upgrades it's a question of fish food/labor and they could put out more catchable trout. This is something that they would be on board with.
    - Joy – Can they tell if they are collecting all that the spring has to offer?

        - WDFW stated that they have no back up if something was to happen to the line. They have no secondary water source.
        - The spring appears to be self-regulating. Turning water on and off in the facility does not influence the static head in the spring box.
    - Greg – Asked the team if they have explored dye testing on the spring to see where the water is going?
        - WDFW – He doesn't know of any dye testing. The cistern is surrounded by a marsh, but the rest is very arid and dry. They do see minimal seepage going into a ditch past the hatchery. It's a trickle till reaching Spring Creek.
    - Greg – When the hatchery was originally built and the piping sized, were there studies on the spring and production was sized accordingly?
        - WDFW – Does not think the restricting factor is the pipe, but rather the lack of elevation in between the spring and the hatchery. There is not enough head pressure to force more water. As Aaron was stating, when you turn water off you don't see any static difference.
    - Greg – What is the head pressure difference?
            - WDFW – 1-2ft, maybe up to 3 in elevation. They stated that they tried to put in an LHO system in the headbox and not enough pressure to force it and it backed up the spring and overflowed.
            - As built drawings should be available on the system. It was built in 1938 and has been remodeled since**.** The cistern and catchment good chance there is cracks.
            - The spring has a series of large dam boards that were replaced over time and create the head and capture the water. Greg stated that the dam boards are starting to leak, but nothing significant.

- Effluent Discharge and Treatment
    - Water is discharged into abatement pond for solids to settle out. Water will then overflow into Spring Creek.

- Permitting
    - WDFW – NPDS permitting done weekly. No specific nutrients or monitoring.

- Rearing Facilities: Refer to WDFW HCCVA Questionaire_Goldendale updated 3/20
    - WDFW – Stated 3 groups in the intermediate raceways and 2 shallow troughs on top. Once they hatch, they go into intermediate and then rear until 250 fish per lb. Once the fish are 250, they go to the raceways by group. In the past could not release soon enough in the spring and had to combine 2 groups.

  - WDFW provided a google earth image of the hatchery layout.
    - Future capital project is to build 8 shallow aluminum toughs to fit over each intermediate to provide another 24 shallow rearing units. They will be crane lifted when not needed. Water into the raceways entering at the head and exists at the back.
    - All single pass.
    - Range between 320 gallons per minute up to 420 depending on changing the water supply.

- Condition of rearing Vessels:
    - Weathering for the raceways, chips etc. The dam boards will need to be replaced and show some seepage.
    - The header for each raceway is all wooden dam boards.
    - Each intake is wooden dam board and not concrete.
    - Mostly the dam boards will need to be replaced.

  - Greg asked WDFW if they vacuum out the raceways and dispose of the solids?
    - They broom into PA Ponds. No issues with Phosphorus at this point.

  - Joy – All water goes to the PA ponds?
    - WDFW confirmed, yes.
    - Aaron – NPDS sampling calls it “inline”.
    - Joy – If they decide to do vacuuming, it will allow for smaller PA ponds and more overall flow for the facility.
    - WDFW – If they did a full remodel to some level part/full recirc the abatement system would be replaced and any future needs.

  - Joy – Asked about the location and condition of the PA ponds.
    - It hasn’t been cleaned out in some time. However, due to being spring fed, sedimentation is minimal in this system.

  - Greg asked if they have any issues with bird predation in the outdoor raceways?

- Fish health: Refer to WDFW HCCA Questionnaire_Goldendale
  - Mainly cold water in the spring. A couple of outbreaks, but no more than 1-2% mortality rate.

- Do they treat with anything?
    - They treat the eggs with formalin and an outbreak if needed. It’s been mainly cold-water issues.
    - They would term it pathogen free water source. They also do not bring outside fish to the facility. They treat bacteria cold water in various forms and maybe fungus in incubation treatments.

- WDFW discusses the location and difference between game and fisheries on purchasing the properties back in the early 1900-950’s. This particular facility used to be farmland and in the 1930’s where the spring is now used to be a dam and pond for irrigation water.

- Species
    - Greg – He hasn’t reviewed the questionnaire for species. Will review.

- General Tab Questions
    - WDFW downloaded all files that were available on SharePoint.
        - Greg – In reviewing the as built if any pictures of the facilities are available, but it would be helpful to capture the facilities.
        - Cody – To upload pictures to the SharePoint site. AI

    - Joy reviewed the tab and data points.
        - Historical data has not been found on the spring.
            - Cody – They have loadings and use all the water available. They have available load data from 2012. However, for loadings, some loadings would have once a month and other once a week depending. They did a review to get a couple years of averages by month.
            - 20–30-year time span and water source not sure they have that type of data.
            - Joy – A by month data would be helpful.

        - Mariza - Would they be interested in future projected meteorological rainfall; air temperature is that pertinent to the hatchery?
            - WDFW – Yes. However, it’s key that the data is linked to seasonal conditions etc. to the hatchery.

        - Mariza – Can WDFW share any vulnerabilities that would be for a hatchery operation associated with precipitation, air temperature and any other variables throughout the year and life cycle of the fish.

  - WDFW – From a Hatchery perspective, there are two tracks –
  - Facilities Security – As it relates to those items, where the hatchery sits, there are no real site safety integrity concerns.
  - They would be very interested in understanding how future conditions will affect the quality and quantity of the water for the spring.
- Mariza – It's a challenging question without a model or study. Do they know if either of those are available for this spring?
  - WDFW – Perhaps the Engineering group or on the county websites or local work that that would tie into that water source. No other information is available from the hatchery.
- Mariza – without that information it would be very speculative to cause and effect.
  - WDFW – Is searching for this information part of the scope for this project? Or is this beyond?

  - Harriet - Discussed that this would not be on the hatcheries to locate.
- WDFW bought up at one of their other facilities, a commercial driller was drilling a well and had to work with Ecology to map out the aquifer. That was through Ecology and to see if similar studies are part of the public record. He knows several large alternative energy proposals that are directly in their footprint. The focus on the spring water. They do have water right and can exercise.

- Mariza and WDFW discussed climate change as it relates to the hatchery.
  - WDFW – Sated that from the hatchery perspective their concern is the spring.

  - Patty and Mariza will review and get back to them a will get back to the hatchery on what they can do within the scope and data available. **AI**

- Sam asked Greg if the NPDS report reflects how many gallons per day are being reported monthly?
  - WDFW – The report only shows the total flow out of each raceway. The one thing he wants to be sure of is all the spring goes through the hatchery. If we're saying using 4800 gallons per minute that is all the spring. The majority of the water is going through the hatchery somewhere.

- Greg – Is the spring fed by snow melt and it come down at spring creek?
    - WDFW – That's the assumption is snowpack and rainfall, but mostly it's snowpack.
    - Greg – Stated that alone climate change could affect.
    - Patty – It will depend on what level of modeling is available.

3.0 Summary of Action Items

- WDFW to check for as built drawings.
- Cody to upload pictures to the SharePoint site**.**
- Patty/Mariza to discuss and depending on the result will have a call with Harriet.
- Greg to review bio programming and get back to WDFW with any questions.
- Joy to get anyone that needs SharePoint access.

4.0 Adjourn

Appendix B. Bioprogramming

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McMillen

Project	WDFW Hatchery Climate Change
Subject	Marblemount Hatchery
Task	Existing Bioprogramming
Job No.	23-034

Species	**Rainbow Trout**

Production Stages	**Total Fish Output**	**Fish Output Size**			**Rearing Unit**	**Tank Volume**	**Width**	**Existing Rearing Units**		**Flow Rate per Rearing Unit**	**Biomass**	**Required Volume**	**Tanks Required for DI**	**Required Flow**	**Tanks Required for FI**
	(#)	**(fpp)**	**(in)**	**DI**	**(Type)**	**(ft^3)**	**(ft)**		**FI**	**(gpm)**	**(lbs)**	**(ft^3)**		**(gpm)**	
Fry (FI = 1.8)	396,605	2,319.0	1.02	0.5	Int. Trough	110.4	3	16	1.8	25	171.02	335.34	4	93.2	4
Juvenile (FI = 1.8)	360,550	665.0	1.5	0.5	Int. Trough	110.4	3	16	1.8	25	542.18	722.91	7	200.8	9
Broodstock (FI = 1.8)	5,000	0.3	21	0.5	Raceway	3,000.0	10	24	1.8	306	16,666.67	1,587.30	1	440.9	2
Fry (FI = 2.7)	396,605	2,319.0	1.02	0.5	Int. Trough	110.4	3	16	2.7	25	171.02	335.34	4	62.1	3
Juvenile (FI = 2.7)	360,550	665.0	1.5	0.5	Int. Trough	110.4	3	16	2.7	25	542.18	722.91	7	133.9	6
Broodstock (FI = 2.7)	5,000	0.3	21	0.5	Raceway	3,000.0	10	24	2.7	306	16,666.67	1,587.30	1	293.9	1

Species	**Spring Chinook**

Production Stages	**Total Fish Output**	**Fish Output Size**			**Rearing Unit**	**Tank Volume**	**Width**	**Existing Rearing Units**		**Flow Rate per Rearing Unit**	**Biomass**	**Required Volume**	**Tanks Required for DI**	**Required Flow**	**Tanks Required for FI**
	(#)	**(fpp)**	**(in)**	**DI**	**(Type)**	**(ft^3)**	**(ft)**		**FI**	**(gpm)**	**(lbs)**	**(ft^3)**		**(gpm)**	
Fry (FI = 1.8)	1,330,000	1,200.0	1.3	0.2	Int. Trough	110.4	3	16	1.8	25	1,108.33	4,262.82	39	473.6	19
Juvenile (FI = 1.8)	787,500	80.0	3.5	0.2	Raceway	3,000.0	10	24	1.8	306	9,843.75	14,062.50	5	1,562.5	6
Yearling (FI = 1.8)	400,000	8.0	7	0.2	Channel Pond	58,275.0	37	4	1.8	2040	50,000.00	35,714.29	1	3,968.3	2
Fry (FI = 2.7)	1,330,000	1,200.0	1.3	0.2	Int. Trough	110.4	3	16	2.7	25	1,108.33	4,262.82	39	315.8	13
Juvenile (FI = 2.7)	787,500	80.0	3.5	0.2	Raceway	3,000.0	10	24	2.7	306	9,843.75	14,062.50	5	1,041.7	4
Yearling (FI = 2.7)	400,000	8.0	7	0.2	Channel Pond	58,275.0	37	4	2.7	2040	50,000.00	35,714.29	1	2,645.5	2

Species	**Summer Chinook**

Production Stages	**Total Fish Output**	**Fish Output Size**			**Rearing Unit**	**Tank Volume**	**Width**	**Existing Rearing Units**		**Flow Rate per Rearing Unit**	**Biomass**	**Required Volume**	**Tanks Required for DI**	**Required Flow**	**Tanks Required for FI**
	(#)	**(fpp)**	**(in)**	**DI**	**(Type)**	**(ft^3)**	**(ft)**		**FI**	**(gpm)**	**(lbs)**	**(ft^3)**		**(gpm)**	
Fry (FI = 1.8)	220,000	1,200.0	1.3	0.2	Int. Trough	110.4	3	16	1.8	25	183.33	705.13	7	78.3	4
Juvenile (FI = 1.8)	200,000	100.0	3.1	0.2	Raceway	3,250.0	10	24	1.8	306	2,000.00	3,225.81	1	358.4	2
Fry (FI = 2.7)	220,000	1,200.0	1.3	0.2	Int. Trough	110.4	3	16	2.7	25	183.33	705.13	7	52.2	3
Juvenile (FI = 2.7)	200,000	100.0	3.1	0.2	Raceway	3,000.0	10	24	2.7	306	2,000.00	3,225.81	2	238.9	1

Species	**Coho**

Production Stages	**Total Fish Output**	**Fish Output Size**			**Rearing Unit**	**Tank Volume**	**Width**	**Existing Rearing Units**		**Flow Rate per Rearing Unit**	**Biomass**	**Required Volume**	**Tanks Required for DI**	**Required Flow**	**Tanks Required for FI**
	(#)	**(fpp)**	**(in)**	**DI**	**(Type)**	**(ft^3)**	**(ft)**		**FI**	**(gpm)**	**(lbs)**	**(ft^3)**		**(gpm)**	
Fry (FI = 1.8)	1,218,335	2,400.0	1	0.3	Raceway	3,000.0	10	24	1.8	306	507.64	1,692.13	1	282.0	1
Juvenile (FI = 1.8)	630,000	25.0	4.7	0.3	Raceway	3,000.0	10	24	1.8	306	25,200.00	17,872.34	6	2,978.7	10
Yearling (FI = 1.8)	500,000	17.0	5.5	0.3	Channel Pond	58,275.0	37	4	1.8	2040	29,411.76	17,825.31	1	2,970.9	2
Fry (FI = 2.7)	1,218,335	2,400.0	1	0.3	Raceway	3,000.0	10	24	2.7	306	507.64	1,692.13	1	188.0	1
Juvenile (FI = 2.7)	630,000	25.0	4.7	0.3	Raceway	3,000.0	10	24	2.7	306	25,200.00	17,872.34	6	1,985.8	7
Yearling (FI = 2.7)	500,000	17.0	5.5	0.3	Channel Pond	58,275.0	37	4	2.7	2040	29,411.76	17,825.31	1	1,980.6	1

Species	**Chum**

Production Stages	**Total Fish Output**	**Fish Output Size**			**Rearing Unit**	**Tank Volume**	**Width**	**Existing Rearing Units**		**Flow Rate per Rearing Unit**	**Biomass**	**Required Volume**	**Tanks Required for DI**	**Required Flow**	**Tanks Required for FI**
	(#)	**(fpp)**	**(in)**	**DI**	(Type)	**(ft^3)**	**(ft)**		**FI**	**(gpm)**	**(lbs)**	**(ft^3)**		**(gpm)**	
Fry (FI = 1.8)	5,500,000	2,400.0	1	0.4	Int. Trough	110.4	3	16	1.8	25	2,291.67	5,729.17	52	1,273.1	51
Juvenile (FI = 1.8)	5,000,000	800.0	1.7	0.4	Raceway	3,000.0	10	24	1.8	306	6,250.00	9,191.18	4	2,042.5	7
Fry (FI = 2.7)	5,500,000	2,400.0	1	0.4	Int. Trough	110.4	3	16	2.7	25	2,291.67	5,729.17	52	848.8	34
Juvenile (FI = 2.7)	5,000,000	800.0	1.7	0.4	Raceway	3,000.0	10	24	2.7	306	6,250.00	9,191.18	4	1,361.7	5

McMillen

Project	WDFW Hatchery Climate Change
Subject	Kendall Creek
Task	Existing Bioprogramming
Job No.	23-034

Species	Spring Chinook

Production Stages	Total Fish Output	Fish Output Size			Rearing Unit	Tank Volume	Existing Rearing Units		Flow Rate per Rearing	Biomass	Required Volume	Tanks Required for DI	Required Flow	Tanks Required for FI
	(#)	(fpp)	(in)	DI	(Type)	(ft^3)		FI	(gpm)	(lbs)	(ft^3)		(gpm)	
Fry	1,424,000	1,101.0	1.45	0.2	Raceways	3,136.3	12	1.91	200	1,293.37	4,459.90	2	467.0	3
Juvenile	1,400,000	250.0	2.4	0.2	Raceways	3,136.3	12	1.91	200	5,600.00	11,666.67	4	1,221.6	7
Juvenile	1,100,000	100.0	3.2	0.2	Adult Ponds	10,800.0	2	1.91	1200	11,000.00	17,187.50	2	1,799.7	2
Juvenile	400,000	80.0	3.5	0.2	Adult Ponds	10,800.0	2	1.91	1200	5,000.00	7,142.86	1	747.9	1

Species	Kendall Creek Coho

Production Stages	Total Fish Output	Fish Output Size			Rearing Unit	Tank Volume	Existing Rearing Units		Flow Rate per Rearing	Biomass	Required Volume	Tanks Required for DI	Required Flow	Tanks Required for FI
	(#)	(fpp)	(in)	DI	(Type)	(ft^3)		FI	(gpm)	(lbs)	(ft^3)		(gpm)	
Fry	546,250	1,202.0	1.33	0.3	Raceways	3,136.3	12	1.91	200	454.45	1,138.97	1	178.9	1
Juvenile-Raceway	518,938	200.0	2.42	0.3	Raceways	3,136.3	12	1.91	200	2,594.69	3,573.95	2	561.4	3
Juvenile-Super Raceway	518,938	200.0	2.42	0.3	Super Raceways	11,565.0	3	1.91	1200	2,594.69	3,573.95	1	561.4	1
Yearling	500,000	17.0	5.5	0.3	Super Raceways	11,565.0	3	1.91	1200	29,411.76	17,825.31	2	2,799.8	3

Species	North Fork Nooksack Chum

Production Stages	Total Fish Output	Fish Output Size			Rearing Unit	Tank Volume	Existing Rearing Units		Flow Rate per Rearing	Biomass	Required Volume	Tanks Required for DI	Required Flow	Tanks Required for FI
	(#)	(fpp)	(in)	DI	(Type)	(ft^3)		FI	(gpm)	(lbs)	(ft^3)		(gpm)	
Fry	5,092,500	1,202.0	1.33	0.3	Asphalt Ponds	53,900.0	2	2.864	1500	4,236.69	10,618.27	1	1,112.2	1
Juvenile	5,000,000	400.0	1.94	0.3	Asphalt Ponds	53,900.0	2	2.864	1500	12,500.00	21,477.66	1	2,249.8	2

Species **Winter Steelhead Trout**

Production Stages	Total Fish Output	Fish Output Size			Rearing Unit	Tank Volume	Existing Rearing Units		Flow Rate per Rearing	Biomass	Required Volume	Tanks Required for DI	Required Flow	Tanks Required for FI
	(#)	(fpp)	(in)	DI	(Type)	(ft^3)		FI	(gpm)	(lbs)	(ft^3)		(gpm)	
Fry	190,000	2,000.0	1.13	0.3	Shallow Troughs	6.8	34	1.91	10	95.00	280.24	42	44.0	5
Juvenile	180,500	200.0	2.42	0.3	Raceways	3,136.3	12	1.91	200	902.50	1,243.11	1	195.3	1
Yearling	150,000	5.0	8.76	0.3	Super Raceways	11,565.0	3	1.91	1200	30,000.00	11,415.53	1	1,793.0	2

Species **Rainbow Trout**

Production Stages	Total Fish Output	Fish Output Size			Rearing Unit	Tank Volume	Existing Rearing Units		Flow Rate per Rearing	Biomass	Required Volume	Tanks Required for DI	Required Flow	Tanks Required for FI
	(#)	(fpp)	(in)	DI	(Type)	(ft^3)		FI	(gpm)	(lbs)	(ft3)		(gpm)	
Fry	128,000	2,500.0	1	0.5	Capilano	90.0	10	1.91	75	51.20	102.40	2	26.8	1
Juvenile	115,200	400.0	1.8	0.5	Raceways	3,136.3	12	1.91	200	288.00	320.00	1	83.8	1
Juvenile	103,680	100.0	2.92	0.5	Super Raceways	11,565.0	3	1.91	1200	1,036.80	710.14	1	185.9	1
Juvenile	37,000	37.0	4.07	0.5	Super Raceways	11,565.0	3	1.91	1200	1,000.00	491.40	1	128.6	1
Adult	43,000	2.0	10	0.5	Super Raceways	11,565.0	3	1.91	1200	21,500.00	4,300.00	1	1,125.7	1
Adult	8,000	1.0	18	0.5	Fg Circular Pond	1,099.6	2	1.91	125	8,000.00	888.89	1	232.7	2

Species **Brown Trout**

Production Stages	Total Fish Output	Fish Output Size			Rearing Unit	Tank Volume	Existing Rearing Units		Flow Rate per Rearing	Biomass	Required Volume	Tanks Required for DI	Required Flow	Tanks Required for FI
	(#)	(fpp)	(in)	DI	(Type)	(ft^3)		FI	(gpm)	(lbs)	(ft3)		(gpm)	
Fry	58,500	2,500.0	1	0.5	Capilano	90.0	10	1.91	10	23.40	46.80	1	12.3	2
Juvenile	46,800	400.0	1.8	0.5	Raceways	3,136.3	12	1.91	200	117.00	130.00	1	34.0	1
Juvenile	32,000	60.0	3.45	0.5	Raceways	3,136.3	12	1.91	200	533.33	309.18	1	80.9	1

Species **Cutthroat Trout**

Production Stages	Total Fish Output	Fish Output Size			Rearing Unit	Tank Volume	Existing Rearing Units		Flow Rate per Rearing	Biomass	Required Volume	Tanks Required for DI	Required Flow	Tanks Required for FI
	(#)	(fpp)	(in)	DI	(Type)	(ft^3)		FI	(gpm)	(lbs)	(ft3)		(gpm)	
Fry	112,000	2,500.0	1	0.5	Shallow Troughs	6.8	34	1.91	10	44.80	89.60	14	23.5	3
Juvenile	95,200	400.0	1.8	0.5	Raceways	3,136.3	12	1.91	200	238.00	264.44	1	69.2	1
Juvenile	72,000	80.0	3.46	0.5	Raceways	3,136.3	12	1.91	200	900.00	520.23	1	136.2	1

Species	**Kokanee**

Production Stages	**Total Fish Output**	**Fish Output Size**			**Rearing Unit**	**Tank Volume**	**Existing Rearing Units**		**Flow Rate per Rearing**	**Biomass**	**Required Volume**	**Tanks Required for DI**	**Required Flow**	**Tanks Required for FI**
	(#)	**(fpp)**	**(in)**	**DI**	**(Type)**	**(ft^3)**		**FI**	**(gpm)**	**(lbs)**	**(ft3)**		**(gpm)**	
Fry	114,000	2,500.0	1	0.3	Shallow Troughs	6.8	34	1.91	10	45.60	152.00	23	23.9	3
Juvenile	108,300	400.0	1.8	0.3	Raceways	3,136.3	12	1.91	200	270.75	501.39	1	78.8	1
Juvenile	100,000	100.0	2.92	0.3	Raceways	3,136.3	12	1.91	200	1,000.00	1,141.55	1	179.3	1

Species	**Skookum Creek Coho**

Production Stages	**Total Fish Output**	**Fish Output Size**			**Rearing Unit**	**Tank Volume**	**Existing Rearing Units**		**Flow Rate per Rearing**	**Biomass**	**Required Volume**	**Tanks Required for DI**	**Required Flow**	**Tanks Required for FI**
	(#)	**(fpp)**	**(in)**	**DI**	**(Type)**	**(ft^3)**		**FI**	**(gpm)**	**(lbs)**	**(ft3)**		**(gpm)**	
Fry	1,140,000	1,202.0	1.33	0.3	Asphalt Ponds	53,900.0	2	2.865	1500	948.42	2,376.99	1	248.9	1
Juvenile	1,083,000	200.0	2.42	0.3	Asphalt Ponds	53,900.0	2	2.865	1500	5,415.00	7,458.68	1	781.0	1
Yearling	1,000,000	35.0	4.32	0.3	Asphalt Ponds	53,900.0	2	2.865	1500	28,571.43	22,045.86	1	2,308.5	2

McMillen

Project	WDFW Hatchery Climate Change
Subject	Samish
Task	Existing Bioprogramming
Job No.	23-034

Species	Chinook Salmon

Production Stages	Total Fish Output	Fish Output Size			Rearing Unit	Existing Volume		Total Flow Rate	Biomass	Required Volume	Required Flow
	(#)	(fpp)	(in)	DI	(Type)	(ft^3)	FI	(gpm)	(lbs)	(ft^3)	(gpm)
Fry	5,500,000	1,300.0	1.3	0.3	Ponds 1-12	48,800	1.41	4,700	4,230.8	10,848.13	2,308.1
Juvenile	5,200,000	200.0	2.42	0.3	Ponds 1-14	162,750	1.41	13,700	26,000.00	35,812.67	7,619.7
Juvenile	5,200,000	90.0	4.42	0.3	Ponds 1-8,13,14	140,400	1.41	12,200	57,777.78	43,572.98	9,270.8
Juvenile Goal	6,500,000	90.0	4.42	0.3	Ponds 1-8,13,14	140,400	1.41	12,200	72,222.22	54,466.23	11,588.6

*Minimum tanks required was not calculated due to the differences in rearing units used for each production stage. Minimum required volume and flow rates were calculated instead.

McMillen

Project	WDFW Hatchery Climate Change
Subject	Goldendale
Task	Existing Bioprogramming
Job No.	23-034

Species	**Rainbow Trout**

Production Stages	Total Fish Output	Fish Output Size		DI	Rearing Unit	Tank Volume	Existing Rearing Units	FI	Flow Rate per Rearing Unit	Biomass	Required Volume	Tanks Required for DI	Required Flow	Tanks Required for FI
	(#)	(fpp)	(in)		(Type)	(ft^3)			(gpm)	(lbs)	(ft^3)		(gpm)	
Fry	220,000	250.0	1.8	0.3	Troughs	10.4	38	1.3	10	880.00	1,629.63	157	376.1	38
Juvenile	200,000	25.0	4.6	0.3	Raceways	1,760.0	10	1.3	380	8,000.00	5,797.10	4	1,337.8	4
Yearling	155,000	2.5	9.9	0.3	Raceways	1,760.0	10	1.3	380	62,000.00	20,875.42	12	4,817.4	13
Adult	12,500	1.0	13	0.3	Adult Raceways	4,800.0	2	1	489	12,500.00	3,205.13	1	961.5	2
Adult	4,500	0.5	16	0.3	Adult Raceways	4,800.0	2	1	489	9,000.00	1,875.00	1	562.5	2
Adult	1,500	0.3	20.2	0.3	Adult Raceways	4,800.0	2	1	489	4,545.45	750.08	1	225.0	1
Adult	4,700	0.2	23.2	0.3	Adult Raceways	4,800.0	2	1	489	23,500.00	3,376.44	1	1,012.9	3
Adult	800	0.1	23.2	0.3	Adult Raceways	4,800.0	2	1	489	8,000.00	1,149.43	1	344.8	1

Species	**Brown Trout**

Production Stages	Total Fish Output	Fish Output Size		DI	Rearing Unit	Tank Volume	Existing Rearing Units	FI	Flow Rate per Rearing Unit	Biomass	Required Volume	Tanks Required for DI	Required Flow	Tanks Required for FI
	(#)	(fpp)	(in)		(Type)	(ft^3)			(gpm)	(lbs)	(ft^3)		(gpm)	
Fry	11,000	300.0	2.02	0.3	Troughs	10.4	38	1.56	10	36.67	60.51	6	11.6	2
Juvenile	9,000	100.0	2.92	0.3	Int. Raceways	201.3	3	1.56	60	90.00	102.74	1	19.8	1

Species	**Tiger Trout**

Production Stages	Total Fish Output	Fish Output Size		DI	Rearing Unit	Tank Volume	Existing Rearing Units	FI	Flow Rate per Rearing Unit	Biomass	Required Volume	Tanks Required for DI	Required Flow	Tanks Required for FI
	(#)	(fpp)	(in)		(Type)	(ft^3)			(gpm)	(lbs)	(ft^3)		(gpm)	
Fry	12,000	300.0	2.02	0.3	Troughs	10.4	38	1.56	10	40.00	66.01	7	12.7	2
Juvenile	10,800	100.0	2.92	0.3	Int. Raceways	201.3	3	1.56	60	108.00	123.29	1	23.7	1

Species **Eastern Brook Trout**

Production Stages	Total Fish Output	Fish Output Size			Rearing Unit	Tank Volume	Existing Rearing Units		Flow Rate per Rearing Unit	Biomass	Required Volume	Tanks Required for DI	Required Flow	Tanks Required for FI
	(#)	(fpp)	(in)	DI	(Type)	(ft^3)		FI	(gpm)	(lbs)	(ft^3)		(gpm)	
Fry	19,000	300.0	2.02	0.3	Troughs	10.4	38	1.56	10	63.33	104.51	11	20.1	3
Juvenile	17,000	100.0	2.92	0.3	Int. Raceways	201.3	3	1.56	60	170.00	194.06	1	37.3	1

Species **Cutthroat Trout**

Production Stages	Total Fish Output	Fish Output Size			Rearing Unit	Tank Volume	Existing Rearing Units		Flow Rate per Rearing Unit	Biomass	Required Volume	Tanks Required for DI	Required Flow	Tanks Required for FI
	(#)	(fpp)	(in)	DI	(Type)	(ft^3)		FI	(gpm)	(lbs)	(ft^3)		(gpm)	
Fry	10,000	250.0	2.25	0.3	Troughs	10.4	38	1.56	10	40.00	59.26	6	11.4	2
Juvenile	6,800	27.2	4.7	0.3	Int. Raceways	201.3	3	1.56	60	250.00	177.30	1	34.1	1

Appendix C. Climate Evaluation Modeling Results

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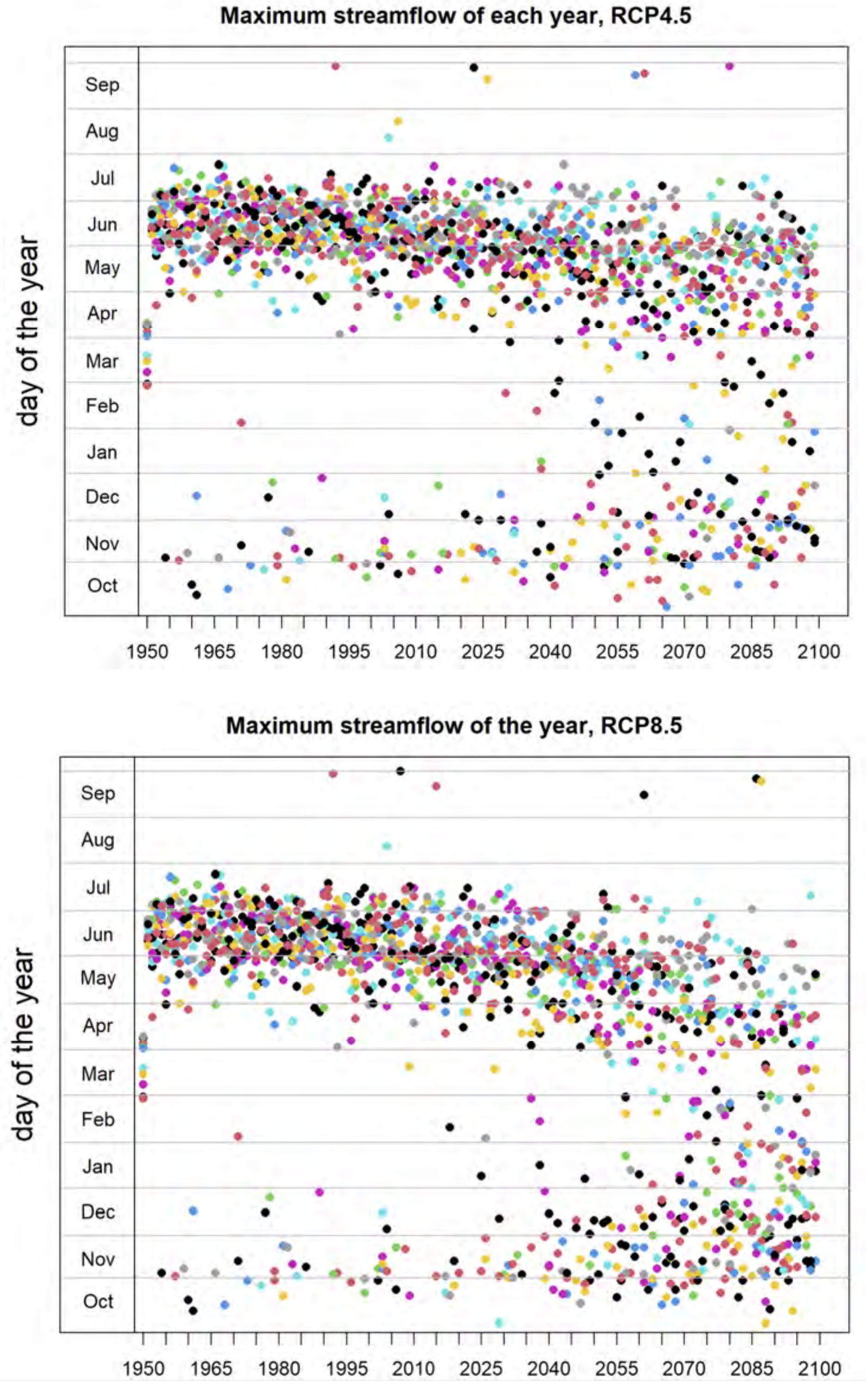


Figure C-1. Day of the water year experiencing the highest streamflow of the year at Cascade River, for all 10 GCMs (in different colors) for RCP4.5 (upper panel) and RCP8.5 (lower panel).

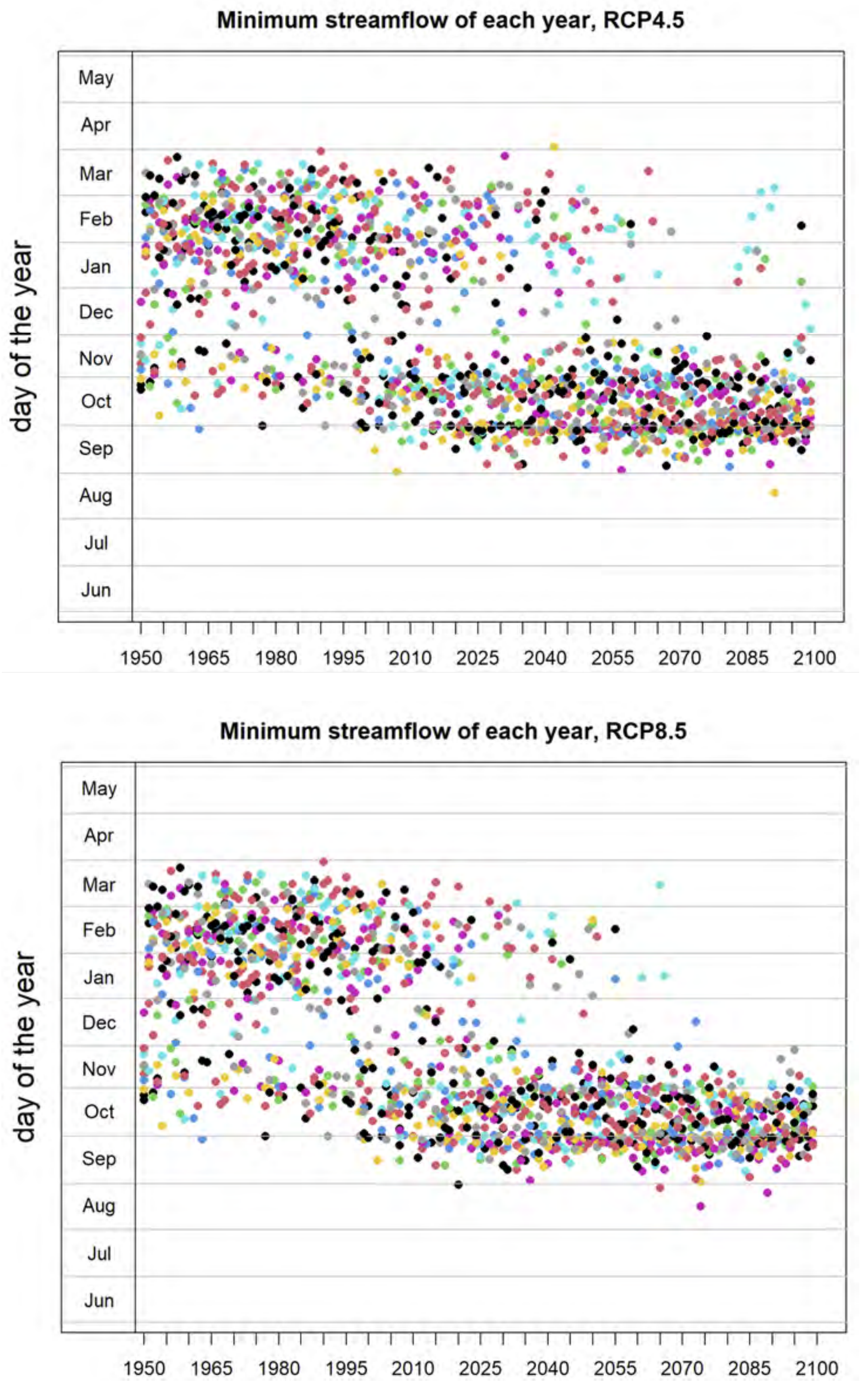


Figure C-2. Day of the water year experiencing the lowest streamflow of the year at Cascade River, for RCP4.5 (upper panel) and RCP8.5 (lower panel). The results of the 10 GCMs are plotted (different colors).

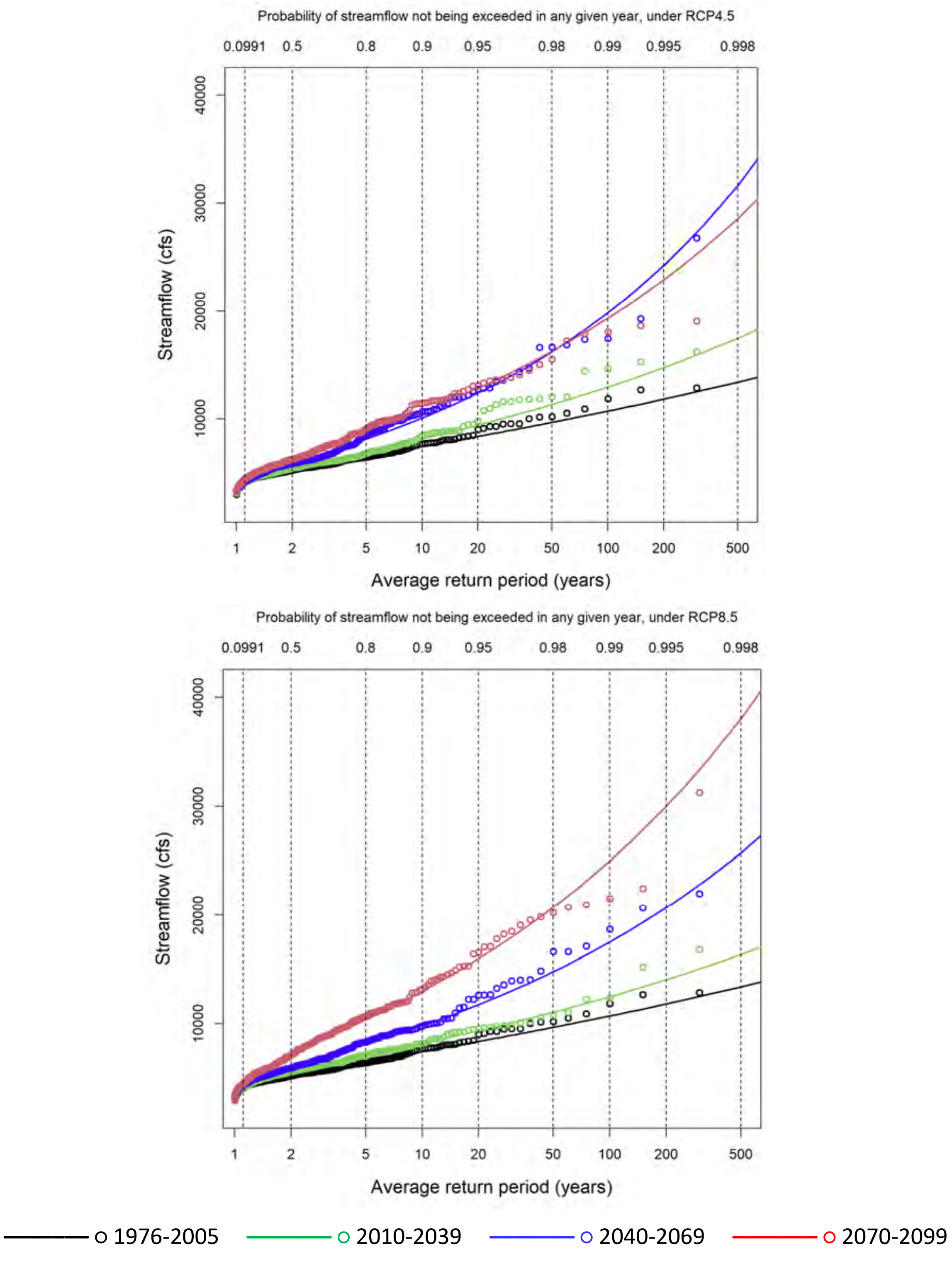
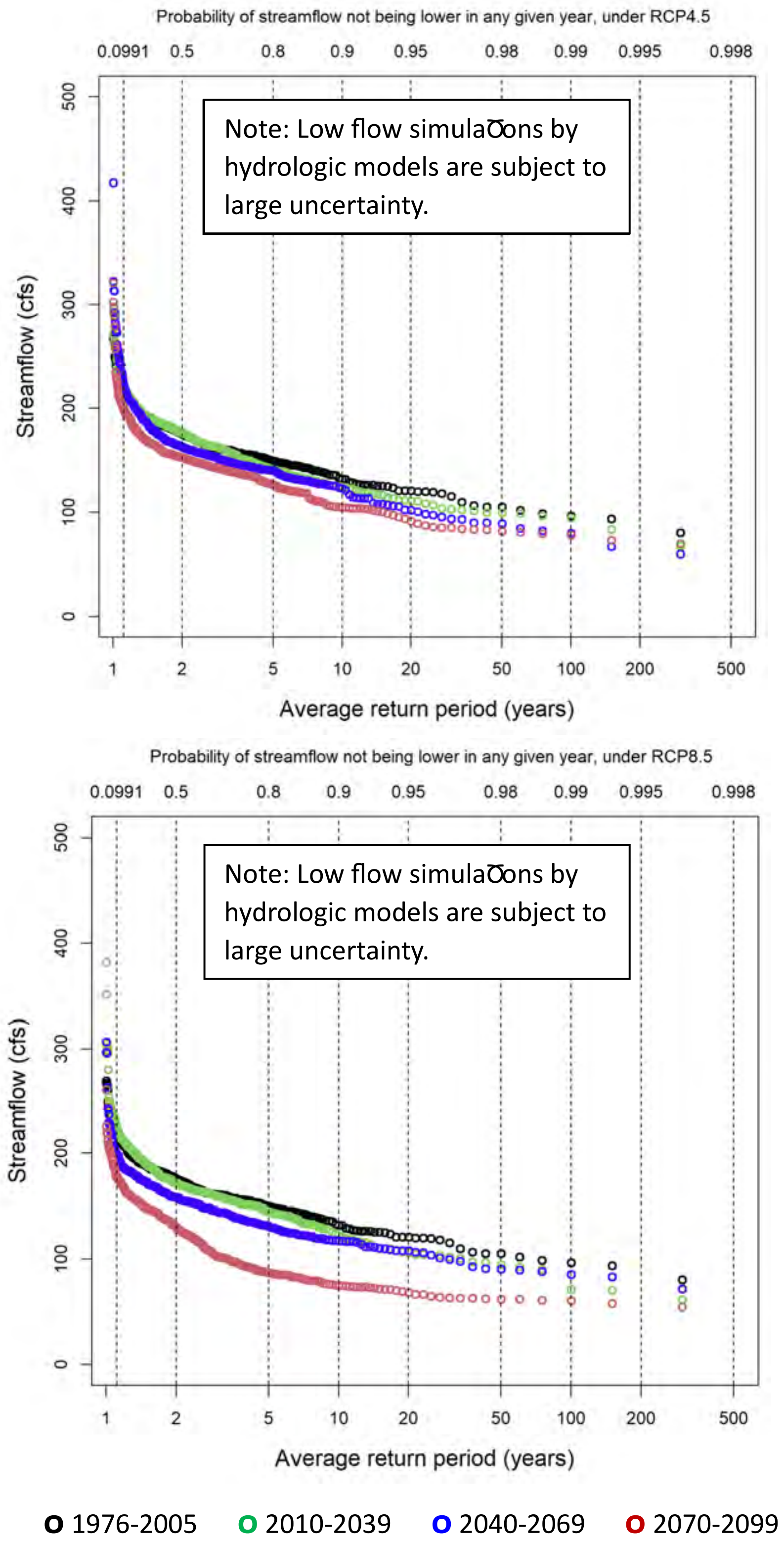


Figure C-3. Frequency analysis of Cascade River high streamflows for different time horizons, under scenarios RCP4.5 (upper panel) and RCP8.5 (lower panel).



Note: Low flow simulations by hydrologic models are subject to large uncertainty.

Note: Low flow simulations by hydrologic models are subject to large uncertainty.

Figure C-4. Frequency analysis of Cascade River lowest streamflows for different time horizons, under scenarios RCP4.5 (upper panel) and RCP8.5 (lower panel).

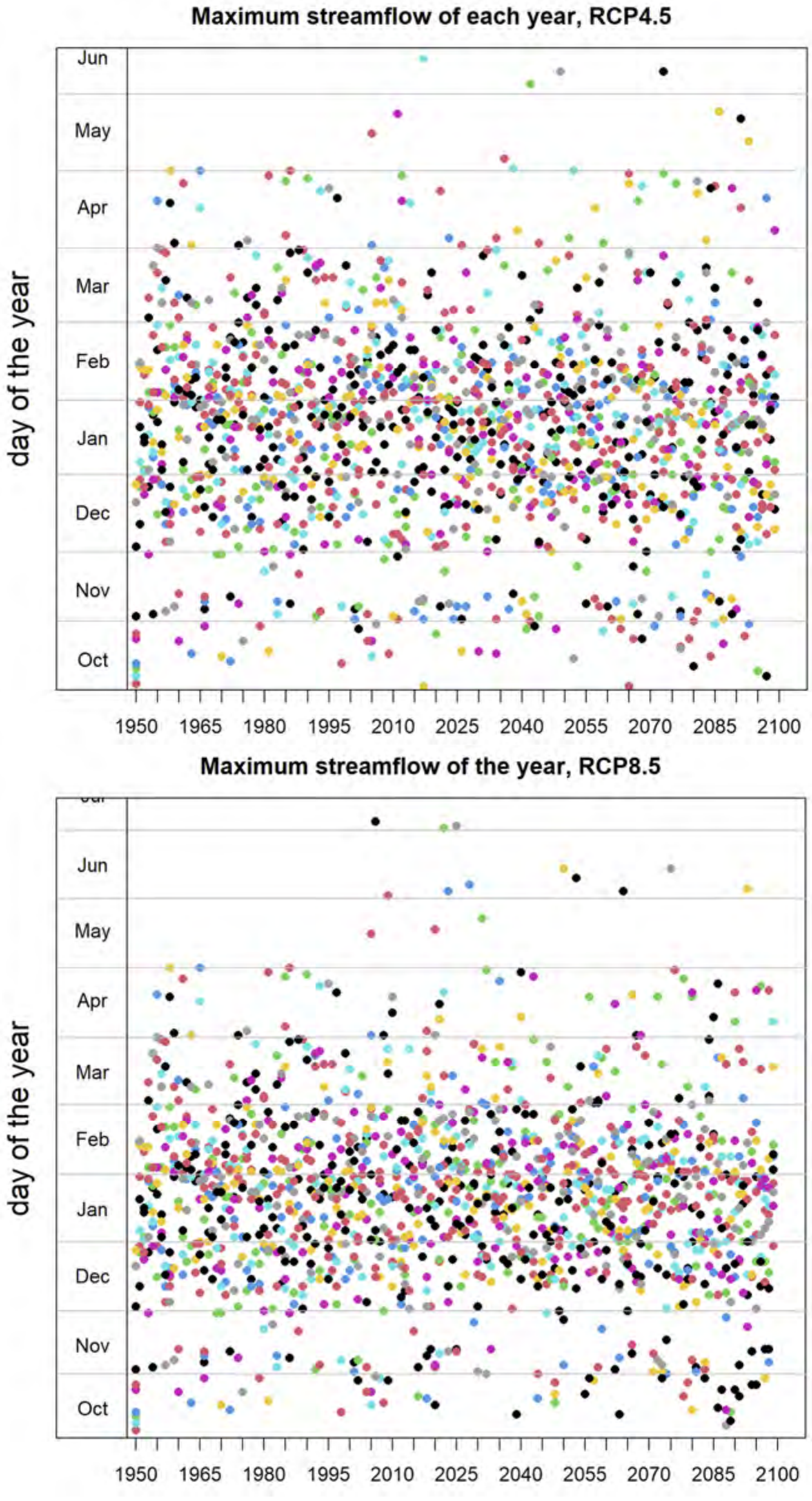


Figure C-5. Day of the water year experiencing the highest streamflow of the year at Kendall Creek, for all 10 GCMs (in different colors) for RCP4.5 (upper panel) and RCP8.5 (lower panel).

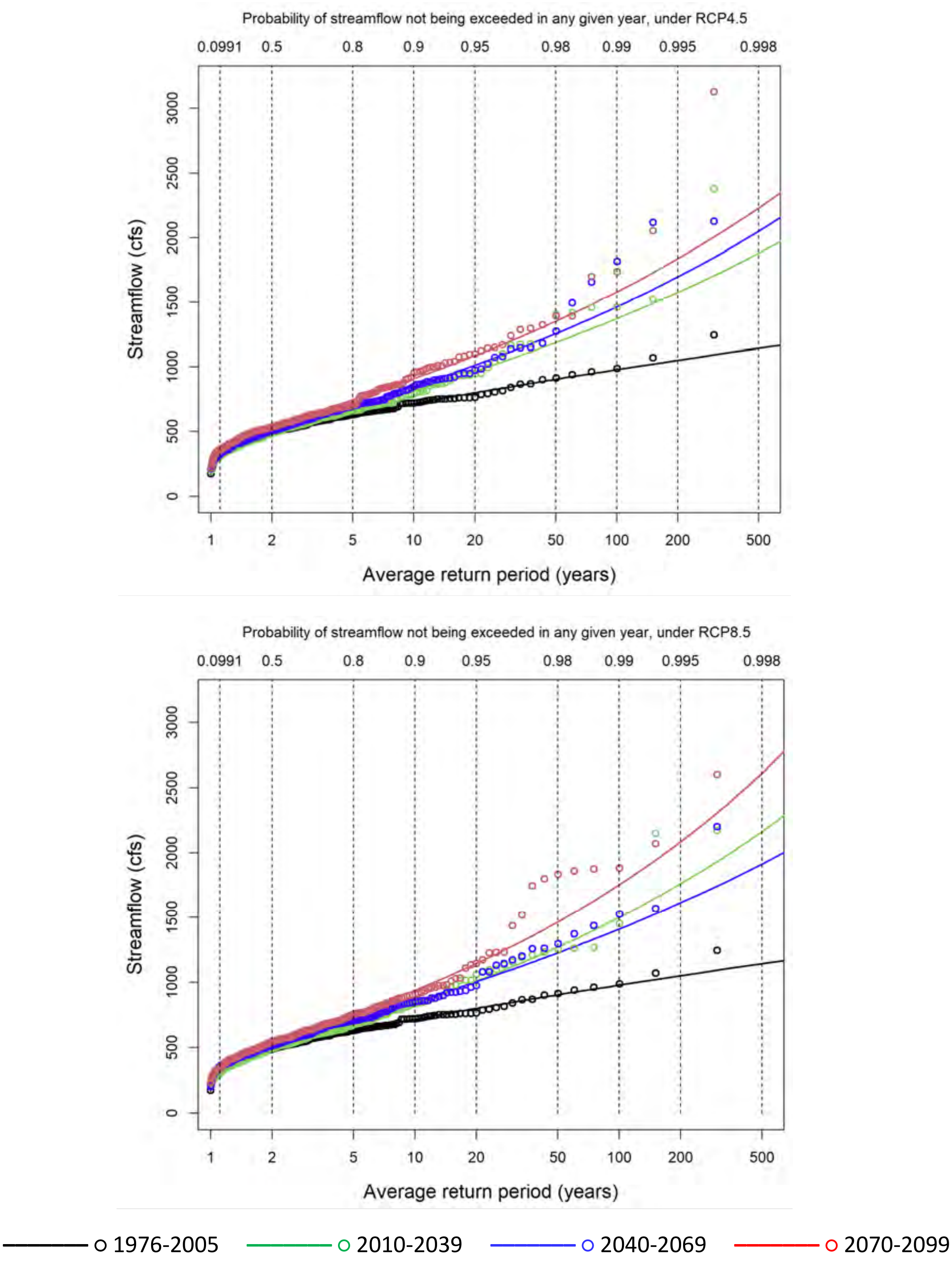


Figure C-6. Frequency analysis of Kendall Creek high streamflows for different time horizons, under scenarios RCP4.5 (upper panel) and RCP8.5 (lower panel). Each line represents a fitted GEV distribution. For plotting the points, empirical plotting positions were used, which are limited by the sample size of 300 years (30 years x 10 GCMs).

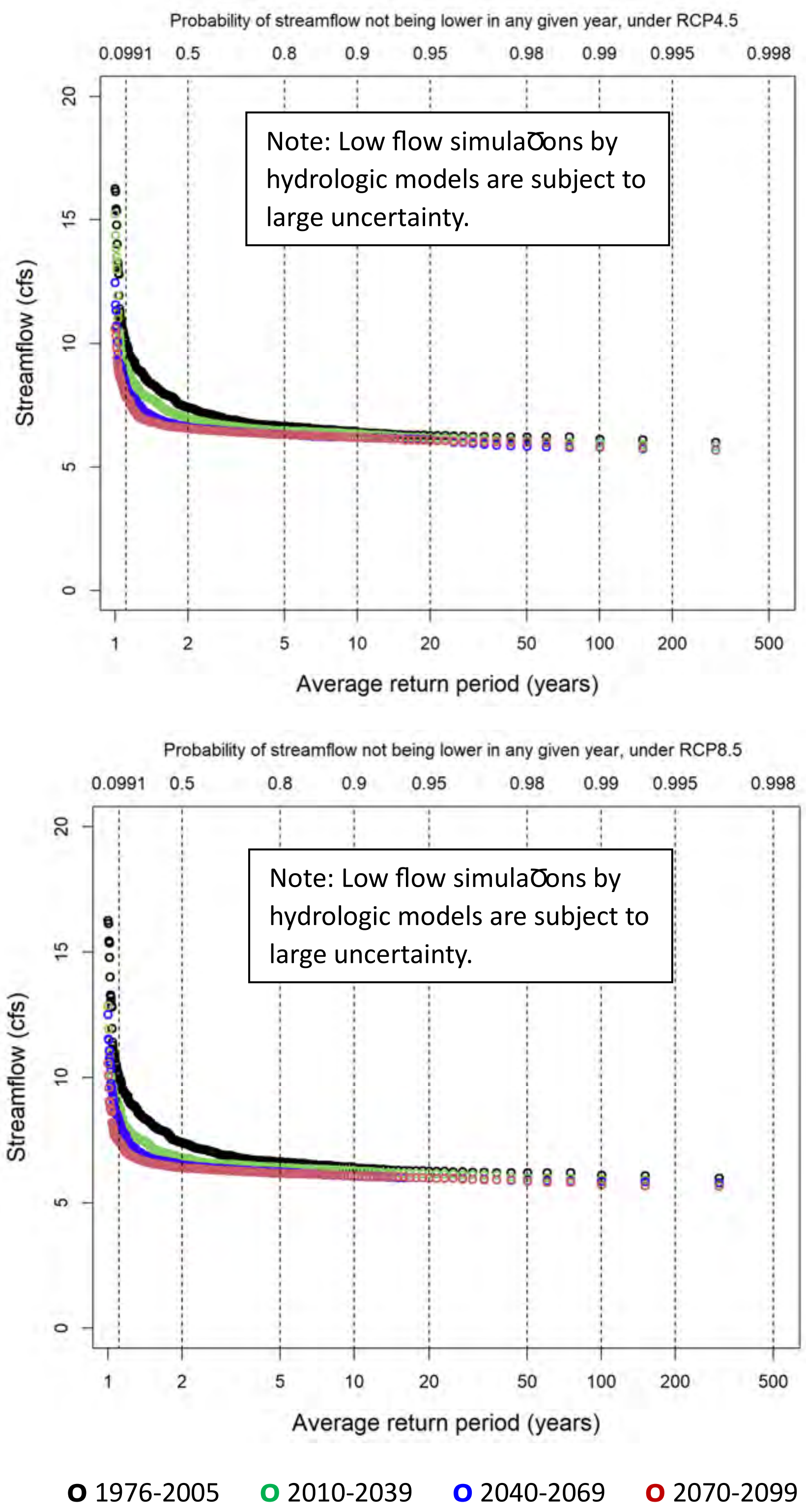


Figure C-7. Frequency analysis of Kendall Creek lowest streamflows for different time horizons, under scenarios RCP4.5 (upper panel) and RCP8.5 (lower panel).

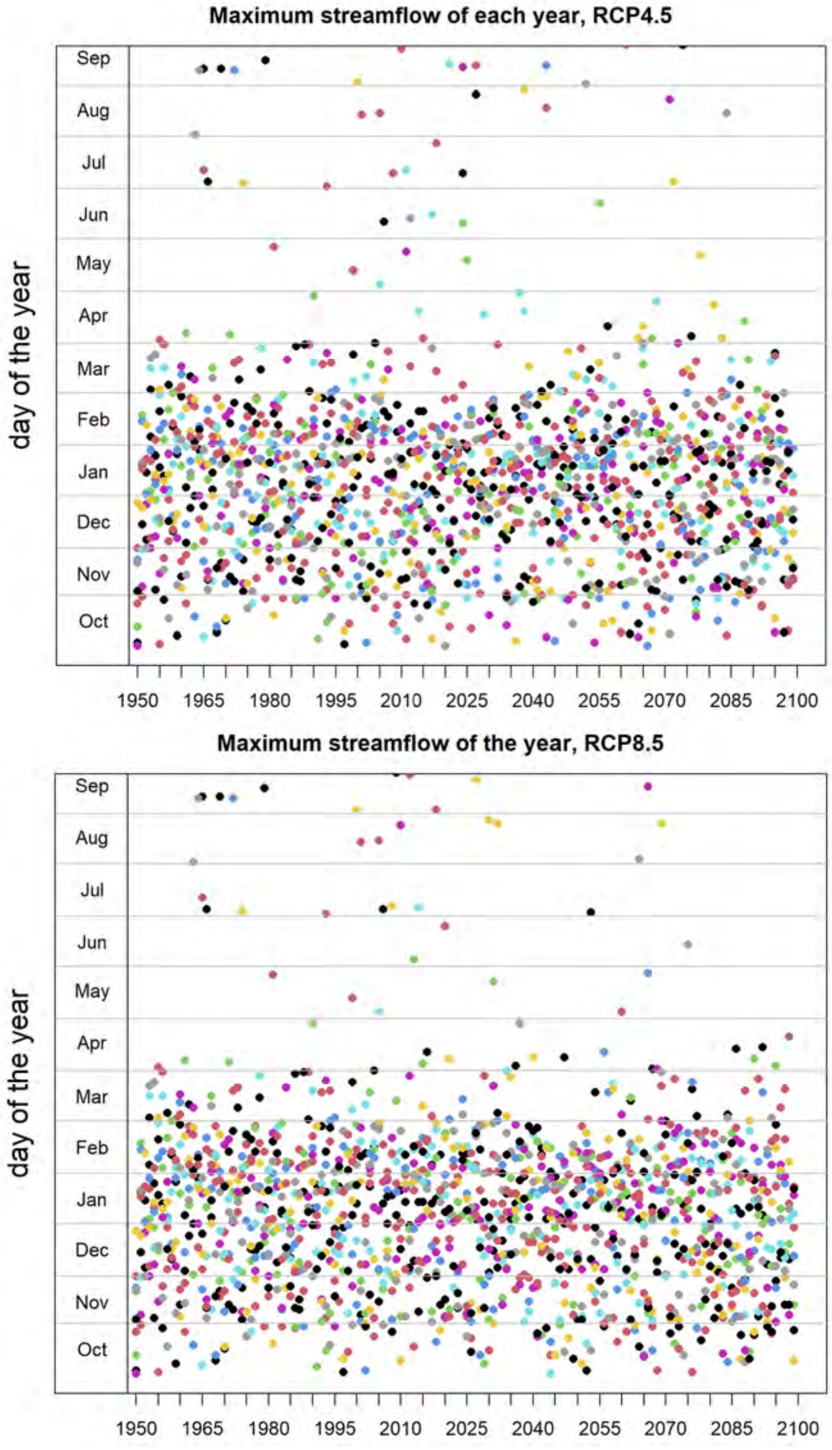


Figure C-8. Day of the water year experiencing the highest streamflow of the year at Friday Creek, for all 10 GCMs (in different colors) for RCP4.5 (upper panel) and RCP8.5 (lower panel).

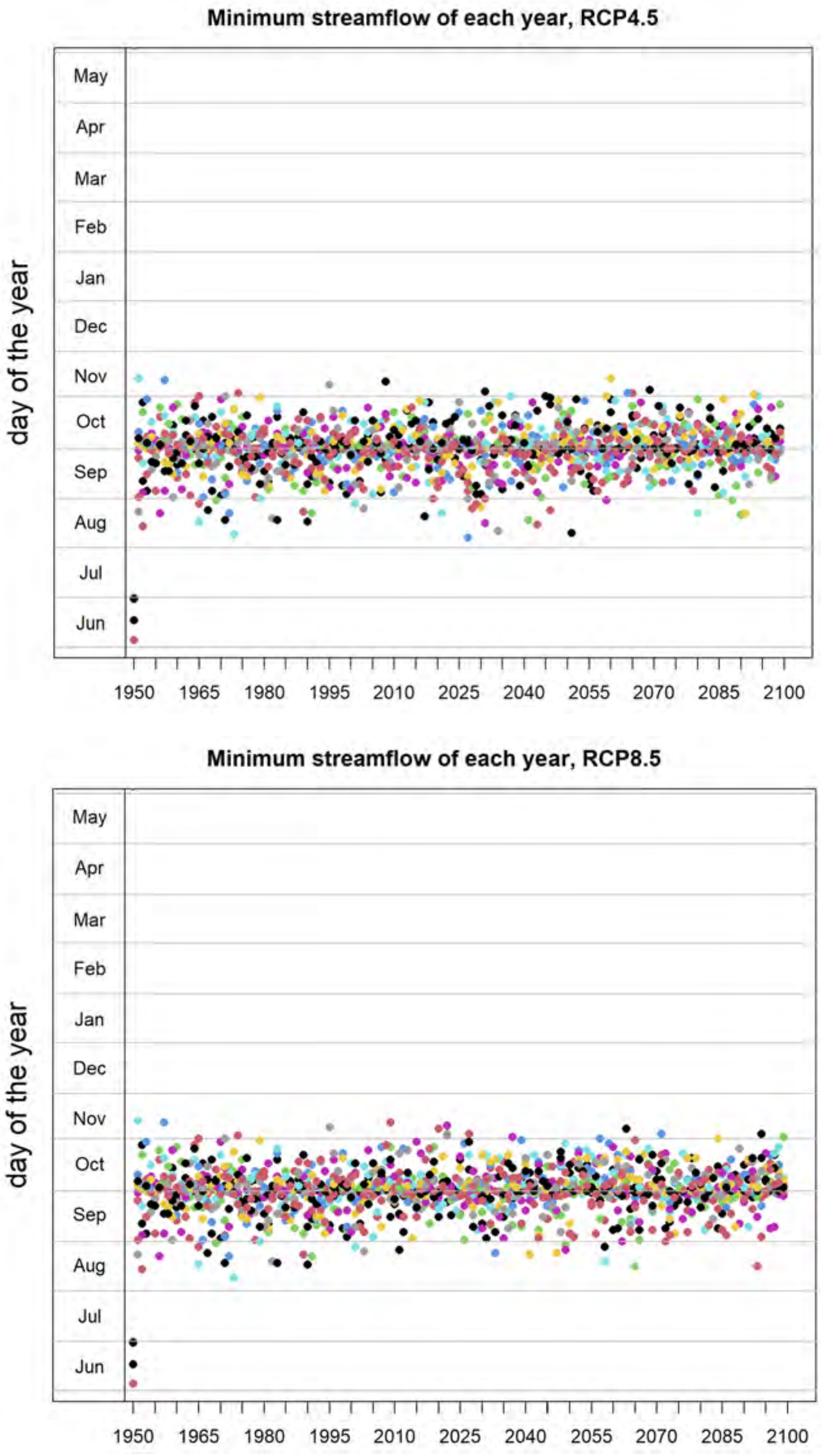


Figure C-9. Day of the water year experiencing the lowest streamflow of the year at Friday Creek, for RCP4.5 (upper panel) and RCP8.5 (lower panel). The results of the 10 GCMs are plotted (different colors).

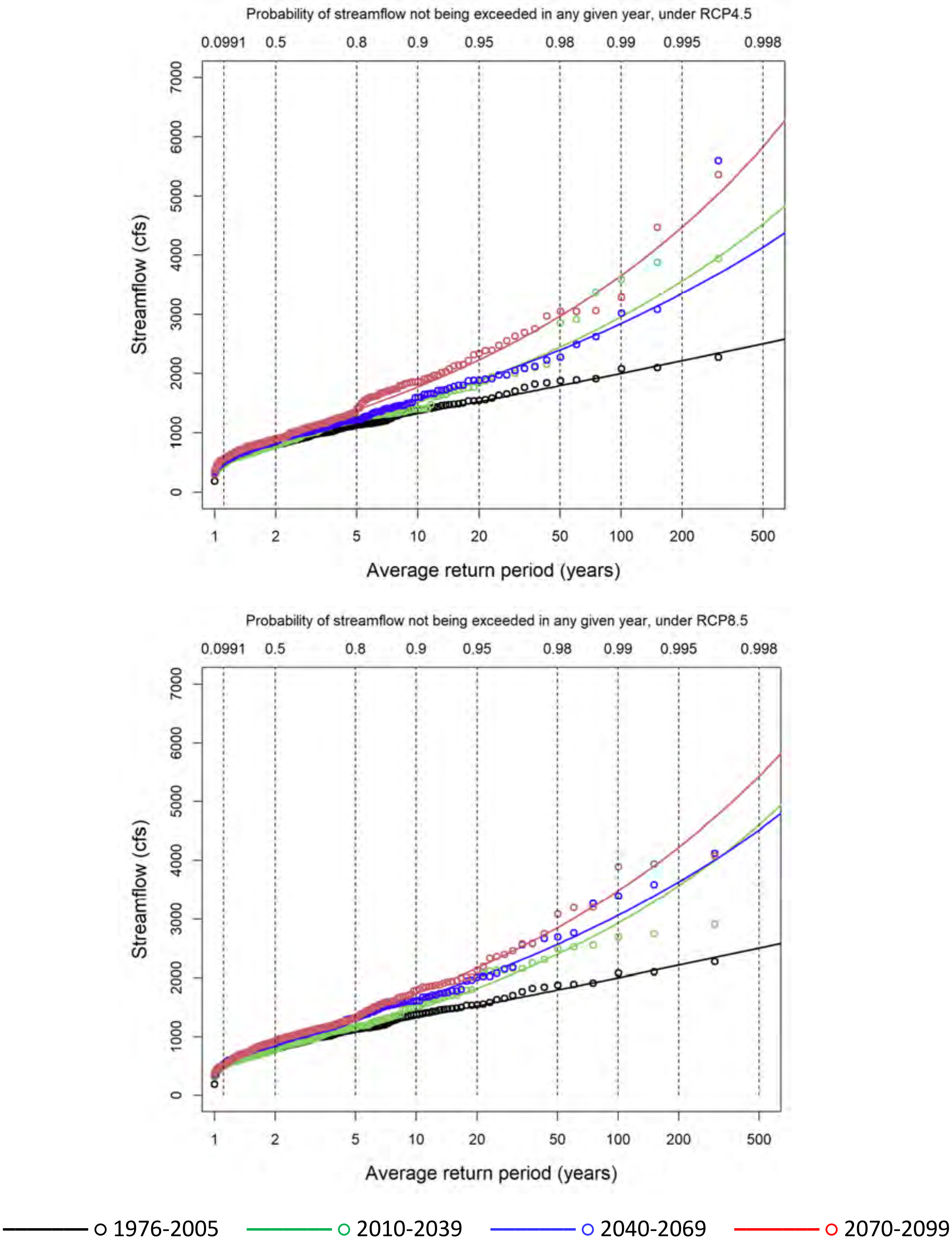
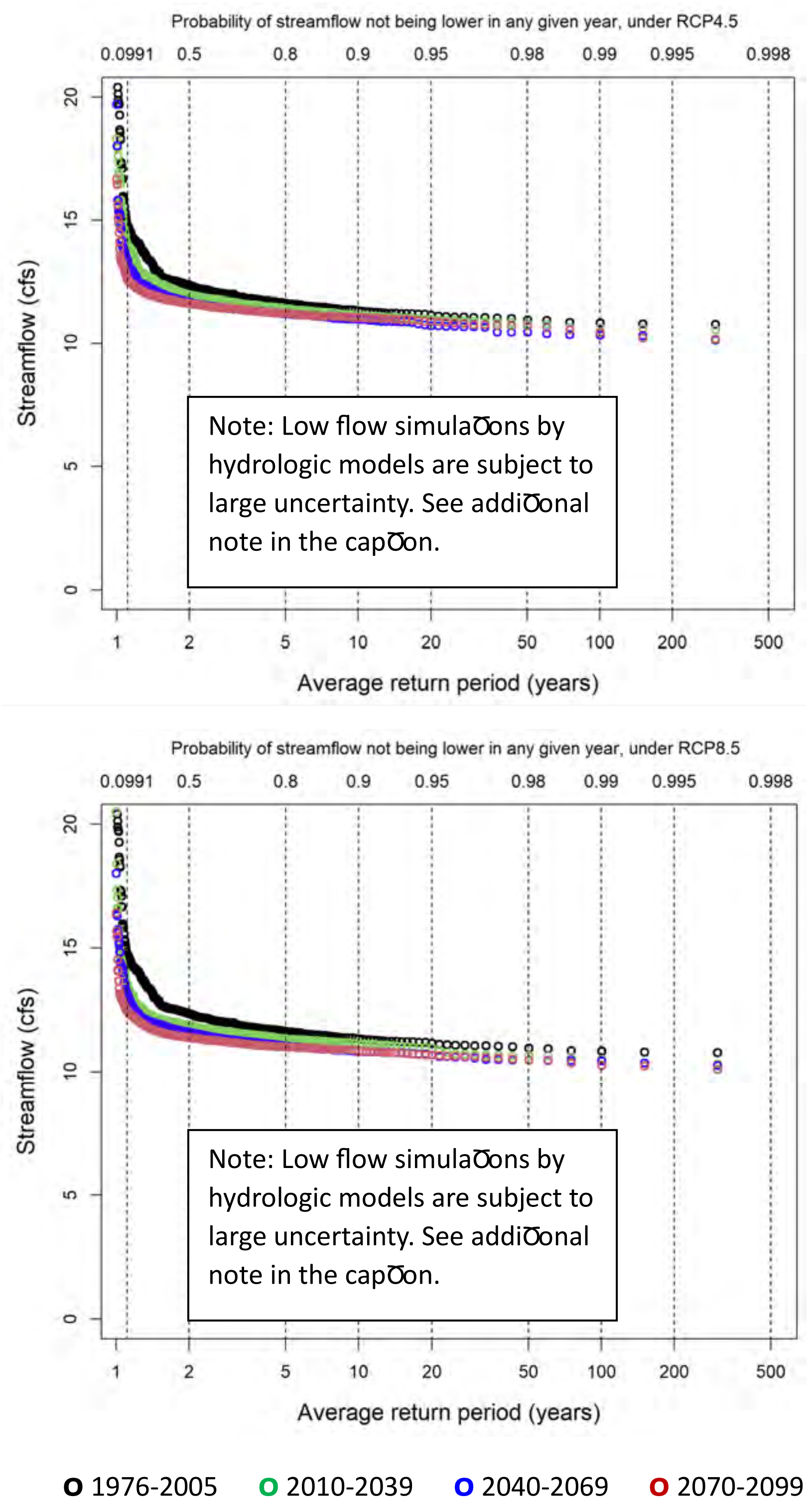


Figure C-10. Frequency analysis of Friday Creek high streamflows for different time horizons, under scenarios RCP4.5 (upper panel) and RCP8.5 (lower panel). Each line represents a fitted GEV distribution. For plotting the points, empirical plotting positions were used, which are limited by the sample size of 300 years (30 years x 10 GCMs).



Note: Low flow simulations by hydrologic models are subject to large uncertainty. See additional note in the caption.

Note: Low flow simulations by hydrologic models are subject to large uncertainty. See additional note in the caption.

Figure C-11. Frequency analysis of Friday Creek lowest streamflows for different time horizons, under scenarios RCP4.5 (upper panel) and RCP8.5 (lower panel). Hydrologic models represent low flows with large uncertainty. In the case of Friday Creek, Samish hatchery staff reported that minimum flows have occasionally dropped to 2 cfs.

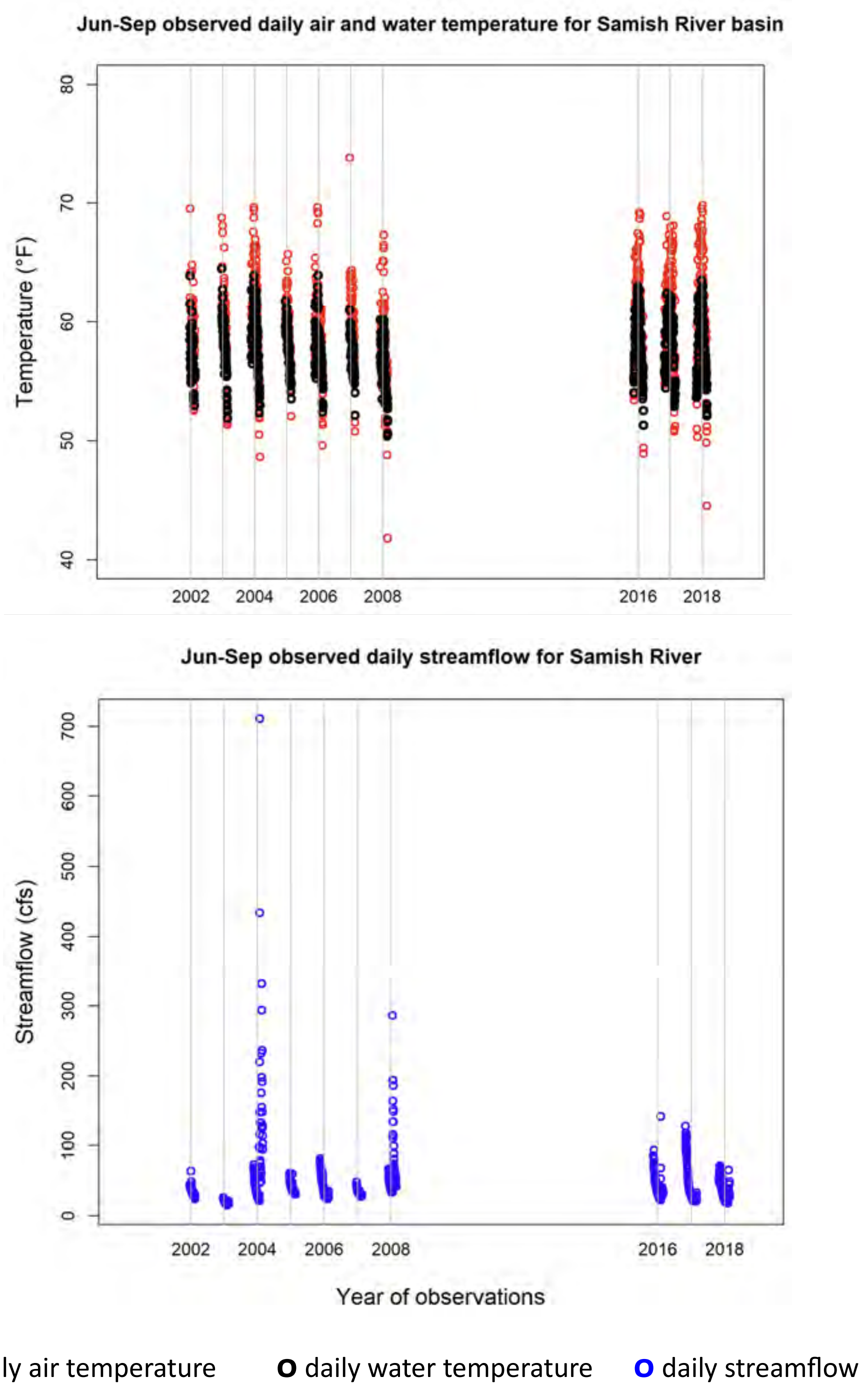


Figure C-12. Observed data used to develop the empirical model for predicting August daily mean water temperature from potential covariates air temperature and streamflow.

No significant correlation is found between mean daily water temperature and streamflow (Figure C-13). Therefore, the empirical model was developed based on the relationship with air temperature. The empirical relationship between daily mean air and water temperature in the warmest months for the Samish River near Burlington is shown in Figure C-14. Most days in the observations have streamflows lower than 40 cfs and cover a range of water temperatures (approx. 55 – 63°F). The average observed August water temperature at the Samish River near Burlington stream gage (i.e., averaging all August days in the 10 years of observations shown in Figure C-12) is 58.7°F. The average August air temperature at the same location is 61.3°F.

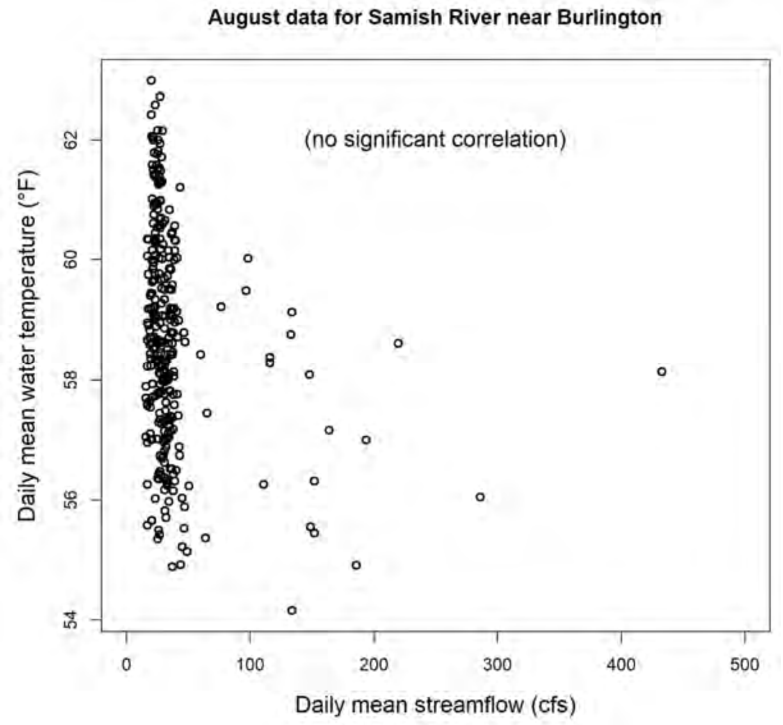


Figure C-13. In the month of August, no significant correlation is found between daily mean water temperature and streamflow rate on the Samish River near Burlington.

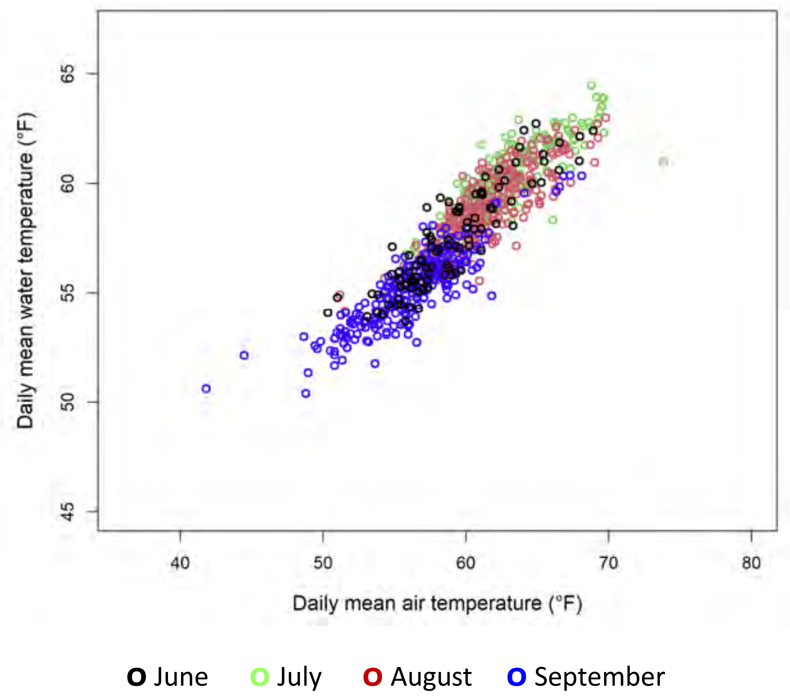


Figure C-14. Observed mean daily air and water temperature for the Samish River near Burlington in the warmest months (indicated by color).

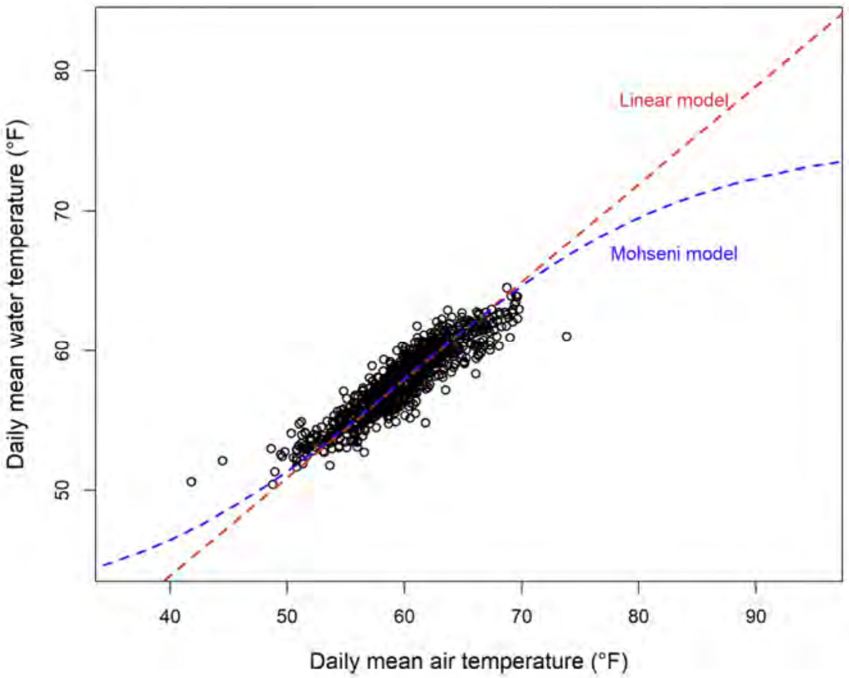


Figure C-15. Observed air and water temperatures for Samish River near Burlington for the warmest months of the year, June – September. Two alternative empirical models were fit to the data in this project and used for obtaining daily water temperature projections from the daily air temperatures projections: A best-fit linear model with line slope 0.7, and a Mohseni model. Data source for temperature: Department of Ecology, Freshwater Information Network. Data source for streamflows: USGS gage #12201500.

Appendix D. Hatchery Figures (Management Actions)

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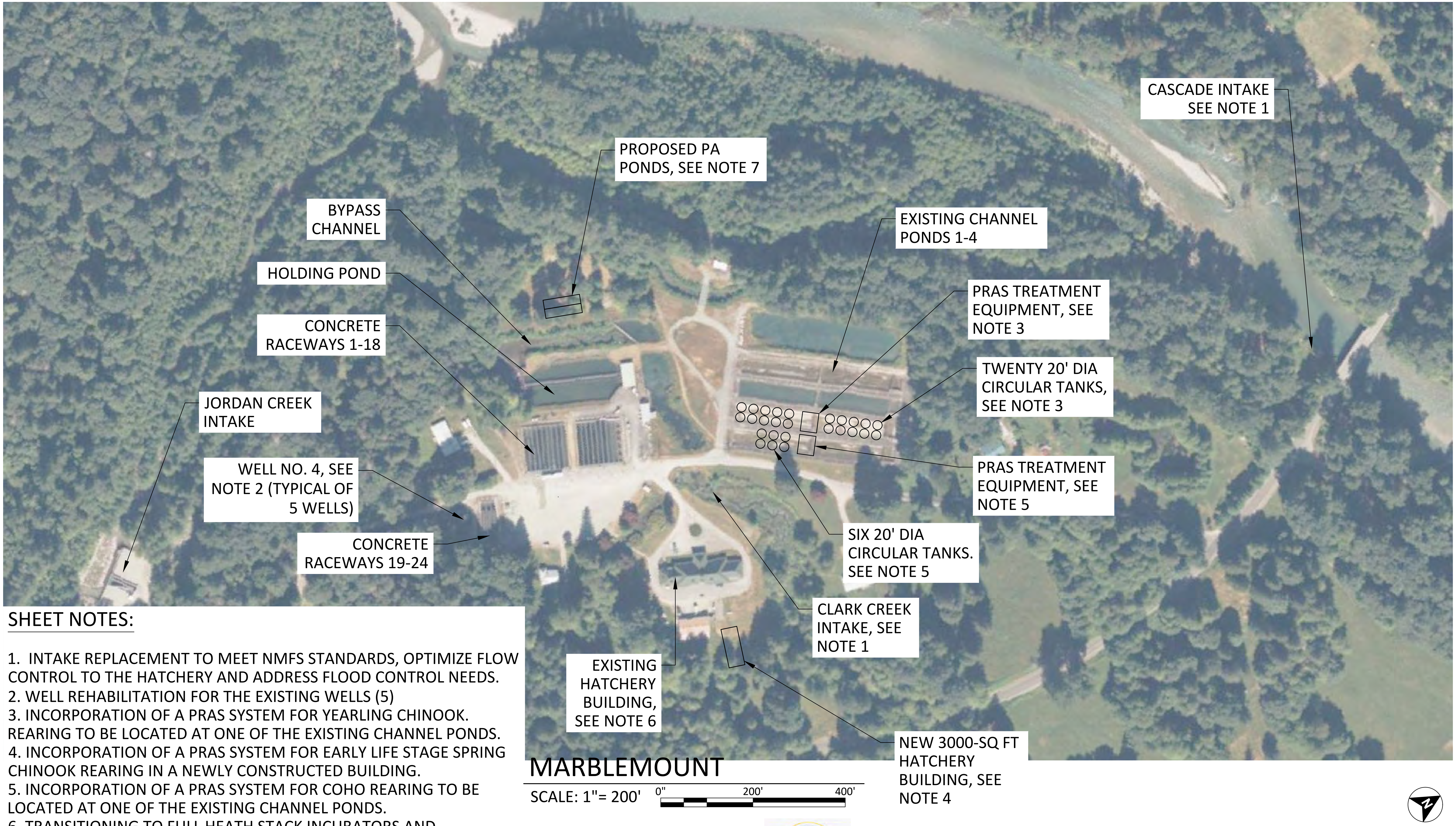

MARBLEMOUNT

SCALE: 1"= 200'

SHEET NOTES:

1. INTAKE REPLACEMENT TO MEET NMFS STANDARDS, OPTIMIZE FLOW CONTROL TO THE HATCHERY AND ADDRESS FLOOD CONTROL NEEDS.
2. WELL REHABILITATION FOR THE EXISTING WELLS (5)
3. INCORPORATION OF A PRAS SYSTEM FOR YEARLING CHINOOK. REARING TO BE LOCATED AT ONE OF THE EXISTING CHANNEL PONDS.
4. INCORPORATION OF A PRAS SYSTEM FOR EARLY LIFE STAGE SPRING CHINOOK REARING IN A NEWLY CONSTRUCTED BUILDING.
5. INCORPORATION OF A PRAS SYSTEM FOR COHO REARING TO BE LOCATED AT ONE OF THE EXISTING CHANNEL PONDS.
6. TRANSITIONING TO FULL HEATH STACK INCUBATORS AND INCORPORATION OF PRAS MODULES FOR INCUBATION.
7. INSTALLATION OF PA PONDS FOR EFFLUENT TREATMENT.
8. DEVELOP INSTRUMENTATION AND CONTROLS TO MINIMIZE WATER US (ENTIRE FACILITY)
9. COVER OUTDOOR REARING AREAS WITH SHADE CLOTH.

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WASHINGTON DEPARTMENT OF FISH & WILDLIFE
HATCHERY CLIMATE CHANGE VULNERABILITY ASSESSMENT
MARBLEMOUNT HATCHERY
PROPOSED IMPROVEMENTS

A-1

SHEET NOTES:

1. KENDALL CREEK INTAKE REPLACEMENT TO MEET NMFS STANDARDS, OPTIMIZE FLOW CONTROL TO THE HATCHERY, AND ADDRESS FLOOD CONTROL NEEDS.
2. WELL IMPROVEMENTS
   - A. WELL REHABILATION FOR EXISTING WELLS NO. 1 THRU 5.
   - B. NEW WELL PUMP FOR WELL NO. 1.
   - C. ADDITIONAL AERATION TOWER FOR WELLS
3. ADDITION OF A NEW HATCHERY BUILDING TO INCLUDE:
   - A.INCORPORATION OF A PRAS FOR WINTER STEELHEAD EARLY REARING
   - B. INCORPORATION OF MULTIPLE PRAS SYSTEMS FOR INCUBATION
4. INCORPORATION OF A REUSE SYSTEM FOR RACEWAYS
5. COVER OUTDOOR REARING AREAS WITH SHADE CLOTH.

KENDAL CREEK HATCHERY

SCALE: 1"= 200'

0" 200' 400'

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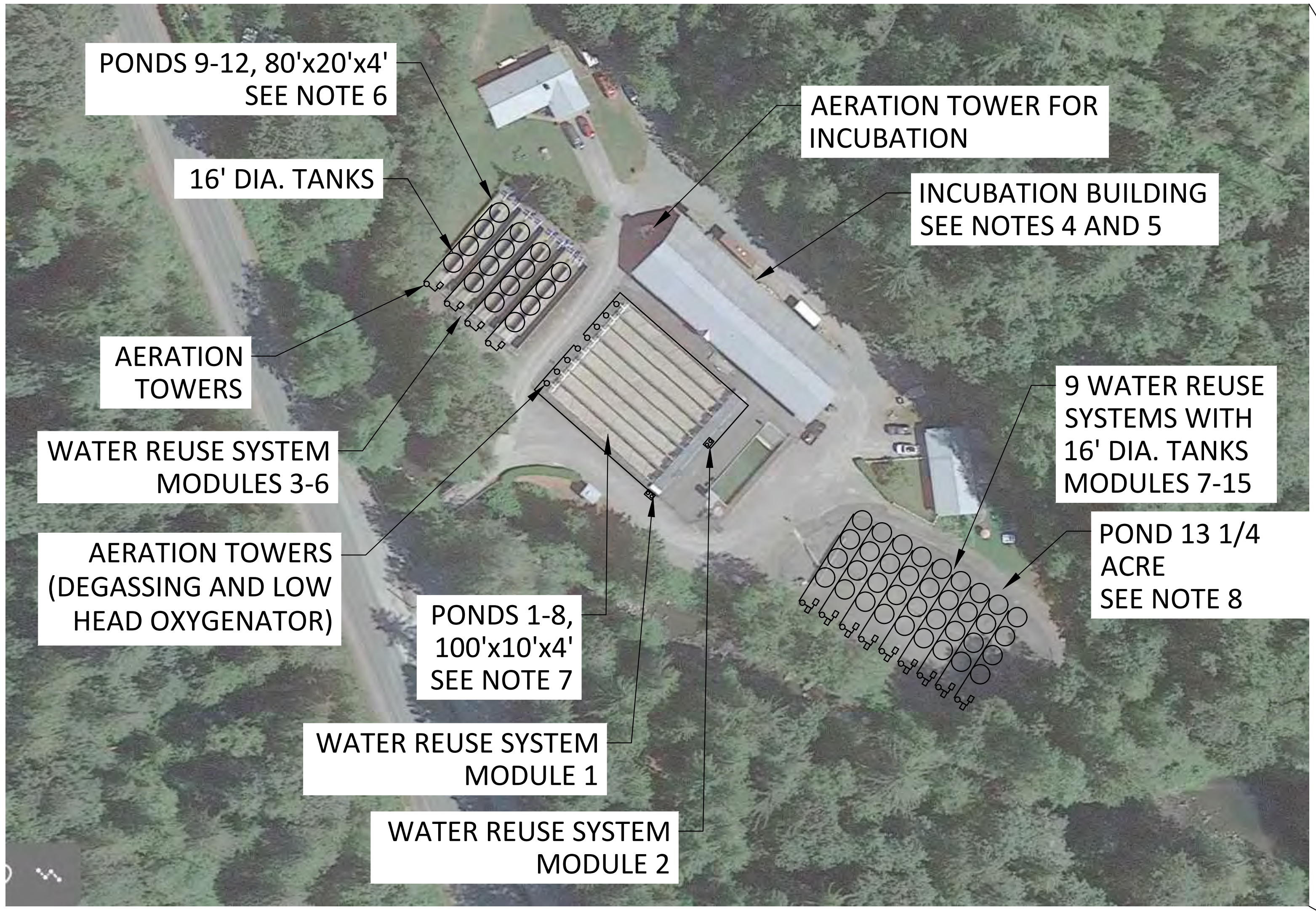
WASHINGTON DEPARTMENT OF FISH & WILDLIFE

HATCHERY CLIMATE CHANGE VULNERABILITY ASSESSMENT

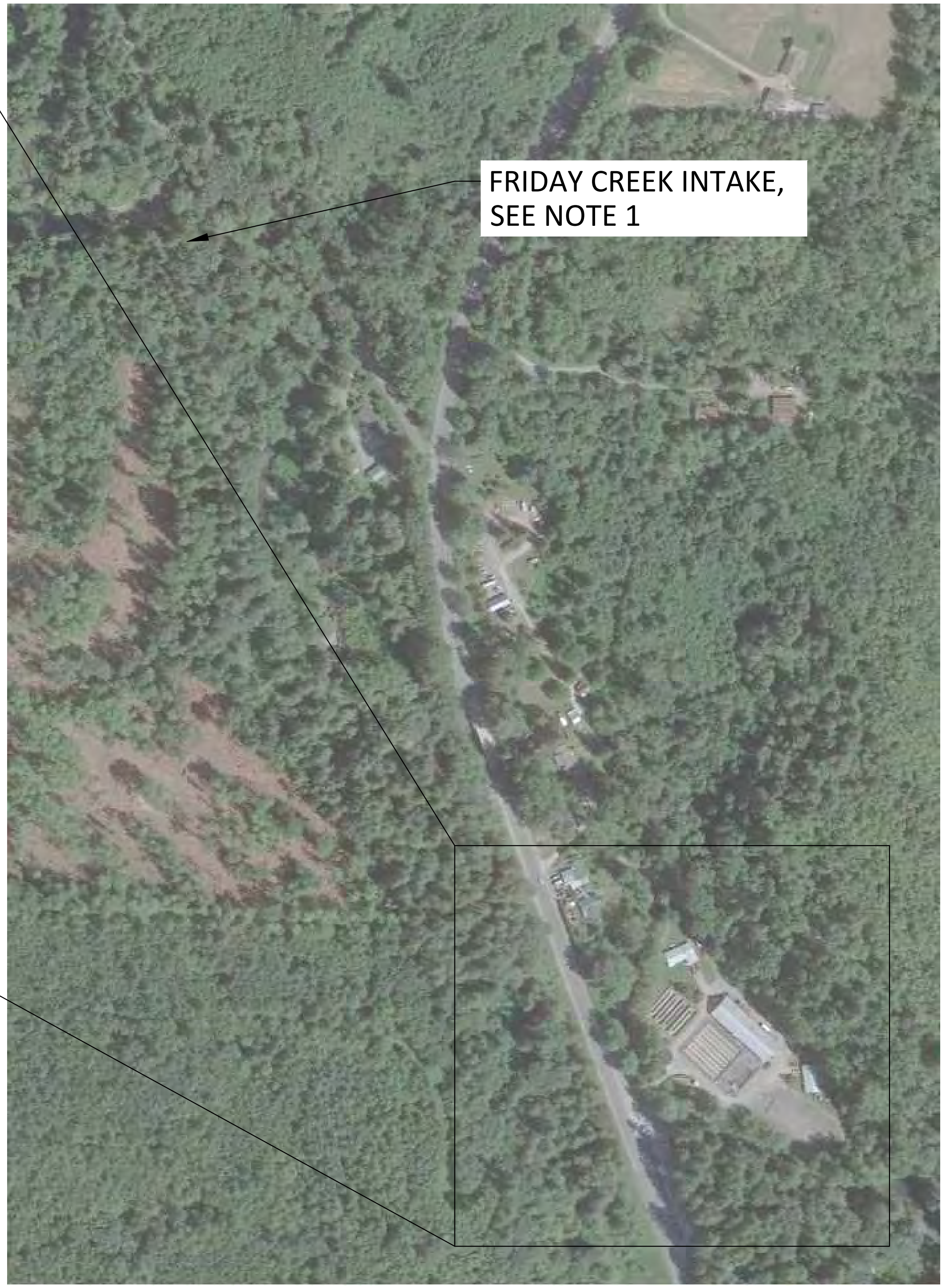
KENDAL CREEK HATCHERY
PROPOSED IMPROVEMENTS

B-1



SAMISH HATCHERY

SCALE: NTS



SAMISH OVERVIEW

SCALE: NTS

SHEET NOTES:

1. FRIDAY CREEK INTAKE REPLACEMENT TO MEET NMFS STANDARDS, OPTIMIZE FLOW CONTROL TO THE HATCHERY, AND ADDRESS FLOOD CONTROL NEEDS.
2. UPGRADES FOR SAMISH INTAKE TO RESOLVE MECHANICAL ISSUES.
3 ADDITION OF NEW WELL SYSTEM AND ASSOCIATED INFRASTRUCTURE.
4. INCORPORATION OF NEW INCUBATION MODULES.
5 RETROFITTING EXISTING INCUBATION MODULES FOR WATER REUSE.
6. RENOVATION OF PONDS 9-12 FOR CIRCULAR TANK 75% WATER REUSE.
7. INCORPORATION OF RACEWAY REUSE SYSTEM FOR PONDS 1-8 FOR FALL CHINOOK. UP TO 75% OF THE WATER IS PUMPED BACK TO THE HEAD OF THE RACWAY TO BE COMBINED WITH THE FLOWS FROM FRIDAY CREEK.(DETERMINE NUMBER OF PUMPS AND GROUPING OF RACEWAYS DURING DETAILED DESIGN PHASE.)
8. RENOVATION OF POND 13 FOR CIRCULAR TANK 75% WATER REUSE SYSTEM.
9. COVER OUT DOOR REARING AREAS WITH SHADE CLOTH.

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WASHINGTON DEPARTMENT OF FISH & WILDLIFE
HATCHERY CLIMATE CHANGE VULNERABILITY ASSESSMENT
SAMISH HATCHERY
PROPOSED IMPROVEMENTS

C-1

SHEET NOTES:

1. FRIDAY CREEK INTAKE REPLACEMENT TO MEET NMFS STANDARDS, OPTIMIZE FLOW CONTROL TO THE HATCHERY, AND ADDRESS FLOOD CONTROL NEEDS.
2. UPGRADES FOR SAMISH INTAKE TO RESOLVE MECHANICAL ISSUES.
3. ADDITION OF NEW WELL SYSTEM AND ASSOCIATED INFRASTRUCTURE.
4. INCORPORATION OF NEW INCUBATION MODULES.
5. RETROFITTING EXISTING INCUBATION MODULES FOR WATER REUSE.
6. RENOVATION OF PONDS 9-12 FOR CIRCULAR TANK 75% WATER REUSE.
7. INCORPORATION OF RACEWAY REUSE SYSTEM FOR PONDS 1-8 FOR FALL CHINOOK. UP TO 75% OF THE WATER IS PUMPED BACK TO THE HEAD OF THE RACWAY TO BE COMBINED WITH THE FLOWS FROM FRIDAY CREEK.
(DETERMINE NUMBER OF PUMPS AND GROUPING OF RACEWAYS DURING DETAILED DESIGN PHASE.)
8. RENOVATION OF POND 13 FOR CIRCULAR TANK 75% WATER REUSE SYSTEM.
9. COVER OUT DOOR REARING AREAS WITH SHADE CLOTH.

SAMISH ADULT PONDS

SCALE: NTS

N

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WASHINGTON DEPARTMENT OF FISH & WILDLIFE
HATCHERY CLIMATE CHANGE VULNERABILITY ASSESSMENT
SAMISH ADULT PONDS
PROPOSED IMPROVEMENTS

C-2

GOLDENDALE HATCHERY

SCALE: 1"= 100' 0" 100' 200'

SHEET NOTES:

1. INCORPORATION OF NEW INCUBATION MODULES.
2. INCORPORATION OF PARTIAL REUSE SYSTEM FOR RACEWAYS. MODULE 1 (ADULTS), MODULE 2 (RAINBOWS), MODULE 3 (OTHERS)
3. COVER OUTDOOR REARING AREAS.
4. MAINTAIN / UPDATE PIPING FROM SPRING TO HATCHERY TO MAXIMIZE WATER COLLECTION. TYPE OF PIPE AND CONDITION OF PIPE ARE UNKNOWN.

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WASHINGTON DEPARTMENT OF FISH & WILDLIFE
HATCHERY CLIMATE CHANGE VULNERABILITY ASSESSMENT
GOLDENDALE HATCHERY
PROPOSED IMPROVEMENTS

D-1

Appendix E. Cost Estimates

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McMillen		Job No. 22-034	No.
Project	WDFW Hatchery Climate Change Vulnerability Assessment	Computed	Date
Subject	Class 5 Cost Estimate	Checked	Date
Task	Summary	Sheet 1	Of 3

PURPOSE:

Provide an engineer's estimate of construction costs required to address climate change impacts for the following WDFW hatcheries: Marblemount, Kendall, Samish and Goldendale.

ASSUMPTIONS:

1 Quantity estimation was performed using the Concept Design figures and descriptions included in the Climate Change Vulnerability Assessment Report.
2 Unit costs were researched and applied to the material quantities to provide an estimate for the cost of the project.
3 Material costs were obtained from past similar projects as well as past engineering and construction experience.
4 See additional assumptions on final pages of this estimate
5 Costs are in 2023 US dollars.
6 Costs to not include intake upgrades or replacments

SUMMARY:

The following summarizes the costs for each hatchery.

		Marblemount	Kendall	Samish	Goldendale
Base Construction Costs		$ 10,999,000	$ 3,773,000	$ 10,467,000	$ 2,227,000
Contingency (Const Cost 25%)		$ 2,750,000	$ 944,000	$ 2,617,000	$ 557,000
Overhead (7%)		$ 962,000	$ 330,000	$ 916,000	$ 195,000
Profit (8%)		$ 1,100,000	$ 377,000	$ 1,047,000	$ 223,000
Bond Rate (Approximate 1%)		$ 137,000	$ 47,000	$ 131,000	$ 28,000
Total Base Construction Price		$ 15,948,000	$ 5,471,000	$ 15,178,000	$ 3,230,000
Design, Permitting, Construction Assitance		$ 2,392,000	$ 821,000	$ 2,277,000	$ 485,000
Total Project Cost - Base Bid		$ 18,340,000	$ 6,292,000	$ 17,455,000	$ 3,715,000
Accuracy Range	-30%	$ 12,838,000	$ 4,404,000	$ 12,219,000	$ 2,601,000
	50%	$ 27,510,000	$ 9,438,000	$ 26,183,000	$ 5,573,000

Washington Department of Fish and Wildlife
Hatchery Climate Change Vulnerability Assessment -
Marblemount Hatchery
Engineer's Estimate

Line Item	Optional BID Item	Quantity	Unit	Unit Cost	Cost	Total
	Division 01 - General Requirements					**$ 2,200,000**
	General Conditions	1	%	15%	$ 1,320,000.00	
	Mobilization/Demobilization	1	%	10%	$ 880,000.00	
	Division 02 - Existing Conditions					
	(Not Used)					
	Division 03 - Concrete					**$ 330,800**
	Raceway Rehabilitation-- Ponds 1-24 (10x100x4)	29500	SF	$ 10.40	$ 306,800.00	
	Raceway Sump for Recyle	2	LS	$ 12,000.00	$ 24,000.00	
	Division 05 - Metals					**$ 364,373**
	Misc Metals-Pond 1-9 (posts 21' long, 8"x8"x.625 HSS, 59.32lbs/ft)	20	EA	$ 6,228.60	$ 124,572.00	
	Carrier Wire Pond 1-9 (3/8" x 140' long)	10	EA	$ 297.36	$ 2,973.60	
	Misc Metals-Pond 10-18 (posts 21' long, 8"x8"x.625 HSS, 59.32lbs/ft)	20	EA	$ 6,228.60	$ 124,572.00	
	Carrier Wire Pond 10-18 (3/8" x 140' long)	10	EA	$ 297.36	$ 2,973.60	
	Misc Metals-Pond 19-24 (posts 21' long, 8"x8"x.625 HSS, 59.32lbs/ft)	14	EA	$ 6,228.60	$ 87,200.40	
	Carrier Wire Pond 19-24 (3/8" x 140' long)	7	EA	$ 297.36	$ 2,081.52	
	Misc Metals	1	LS	$ 20,000.00	$ 20,000.00	
	Division 06 - Woods and Plastics					
	(Not Used)					
	Division 07 - Thermal and Moisture protection					
	(Not Used)					
	Division 08 - Openings					
	(Not Used)					
	Division 09 - Finishes					
	(Not Used)					
	Division 10 - Specials					
	(Not Used)					
	Division 11 - Equipment					**$ 2,285,000**
	Spring Chinook Rearing PRAS					
	Dual Drain tanks 20' dia 6' tall	20	EA	$ 37,800.00	$ 756,000.00	
	Coho Rearing PRAS					
	Dual Drain tanks 20' dia 6' tall	10	EA	$ 37,800.00	$ 378,000.00	
	Chinook Early Rearing					
	Dual Drain Tanks 6' dia 4' tall	44	EA	$ 4,050.00	$ 179,000.00	
	Incubation Equipment					
	Recirculating egg incubation system. 8 full stacks of 16 trays each with pumps, chiller, UV, degassing.	8	EA	$ 121,500.00	$ 972,000	
	Division 13 - Special Construction					**$ 753,616**
	Pre-Engineered Metal Building (PEMB) - Hatchery Building, 85' X 35'	2975	SF	$ 225.00	$ 669,375.00	
	Raceway Shade Covers--Ponds 1-9 (11,100 sq ft), Ponds 10-18 (11,200 sq ft), Ponds 19-24 (7,500 sq ft)	29500	SF	$ 2.75	$ 81,125.00	
	Raceway Permimeter 18 ft high--Ponds 1-9 (424 ft), Ponds 10-18 (424 ft), Ponds 19-24 (285 sq ft)	1133	LF	$ 2.75	$ 3,115.75	
	Division 23 - Mechanical & HVAC					**$ 148,750**
	New Hatchery Building HVAC, Building Size 85' X 35'	2975	SF	$ 50.00	$ 148,750.00	
	Division 26 - Electrical					**$ 950,000**
	New Electrical, Lights, heaters, outlets,, Building Size 85' X 35'	1	LS	$ 950,000.00	$ 950,000.00	
	Division 31 - Earthwork					**$ 77,722**
	Site Work and Yard Piping					
	Erosion Control	1	LS	$ 7,500.00	$ 7,500.00	
	Trench Excavation for Chinook PRAS, 2 trenches, each 300 ft long, 5' wide	450	CY	$ 40.00	$ 18,000.00	
	Pipe Bedding for Chinook PRAS	111	CY	$ 65.00	$ 7,222.22	
	Pipe Backfill for Chinook PRAS	333	CY	$ 65.00	$ 21,666.67	
	Trench Excavation for Coho PRAS, 2 trenches, each 150 ft long, 5' wide	222	CY	$ 40.00	$ 8,888.89	
	Pipe Bedding for Coho PRAS	56	CY	$ 65.00	$ 3,611.11	
	Pipe Backfill for Coho PRAS	167	CY	$ 65.00	$ 10,833.33	
	Division 32 - Exterior Improvements					
	(Not Used)					
	Division 33 - Utilities					
	(Not Used)					
	Division 35 - Waterways and Marine Construction					
	(Not Used)					
	Division 40 - Process Interconnections and Instrumentation and Controls					**$ 374,000**
	Instrumentation and Controls					
	Level Alarms	1	LS	$ 1,500.00	$ 1,500.00	
	Flow Control and Balance	1	LS	$ 100,000.00	$ 100,000.00	
	New Hatchery Building, Building Size 85' X 35'					
	Incubation and Early Rearing, Supply, Drainage, and Effluent Piping, Valves, Meters, and Fittings	1	LS	$ 30,000.00	$ 30,000.00	
	Yard Piping					
	Water Supply Yard Piping and Fittings, C900, 12" pipes, 2 pipes @ 300' each and 2 pipes @ 200 ft; each	900	LF	$ 100.00	$ 90,000.00	
	Water Supply Yard Piping, Valves, 3 per system	1	LS	$ 20,000.00	$ 20,000.00	
	Water Supply Yard Piping, Valves, Meter	2	EA	$ 10,000.00	$ 20,000.00	
	Drain Yard Piping and Fittings, C900, 16" pipes, 2 pipes @ 300' each and 2 pipes @ 200 ft; each	900	LF	$ 125.00	$ 112,500.00	
	Division 43 - Process Gas and Liquid Handling					
	(Not Used)					

	Division 44 - Pumps					**$ 665,000**
	Well Improvements					
	Well Rehabilitation	5.0	EA	$25,000	$ 125,000.00	
	Spring Chinook Rearing PRAS (4 modules), Total 4500 gpm, 1,125 gpm per module					
	Recyle Pumps and VFDs (1 duty, 1 standby per module)	8.0	EA	$27,000	$ 216,000.00	
	Coho Rearing PRAS (2 Modules), Total 3,380 gpm, 1690 gpm per module					
	Recyle Pumps and VFDs (1 duty, 1 standby per module)	4.0	EA	$33,750	$ 135,000.00	
	Chinook Early Rearing PRAS (2 Modules). Total 540 gpm, 270 gpm per module					
	Recyle Pumps and VFDs (1 duty, 1 standby per module)	4.0	EA	$20,250	$ 81,000.00	
	Raceway PRAS (2 modules). 3,060 gpm per module					
	Recyle Pumps and VFDs (1 duty, 1 standby per module)	2.0	EA	$54,000	$ 108,000.00	
	Division 46 - Water and Wastewater Equipment					**$ 2,849,850**
	Spring Chinook Rearing PRAS Treatment (4 modules), Total 4500 gpm, 1,125 gpm per module					
	Microscreen Drum Filter	4	EA	$ 33,750.00	$ 135,000.00	
	UV system	4	EA	$ 33,750.00	$ 135,000.00	
	Degassing / LHO	4	EA	$ 50,625.00	$ 202,500.00	
	Coho Rearing PRAS Treatment (2 Modules), Total 3,400 gpm, 1700 gpm per module					
	Microscreen Drum Filter	2	EA	$ 47,250.00	$ 94,500.00	
	UV system	2	EA	$ 40,500.00	$ 81,000.00	
	Degassing / LHO	2	EA	$ 67,500.00	$ 135,000.00	
	Chinook Early Rearing PRAS Treatment (2 Modules). Total 540 gpm, 270 gpm per module					
	Microscreen Drum Filter	2	EA	$ 24,300.00	$ 48,600.00	
	UV system	2	EA	$ 27,000.00	$ 54,000.00	
	Degassing / LHO	2	EA	$ 37,125.00	$ 74,250.00	
	Raceway PRAS Treatment (8 modules). Total 24,480 gpm, 3,060 gpm per module					
	Microscreen Drum Filter	8	EA	$ 74,250.00	$ 594,000.00	
	UV system	8	EA	$ 60,750.00	$ 486,000.00	
	Degassing / LHO	8	EA	$ 101,250.00	$ 810,000.00	
	Construction Subtotal (without Division 01)					$ 8,799,000
	Construction Subtotal with Div 01					**$ 10,999,000**
	Contingency (% of Construction Cost)	25%	%	$ 2,749,750.00	$ 2,750,000.00	
	Construction Cost (w/ Contingency)					**$ 13,749,000**
	Overhead	7%	%	$ 962,430.00	$ 962,000.00	
	Profit	8%	%	$ 1,099,920.00	$ 1,100,000.00	
	Bond Rate (Approximate)	1%	%	$ 137,490.00	$ 137,000.00	
	Total Construction Price (OH, Profit, Bond)					**$ 15,948,000**
	Design, Permitting and Construction Support	15%	%	$ 2,392,200.00	$ 2,392,000.00	
	Total Cost Estimate					**$ 18,340,000**
	Accuracy Range					
	+50%					**$ 27,510,000**
	-30%					**$ 12,838,000**

Washington Department of Fish and Wildlife
Hatchery Climate Change Vulnerability Assessment -
Kendall Creek Hatchery
Engineer's Estimate

Line Item	Optional BID Item	Quantity	Unit	Unit Cost	Cost	Total
	Division 01 - General Requirements					**$ 755,000.00**
	General Conditions	1	%	15%	$ 453,000.00	
	Mobilization/Demobilization	1	%	10%	$ 302,000.00	
	Division 02 - Existing Conditions					
	(Not Used)					
	Division 03 - Concrete					**$ 281,920.00**
	Raceway Recycle Sump	2	LS	$ 12,000.00	$ 24,000.00	
	Raceway Rehabilitation	24800	SF	$ 10.40	$ 257,920.00	
	Division 05 - Metals					**$ 20,000.00**
	Misc Metals	1	LS	$ 20,000.00	$ 20,000.00	
	Division 06 - Woods and Plastics					
	(Not Used)					
	Division 07 - Thermal and Moisture protection					
	(Not Used)					
	Division 08 - Openings					
	(Not Used)					
	Division 09 - Finishes					
	(Not Used)					
	Division 10 - Specials					
	(Not Used)					
	Division 11 - Equipment					**$ 706,000.00**
	Winter Steelhead Early Rearing					
	Dual Drain tanks 4' dia 4' tall	24	EA	$ 4,050.00	$ 98,000.00	
	Egg Incubation		EA		$ -	
	Recirculating egg incubation system. 8 full stacks of 16 trays each with pumps, chiller, UV.	5	EA	$ 121,500.00	$ 608,000.00	
					$ -	
	Division 13 - Special Construction					**$ 375,250.00**
	Pre-Engineered Metal Building (PEMB) - Hatchery Building (45' x 30')	1350	SF	$ 225.00	$ 303,750.00	
	Raceway Shade Covers-- 12 raceways, 1400 sq ft per raceway plus 8000 sq ft for super raceway	24800	SF	$ 2.75	$ 68,200.00	
	Raceway Permimeter 18 ft high	1200	LF	$ 2.75	$ 3,300.00	
	Division 23 - Mechanical & HVAC					**$ 67,500.00**
	New Hatchery Building HVAC, Building Size 45' X 30'	1350	SF	$ 50.00	$ 67,500.00	
	Division 26 - Electrical					**$ 350,000.00**
	New electrical, Lights, heaters, outlets, Building Size 45' X 30'	1	LS	$ 350,000.00	$ 350,000.00	
	Division 31 - Earthwork					**$ 31,455.56**
	Erosion Control	1	LS	$ 7,500.00	$ 7,500.00	
	Trench Excavation for raceways	228	CY	$ 40.00	$ 9,125.93	
	Pipe Bedding for raceways	57	CY	$ 65.00	$ 3,707.41	
	Pipe Backfill for raceways	171	CY	$ 65.00	$ 11,122.22	
	Division 32 - Exterior Improvements					
	(Not Used)					
	Division 33 - Utilities					
	(Not Used)					
	Division 35 - Waterways and Marine Construction					
	(Not Used)					
	Division 40 - Process Interconnections and Instrumentation and Control					**$ 96,500.00**
	Level Alarms	1	LS	$ 1,500.00	$ 1,500.00	
	Flow Control and Balance	1	LS	$ 75,000.00	$ 75,000.00	
	New Hatchery Building 45' X 30' (Incubation and Early Rearing) Piping, Valves, and Meters	1	LS	$ 20,000.00	$ 20,000.00	
	Division 43 - Process Gas and Liquid Handling					
	(Not Used)					

	Division 44 - Pumps					**$ 527,500.00**
	Steelhead Early Rearing PRAS (2 modules), Total 200 gpm, 100 gpm per module.					
	Recyle Pumps and VFDs (1 duty, 1 standby per module)	4	EA	$ 9,750.00	$ 39,000.00	
	Raceway PRAS (3 modules), Total 5,400 gpm, 1,800 gpm per module					
	Recyle Pumps and VFDs (1 duty, 1 standby per module)	6.0	EA	$ 47,250.00	$ 283,500.00	
	Well pumps (Replacement)	1.0	EA	$ 80,000.00	$ 80,000.00	
	Well development	5.0	EA	$ 25,000.00	$ 125,000.00	
	Division 46 - Water and Wastewater Equipmen					**$ 561,600.00**
	Raceway PRAS (3 modules), Total 5,400 gpm, 1,800 gpm per module					
	Microscreen Drum Filter	3	EA	$ 47,250.00	$ 141,750.00	
	UV system	3	EA	$ 40,500.00	$ 121,500.00	
	Degassing / LHO	3	EA	$ 67,500.00	$ 202,500.00	
	Early Rearing PRAS Treatment Equipment (2 modules), Total 200, 100 gpm per module				$ -	
	Microscreen Drum Filter	2	EA	$ 17,550.00	$ 35,100.00	
	UV system	2	EA	$ 10,125.00	$ 20,250.00	
	Degassing / LHO	2	EA	$ 20,250.00	$ 40,500.00	
	Project Subtotal (without Division 01)					$ 3,018,000.00
	Project Subtotal (with Division 01)					**$ 3,773,000.00**
	Contingency (% of Construction Cost)	25%	%	$ 943,250.00	$ 944,000.00	
	Construction Cost (w/ Contingency)					**$ 4,717,000.00**
	Overhead	7%	%	$ 330,190.00	$ 330,000.00	
	Profit	8%	%	$ 377,360.00	$ 377,000.00	
	Bond Rate (Approximate)	1%	%	$ 47,170.00	$ 47,000.00	
	Total Construction Price (OH, Profit, Bond)					**$ 5,471,000.00**
	Design, Permitting and Construction Suppor	15%	%	$ 820,650.00	$ 821,000.00	
	Total Cost Estimate					**$ 6,292,000.00**
	Accuracy Range					
	+50%					**$ 9,438,000.00**
	-30%					**$ 4,404,000.00**

Washington Department of Fish and Wildlife
Hatchery Climate Change Vulnerability Assessment -
Samish Hatchery
Engineer's Estimate

Line	Optional BID			Unit		
Item	**Item**	**Quantity**	**Unit**	**Cost**	**Cost**	**Total**
	Division 01 - General Requirements					**$ 2,093,000.00**
	General Conditions	1	%	15%	$ 1,256,000.00	
	Mobilization/Demobilization	1	%	10%	$ 837,000.00	
	Division 02 - Existing Conditions					**$ 16,000.00**
	Sawcutting (Raceway 9-12) 80' long, includes removal	320	lf	$ 50.00	$ 16,000.00	
	Division 03 - Concrete					**$ 336,416.00**
	Raceway Recycle Sump	15	LS	$ 12,000.00	$ 180,000.00	
	Raceway Rehabilitation-- Ponds 1-8 (10x100x4)	15040	SF	$ 10.40	$ 156,416.00	
	Division 05 - Metals					**$ 376,522.34**
	Misc Metals-Pond 1-8 (posts 21' long, 8"x8"x.625 HSS, 59.32lbs/ft)	18	EA	$ 6,228.60	$ 112,114.80	
	Carrier Wire Pond 1-8 (3/8" x 140' long)	9	EA	$ 297.36	$ 2,676.24	
	Misc Metals-Pond 9-12 (posts 21' long, 8"x8"x.625 HSS, 59.32lbs/ft)	18	EA	$ 6,228.60	$ 112,114.80	
	Carrier Wire Pond 9-12 (3/8" x 125' long)	9	EA	$ 265.50	$ 2,389.50	
	Misc Metals-Pond 13 (posts 21' long, 8"x8"x.625 HSS, 59.32lbs/ft)	20	EA	$ 6,228.60	$ 124,572.00	
	Carrier Wire Pond 13 (3/8" x 125' long)	10	EA	$ 265.50	$ 2,655.00	
	Misc Metals	1	LS	$ 20,000.00	$ 20,000.00	
	Division 06 - Woods and Plastics					
	(Not Used)					
	Division 07 - Thermal and Moisture protection					
	(Not Used)					
	Division 08 - Openings					
	(Not Used)					
	Division 09 - Finishes					
	(Not Used)					
	Division 10 - Specials					
	(Not Used)					
	Division 11 - Equipment					**$ 2,392,000.00**
	Incubation Equipment					
	Recirculating egg incubation system. 8 full stacks of 16 trays each with pumps, chiller, UV.	10	EA	$ 90,000.00	$ 900,000.00	
	Additional incubation trays	245	EA	$ 144.00	$ 36,000.00	
	Tanks				$ -	
	Dual Drain Tanks 16' dia 5' tall	52	EA	$ 28,000.00	$ 1,456,000.00	
				`		
	Division 13 - Special Construction					**$ 196,149.25**
	Raceway Shade Covers-- Pond 1-8, (11,100 sq.ft.) Ponds 9-12 (7720 sq.ft.) Pond 13 (24,000 sq.f	69196	SF	$ 2.75	$ 190,289.00	
	Raceway Permimeter 18 ft high--Pond 1-8 (424 ft) Ponds 9-12 (352 ft) Pond 13 (654 ft) Pond 14 (	2131	LF	$ 2.75	$ 5,860.25	
	Division 23 - Mechanical & HVAC					
	(Not Used)					
	Division 26 - Electrical					**$ 200,000.00**
	Electrical, Lights, recirc pumps	1	LS	$ 200,000.00	$ 200,000.00	
	Division 31 - Earthwork					**$ 31,455.56**
	Erosion Control	1	LS	$ 2,500.00	$ 2,500.00	
	Trench Excavation (Modules 1 and 2 on Ponds 1-8)	228	CY	$ 40.00	$ 9,125.93	
	Pipe Bedding	57	CY	$ 65.00	$ 3,707.41	
	Pipe Backfill	171	CY	$ 65.00	$ 11,122.22	
	Earthwork removal of Pond 13 (120x60x5) just the sloped edges (assume 5' width on a 1:1 slope	167	CY	$ 30.00	$ 5,000.00	
	Division 32 - Exterior Improvements					
	(Not Used)					
	Division 33 - Utilities					
	(Not Used)					
	Division 35 - Waterways and Marine Construction					
	(Not Used)					
	Division 40 - Process Interconnections and Instrumentation and Control					**$ 1,767,500.00**
	Level Alarms	15	LS	$ 1,500.00	$ 22,500.00	
	Flow Control and Balance	15	LS	$ 10,000.00	$ 150,000.00	
	Water Supply Yard Piping and Fittings, C900, 12" pipes, 15 modules, each with 2 pipes @ 100'	3000	LF	$ 100.00	$ 300,000.00	
	Water Supply Yard Piping, Valves, 3 per system	45	LS	$ 20,000.00	$ 900,000.00	
	Water Supply Yard Piping, Valves, Meter	1	EA	$ 10,000.00	$ 10,000.00	
	Drain Yard Piping and Fittings, C900, 16" pipes, 15 modules, each with 2 pipes @ 100' each	3000	LF	$ 125.00	$ 375,000.00	
	Division 43 - Process Gas and Liquid Handling					
	(Not Used)					

	Division 44 - Pumps					**$ 1,127,100.00**
	Ponds 1-8 PRAS (2 modules). Total 12,800 gpm, 1,600 gpm per module					
	Recyle Pumps and VFDs (1 duty, 1 standby per module)2 Modules	4	EA	$ 47,250.00	$ 189,000.00	
	Ponds 9-12 PRAS (4 modules). Total 8,000 gpm, 2,000 gpm per module					
	Recyle Pumps and VFDs (1 duty, 1 standby per module) 4 Modules	8	EA	$ 56,700.00	$ 453,600.00	
	Pond 13 PRAS (9 modules). Total 4,500 gpm, 500gpm per module					
	Circulation Pumps and VFDs (1 duty, 1 standby per module) 9 Modules	18	EA	$ 20,250.00	$ 364,500.00	
	New wells (340 gpm total) (assume low producing wells at 200 ft and 30 gpm)	12.0	EA	$ 10,000.00	$ 120,000.00	
	Division 46 - Water and Wastewater Equipmen					**$ 1,930,500.00**
	Ponds 1-8 PRAS Treatment, Total 12,800 gpm, 1,600 gpm per module					
	Microscreen Drum Filter	2	EA	$ 47,250.00	$ 94,500.00	
	UV system	2	EA	$ 40,500.00	$ 81,000.00	
	Degassing / LHO	2	EA	$ 67,500.00	$ 135,000.00	
	Ponds 9-12 PRAS Treatment, Total 8,000 gpm, 2,000 gpm per module					
	Microscreen Drum Filter	4	EA	$ 56,700.00	$ 226,800.00	
	UV system	4	EA	$ 48,600.00	$ 194,400.00	
	Degassing / LHO	4	EA	$ 81,000.00	$ 324,000.00	
	Pond 13 PRAS Treatment, Total 4,500 gpm, 500gpm per module					
	Microscreen Drum Filter	9	EA	$ 27,000.00	$ 243,000.00	
	UV system	9	EA	$ 29,700.00	$ 267,300.00	
	Degassing / LHO	9	EA	$ 40,500.00	$ 364,500.00	
	Project Subtotal (without Division 01)					$ 8,374,000.00
	Project Subtotal (with Division 01)					**$ 10,467,000.00**
	Contingency (% of Construction Cost)	25%	%	$ 2,616,750.00	$ 2,617,000.00	
	Construction Cost (w/ Contingency)					**$ 13,084,000.00**
	Overhead	7%	%	$ 915,880.00	$ 916,000.00	
	Profit	8%	%	$ 1,046,720.00	$ 1,047,000.00	
	Bond Rate (Approximate)	1%	%	$ 131,000.00	$ 131,000.00	
	Total Construction Price (OH, Profit, Bond)					**$ 15,178,000.00**
	Design, Permitting and Construction Suppor	15%	%	$ 2,276,700.00	$ 2,277,000.00	
	Total Cost Estimate					**$ 17,455,000.00**
	Accuracy Range					
	+50%					**$ 26,183,000.00**
	-30%					**$ 12,219,000.00**

Washington Department of Fish and Wildlife
Hatchery Climate Change Vulnerability Assessment -
Goldendale Hatchery
Engineer's Estimate

Line Item	Optional BID Item	Quantity	Unit	Unit Cost	Cost	Total
	Division 01 - General Requirements					**$ 445,000.00**
	General Conditions	1	%	15%	$ 267,000.00	
	Mobilization/Demobilization	1	%	10%	$ 178,000.00	
	Division 02 - Existing Conditions					
	(Not Used)					
	Division 03 - Concrete					**$ 224,240.00**
	Raceways 1-10 Rehabilitation (80x10x3.5)	13950	SF	$ 10.40	$ 145,080.00	
	Raceways Adults Rehabilitation 2x (80x15x5)	4150	SF	$ 10.40	$ 43,160.00	
	Raceway Sump for Recyle	3	LS	$ 12,000.00	$ 36,000.00	
	Division 05 - Metals					**$ 235,489.40**
	Misc Metals (posts 21' long, 8"x8"x.625 HSS, 59.32lbs/ft)	34	EA	$ 6,228.60	$ 211,772.40	
	Carrier Wire (3/8" x 125 long)	14	EA	$ 265.50	$ 3,717.00	
	Misc Metals General	1	LS	$ 20,000.00	$ 20,000.00	
	Division 06 - Woods and Plastics					
	(Not Used)					
	Division 07 - Thermal and Moisture protectior					
	(Not Used)					
	Division 08 - Openings					
	(Not Used)					
	Division 09 - Finishes					
	(Not Used)					
	Division 10 - Specials					
	(Not Used)					
	Division 11 - Equipment					**$ 450,000.00**
	Incubation Equipment					
	Recirculating egg incubation system. 8 full stacks of 16 trays each with pumps, chiller, UV.	5	EA	$ 90,000.00	$ 450,000.00	
	Division 13 - Special Construction					**$ 70,721.75**
	Raceway Shade Covers	17437	SF	$ 2.75	$ 47,951.75	
	Raceway Perimeters 18 feet high (all ponds 460 ft)	8280	SF	$ 2.75	$ 22,770.00	
	Division 23 - Mechanical & HVAC					
	(Not Used)					
	Division 26 - Electrical					**$ 35,000.00**
	Electrical, recirc pumps	1	LS	$ 35,000.00	$ 35,000.00	
	Division 31 - Earthwork					**$ 21,500.00**
	Erosion Control	1	LS	$ 7,500.00	$ 7,500.00	
	Trench Excavation	133	CY	$ 40.00	$ 5,333.33	
	Pipe Bedding	100	CY	$ 65.00	$ 6,500.00	
	Pipe Backfill	33	CY	$ 65.00	$ 2,166.67	
	Division 32 - Exterior Improvements					
	(Not Used)					
	Division 33 - Utilities					
	(Not Used)					
	Division 35 - Waterways and Marine Constructior					
	(Not Used)					
	Division 40 - Process Interconnections and Instrumentation and Control					**$ 331,500.00**
	Level Alarms	1	LS	$ 1,500.00	$ 1,500.00	
	Flow Control and Balance	1	LS	$ 5,000.00	$ 5,000.00	
	Water Supply Yard Piping and Fittings, C900, 8" pipes, 3 modules, each with 2 pipes @ 100'	600	LF	$ 75.00	$ 45,000.00	
	Water Supply Yard Piping, Valves, 3 per module	9	LS	$ 20,000.00	$ 180,000.00	
	Water Supply Yard Piping, Valves, Meter, 1 per module	3	EA	$ 10,000.00	$ 30,000.00	
	Drain Yard Piping and Fittings, C900, 12" pipes, 3 modules, each with 2 pipes @ 100' each	600	LF	$ 100.00	$ 60,000.00	
	Division 43 - Process Gas and Liquid Handlinç					
	(Not Used)					

	Division 44 - Pumps					**$ 121,500.00**
	Raceway PRAS (3 modules), Total 1500 gpm, 500 gpm per module					
	Recyle Circulation Pumps with VFDs (Raceway PRAS, 500 gpm)	6.0	EA	$ 20,250.00	$ 121,500.00	
	Division 46 - Water and Wastewater Equipmen					**$ 291,600.00**
	Raceway PRAS (3 modules), Total 1500 gpm, 500 gpm per module					
	Microscreen Drum Filter	3	EA	$ 27,000.00	$ 81,000.00	
	UV system	3	EA	$ 29,700.00	$ 89,100.00	
	Degassing / LHO	3	EA	$ 40,500.00	$ 121,500.00	
	Project Subtotal (without Division 01)					$ 1,782,000.00
	Project Subtotal (with Division 01)					**$ 2,227,000.00**
	Contingency (% of Construction Cost)	25%	%	$ 556,750.00	$ 557,000.00	
	Construction Cost (w/ Contingency)					**$ 2,784,000.00**
	Overhead	7%	%	$ 194,880.00	$ 195,000.00	
	Profit	8%	%	$ 222,720.00	$ 223,000.00	
	Bond Rate (Approximate)	1%	%	$ 27,840.00	$ 28,000.00	
	Total Construction Price (OH, Profit, Bond)					**$ 3,230,000.00**
	Design, Permitting and Construction Suppor	15%	%	$ 484,500.00	$ 485,000.00	
	Total Cost Estimate					**$ 3,715,000.00**
	Accuracy Range					
	+50%					**$ 5,573,000.00**
	-30%					**$ 2,601,000.00**