Climate Induced Hatchery Upgrades

Feather River Hatchery

Alternatives Analysis Submittal

Final Report
Revision No. 4

McMillen

February 2025

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Revision Log

Revision No.	Date	Revision Description
0	03/28/2024	65% Draft Internal Technical Review
1	04/02/2024	65% Draft for CDFW Review
2	08/23/2024	100% Draft for CDFW and Internal Technical Review
3	10/31/2024	Final Submittal to CDFW
4	2/28/2025	Final Submittal to CDFW, ADA Accessible Document

Appendices

The appendices that accompany this document are not ADA compliant. For access to the following appendices, contact Fisheries@wildlife.ca.gov. If assistance is needed for an ADA compliant version of the appendices, please include that in the email.

- Appendix A. Site Visit Report
- Appendix B. Bioprogramming
- Appendix C. Concept Alternative Drawings
- Appendix D. Design Criteria TM
- Appendix E. Alternatives Development TM
- Appendix F. Cost Estimates
- Appendix G. Meeting Minutes
- Appendix H. LEED and NZE Evaluations

Executive Summary

McMillen, Inc. (McMillen) was retained by the California Department of Fish and Wildlife (CDFW) to provide an assessment of 21 CDFW fish hatcheries throughout the State of California in the context of their vulnerability to the effects of climate change. Climate modeling was performed by Northwest Hydraulic Consultants (NHC).

The Feather River Hatchery (FRH) is a California State Water Project facility that was constructed to mitigate for the loss of salmonid access to spawning and rearing habitat. Over the years following the hatchery's construction, other fish production programs have emerged that utilize the hatchery's resources and have changed the fish production goals. The FRH is owned by the California Department of Water Resources (DWR) and is a component of DWR's hydropower license that is administered by the Federal Energy Regulatory Commission (FERC). DWR anticipates receiving a new FERC license in the upcoming years. It is expected that a new FERC license would require DWR to complete a Comprehensive Facility Assessment of the FRH. If implemented, the Comprehensive Facility Assessment would utilize information from this hatchery's Climate Induced Upgrades Report, along with other analyses, to determine maintenance and repair needs, facility improvements, and the sequencing of construction activities to minimize impacts to hatchery operations.

The Feather River Hatchery has aging infrastructure and deficiencies that need to be addressed in the near future in order to continue meeting the fish production goals. Historically, the hatchery has been able to maintain infrastructure by using the Feather River Annex as a temporary holding facility for steelhead during the summer when the main hatchery water supply line is shut down for maintenance. However, the Annex is no longer operational, so an alternative procedure will be needed for the steelhead during the summer when the main hatchery water supply line is shut down for maintenance, which occurs approximately every 5-10 years. The hatchery currently uses a retrofitted spawning channel as production space, which provides a significant volume of rearing space but is difficult to access for fish culture activities and is limited by the amount of water flow supplied to the channel. Additionally, the inland Chinook Salmon hatchery building was constructed higher than the specified grade, which causes head pressure issues that staff must manage through altered operations. Total production of inland salmon is also limited by a lack of raceway rearing space. The surface water source has also recently experienced a slight decrease in dissolved oxygen and conductivity in recent years; the cause or duration of this change is unknown but may impact fish production in the future.

The preferred alternative identified in this report for facility upgrades includes adding water filtration for the hatchery building and production raceways that is capable of treating enough water to allow fish to reach the target size for marking. Water treatment upgrades also include UV disinfection for the entire hatchery building and production raceways, and oxygenation for all rearing areas. Other improvements include adding booster pumps for the inland production area to overcome existing head loss, constructing additional inland Chinook Salmon raceways, replacing deteriorated or aging valves and pipes throughout the facility, refurbishing deteriorated concrete, and replacing production in the rearing channel with a new circular tank partial recirculating aquaculture system (PRAS). Power upgrades, such as standby emergency generators, are proposed to ensure smooth operation of all new equipment as well as any existing equipment.

The Class 5 Opinion of Probable Construction Cost (OPCC) for constructing the preferred alternative upgrades can be found in the table below (Table 6-2 provides the Class 5 OPCC summary). The table also includes the estimated cost of photovoltaic systems to offset the energy consumption of the new equipment and to maintain zero net energy. These upgrades would not significantly affect fire or flood risks at the facility, and all work would occur within already developed areas. Operationally, CDFW would need to update feeding, harvesting, and water quality monitoring protocols to accommodate the transition to partial recirculating aquaculture systems with circular tanks. The proposed upgrades would provide a solid foundation for CDFW to sustain fish production at the hatchery, even as climate change increasingly disrupts current and future operations.

Project Total	Photovoltaic – Zero Net Energy
$64,660,000	$9,795,600

1.0 Introduction

1.1 Project Authorization

McMillen, Inc. (McMillen) was retained by the California Department of Fish and Wildlife (CDFW) to provide a climate change evaluation for 21 hatcheries operated by CDFW throughout the State of California. The contract for this Climate Induced Hatchery Upgrade Project (Project) was executed on March 21, 2023.

1.2 Project Background

California relies on CDFW hatcheries to provide recreational fishing opportunities for the public and for the conservation of endangered or threatened species. However, climate change threatens the business-as-usual production of fish with the existing CDFW hatchery infrastructure. Climate change impacts have already affected many CDFW hatcheries, resulting in altered or inconsistent operation schedules, lowered production, and emergency fish evacuations. These climate impacts include increasing water and air temperatures, changes to groundwater availability, low flows and water shortages, increased flood and fire risks, and other second-hand impacts associated with each of these categories (i.e., emerging pathogens and non-infectious diseases, low adult salmon returns, decreased worker safety, etc.).

A total of 21 hatcheries were visited by McMillen to evaluate the existing infrastructure and fish production operations. During these visits, McMillen assessed the existing hatchery infrastructure deficiencies and replacement needs. The assessment was used to aid in determining the potential upgrades for each hatchery that would maintain existing program production goals for the various species reared at each facility while providing conceptual alternatives climate resilience. Climate change has had an impact worldwide and will continue to affect CDFW's statewide fish production operations. Developing technologies and methods to meet fishery conservation and sport fisheries is critical to CDFW's goal of maintaining hatchery productivity while conserving precious cold-water supplies for native species.

We have based our detailed work plan on achieving the following project objectives stated in the Request for Proposals (RFP). As presented in Sections 2 and 3 of our proposal, we have intentionally comprised our team of experts in all required disciplines with experience in fish husbandry and hatchery engineering and design to successfully meet all CDFW's project goals.

- **Objective 1:** Review the state of each facility via data collection, review of documents, site visits, and discussions with hatchery personnel. Identify climate change impacts that are likely to negatively impact operations at each hatchery over the next 40 years.

- **Objective 2:** Develop cost effective and programmatically viable alternatives that will maintain current fish propagation goals given climatic impacts in the future.
- **Objective 3:** Assess the risks of each alternative to natural biological systems, environmental conditions, husbandry techniques for fish health and fish safety, and potential impacts to water quality.
- **Objective 4:** Determine the short- and long-term economic costs for the modifications to each hatchery in current year dollars. Account for construction, permitting, design, operational, and maintenance costs within the overall economic analysis. Prioritize the list of alternatives and associated hatcheries based on limited annual hatchery budgets.
- **Objective 5, Phase 2 Work**: Provide complete designs with issued for construction drawings and specifications for projects at as many hatcheries as are feasible. The focus shall be on those hatcheries that are deemed most susceptible to negative climate change impacts identified from the evaluation in the four previous objectives.

1.3 Project Purpose

The purpose of the Project is to determine the CDFW hatcheries and the existing infrastructure conditions that are most susceptible to reduced fish production attributable to climate change and provide a prioritization of the hatcheries for improvements. With input from CDFW, designs for climate change resiliency upgrades will be advanced for as many facilities as is feasible.

1.4 Project Location Description

The Feather River Hatchery is located in the town of Oroville, CA downstream of the Thermalito Diversion Dam on the Feather River (Figure 1-1). The map shows an aerial view of the area surrounding the Feather River Hatchery. City and highway labels are included with a pin locating the hatchery.

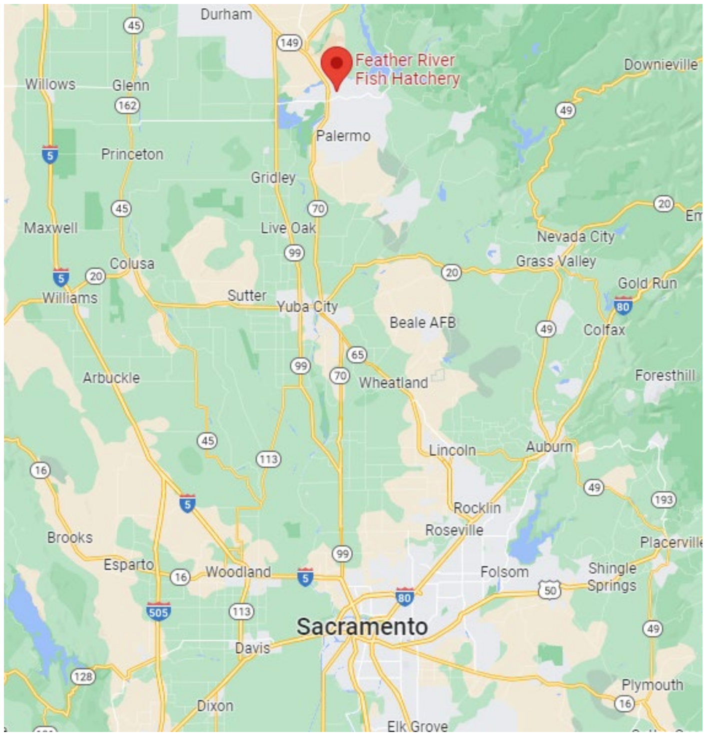

Figure 1-1. Feather River Hatchery Location Map.

The Feather River Hatchery is an anadromous production facility, raising spring and fall-run Chinook Salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) to mitigate impacts from the construction of the Oroville Dam, built by California Department of Water Resources (DWR). The hatchery also produces Chinook Salmon for the Inland Chinook Program. The hatchery's water supply is diverted from the Thermalito Diversion Dam at a maximum intake flow rate of approximately 110 cfs. The hatchery is operated as a flow-through system.

The facility is cooperatively managed by CDFW, which is responsible for operations and daily maintenance, and DWR, which is the hatchery's mitigator and is responsible for funding and infrastructure maintenance. The general facilities are shown in Figure 1-2. See the Site Visit Report (Appendix A) for additional details regarding the existing facilities.

Figure 1-2. Feather River Facility Layout. Google Earth Image Date: 5/2/2021.

2.0 Bioprogram

2.1 Production Goals and Existing Capacity

The Feather River Hatchery was established to mitigate the loss of salmon and steelhead spawning and rearing habitat after the construction of the Oroville Dam. Production also supplements steelhead fisheries to offset adverse impacts from the diversion of water at the Harvey O. Banks Delta Pumping Plant, part of a 1986 Delta Fish Agreement between California's Department of Water Resources (DWR) and CDFW; other production goals are sometimes included to boost commercial and recreational fishery opportunities in the ocean and river. The facility was constructed by DWR and is operated by CDFW. The hatchery produces Central Valley spring-run Chinook Salmon and steelhead, both of which are listed as threatened under the Endangered Species Act (ESA), as well as Central Valley fall-run Chinook Salmon and inland (triploid) Chinook Salmon. The current production goals for the Feather River Hatchery are shown in Table 2-1. Production is split to show minimum production to meet mitigation requirements, and supplemental production to increase benefits to the fishery or to assist with scientific studies. Due to the supplemental production numbers shown in Table 2-1, the assumed production goal approaches the maximum capacity of the Feather River Hatchery. However, actual supplemental production changes are annually based on budget, environmental conditions, and egg availability.

Table 2-1. Assumed Production Goals at the Feather River Hatchery

Species/Strain	Minimum Mitigation Requirements	Supplemental Production[a]	Assumed Production Goal
Spring-Run Chinook Salmon	2 million smolts released (120 to 60 fpp[b] 3.0 to 3.8 inches)[c]	17,000 smolts (scientific study requests)	2.017 million smolts
Fall-Run Chinook Salmon	6 million smolts released (60 fpp, 3.8 inches)	1.5 million fingerlings (170 fpp, 2.7 inches) 2 million smolts (drought mitigation)	1.5 million fingerlings 8 million smolts

Species/Strain	Minimum Mitigation Requirements	Supplemental Production[a]	Assumed Production Goal
Steelhead Trout	450,000 yearlings released (4 fpp, 8.9 inches)	None	450,000 yearlings
Inland Chinook Salmon	>1 million eggs (transfers) 125,000 yearlings released (3 fpp, 10.4 inches)[d]	None	>1 million eggs 125,000 yearlings

[a] Supplemental production varies annually depending on budget, environmental conditions, and egg availability.
[b] fpp = fish per pound.
[c] Recently, the FRH has increased its spring-run Chinook Salmon production to 3 million smolts. The hatchery assessment was conducted under previous goals for 2 million smolts produced.
[d] The Feather River Hatchery currently releases fish at 25 fpp (5.1 inches) due to a lack of rearing space.

The Capacity Biological Program (Capacity Bioprogram) for the facility was developed for the Site Visit Report (Appendix A) and provides the total numbers of fish and biomass that can be produced for all rearing tanks based on tank volume, operational water flows, and size of the fish. The calculations utilize the density and flow indices previously identified for the preliminary bioprograms which encompass water temperature and elevation criteria to ensure oxygen levels appropriately align with production. This information is available in the Site Visit Report (Appendix A). The calculations include a 10% safety factor to provide a 90% maximum capacity based on both the density index (DI) and flow index (FI; recommended values according to Piper et al. 1982) requirements identified. A summary of the rearing capacities identified in the Capacity Bioprogram is shown in Table 2-2 through Table 2-5. The following are the fish production goals for each species:

- Spring-Run Chinook Salmon: 2 million smolts
- Fall-Run Chinook Salmon: 8 million smolts and 1.5 million fingerlings
- Inland Chinook Salmon: 125,000 yearlings
- Steelhead: 450,000 yearlings

Table 2-2. Production Spring-Run Chinook Salmon Capacity of Various Rearing Units at the Feather River Hatchery per the Capacity Bioprogram (Appendix A).

Rearing Unit (max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
Raceways (170 fpp/2.7 inches)	1,705,483	Water flow
Raceways (67 fpp/3.7 inches)	921,109	Water flow

[a] This is an estimate of 90% production capacity to allow for a buffer in circumstances where more flexibility is needed for hatchery operations.

Table 2-3. Production Fall-Run Chinook Salmon Capacity of Various Rearing Units at the Feather River Hatchery per the Capacity Bioprogram (Appendix A).

Rearing Unit (max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
Raceways (170 fpp/2.7 inches)	5,116,450	Water flow
Raceways (60 fpp/3.8 inches)	2,541,504	Water flow
Rearing channel (60 fpp/3.8 inches)	1,694,572	Water flow

[a] This is an estimate of 90% production capacity to allow for a buffer in circumstances where more flexibility is needed for hatchery operations.

Table 2-4. Production Inland Chinook Salmon Capacity of Various Rearing Units at the Feather River Hatchery per the Capacity Bioprogram (Appendix A).

Rearing Unit (max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
Fry tanks (400 fpp/2.0 inches)	131,328	Rearing volume
Raceways (25 fpp/5.1 inches)	473,745	Water flow
Raceways (3 fpp/10.4 inches)	115,928	Water flow

[a] This is an estimate of 90% production capacity to allow for a buffer in circumstances where more flexibility is needed for hatchery operations.

Table 2-5. Production Steelhead Capacity of Various Rearing Units at the Feather River Hatchery per the Capacity Bioprogram (Appendix A).

Rearing Unit (max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
Fry Tanks (800 fpp/1.5 inches)	77,760	Rearing Volume
Raceways (150 fpp/2.7 inches)	1,504,838	Water Flow
Rearing Channel (4 fpp/8.9 inches)	264,591	Water Flow

[a] This is an estimate of 90% production capacity to allow for a buffer in circumstances where more flexibility is needed for hatchery operations.

2.2 Bioprogram Summary

The Capacity Bioprogram in the Site Visit Report (Appendix A) demonstrates the total capacity of each rearing area at the Feather River Hatchery for several stages of fish production. The capacity of each rearing area (-10% to provide an additional safety factor), limited by water flow or available rearing volume, are shown in Table 2-2 through Table 2-5. At a high level, the total capacity for the Feather River Hatchery falls short of the production goal shown in Table 2-1, though nuances of the timing of egg collections and fish releases allows for annual production to meet their goals. Additionally, the rearing channel is flow limited but has an excess of rearing volume; low stocking densities used by the hatchery can alleviate some concerns about low oxygen when water flows are limiting. Details about the various rearing areas and infrastructure are discussed in the Site Visit Report, found in Appendix A.

In this current report, we developed an initial Production Bioprogram (Appendix B) to illustrate the potential production that the facility is capable of while remaining within the limits set by the Capacity Bioprogram including the criteria presented in Table 2-6.

2.2.1 Criteria

The methods and reasoning used to determine the criteria associated with biological programming for the Feather River Hatchery can be found in Appendix A. For reference, the established criteria are shown in Table 2-6. To model the production cycle schedule for the Production Bioprogram, several assumptions are made and included in Table 2-7. This bioprogram also assumes optimal egg development and fish growth given the water temperatures experienced at the facility. Variable growth rates are also based on tagging operations and feed rationing. Survival rates and growth rates were provided by Feather River Hatchery staff.

Table 2-6. Criteria Used for the Production Bioprogram. Criteria are Discussed in Detail in Appendix A.

Criteria	Value
Density index (DI)	Spring- or fall-run Chinook Salmon: 0.26 Inland Chinook: 0.38 Steelhead: 0.30
Condition factor	Chinook Salmon: $C = 3{,}000 \times 10^{-7}$ Steelhead: $C = 3{,}500 \times 10^{-7}$
Flow index (FI)	1.15
Water temperature	Variable between 42 and 64 °F

Table 2-7. Assumptions Used for the Production Bioprogram.

Species	Survival
Chinook Salmon	Egg-to-fry: 87% Fry-to-juvenile (170 fpp): 90% Juvenile-to-outplant (60 fpp): 95%
Steelhead	Egg-to-fry (800 fpp): 90% Fry-to-juvenile (300 fpp): 80% Juvenile-to-outplant (4 fpp): 80%

2.2.2 Production Bioprogram

This bioprogram (Appendix B) is meant to view hatchery operations at a high level and does not capture the nuances of specific timing of fish transfers, grading, sorting, or stocking. The model is meant to show an example of how production may occur given the criteria and assumptions outlined in the previous section.

The Feather River Hatchery fish ladder operates with 20 cubic feet per second (cfs) of water flow from April through June to mark spring-run Chinook Salmon that arrive early. The ladder operates for spawning from September to February to capture all three distinct groups of fish (spring-run and fall-run Chinook and steelhead trout) raised at the facility.

Spawning for the spring-run Chinook begins in mid-September and lasts two weeks. Approximately 3 million eggs are collected and incubated to meet the mitigation goal of 2 million smolts. Additional eggs may be collected and culled based on genetic data. For this bioprogram, which adheres to the criteria in Table 2-6, approximately 1.55 million are transferred directly to two raceways (Table 2-8) in late November and early December. By the end of December, approximately 1.47 million fish occupy two raceways at an approximate size of 400 fish per pound (fpp) (2 inches). In early February, fish reach approximately 170 fpp (2.7 inches) and marking operations begin for approximately 1.36 million fish. Growth rates are typically reduced during February because of required fasting prior to marking and the result of handling stress during and after marking. At the end of March, approximately 1.32 million fish will reach an average size of 94 fpp (3.3 inches) and reach the safety buffer for the FI criteria in two raceways. Stocking of this population occurs in April, in rare instances stocking may occur in May or June. It is difficult to predict the size at release because it is dependent on feed rationing practices and the specific egg lots to be stocked. Growth is modeled at a slower rate after marking to depict the average size of all egg lots; however, fish from early spawn dates are expected to be near 62 fpp (3.8 inches) at release. Total production from this bioprogram is approximately 1.3 million spring-run Chinook; however, actual production practices allow for total fish releases of approximately 2 million fish annually.

Table 2-8. End of Month Production Information for the Spring-Run Chinook Salmon Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Late Nov/Early Dec	Raceways	2	1,200	1.40	1,555,556	1,296.3	8.0	0.03	0.26
Dec	Raceways	2	400	2.00	1,477,778	3,694.4	8.0	0.05	0.51
Jan	Raceways	2	190	2.60	1,400,000	7,368.4	8.0	0.08	0.79
Feb	Raceways	2	125	3.00	1,362,500	10,900.0	8.0	0.10	1.01
Mar	Raceways	2	94	3.30	1,325,000	14,095.7	8.0	0.12	1.19[a]
Apr	Raceways	2	62	3.80	875,000	14,112.9	8.0	0.10	1.03

[a] This is the maximum capacity of the raceways for fish at this size; additional fish production would exceed the established safety factor for the FI criteria.

Spawning operations for the fall-run Chinook population begin in early October and span through November. Multiple egg lots are collected throughout this spawning window; the bioprogram models the production schedule based on the progeny originating from the first spawning event in October. Growth rates for this population are adjusted by CDFW based on the number of months between spawning and the target release date. It is normal practice to reduce feed to slow growth for fish from earlier spawn dates and increase feed rates for fish from later spawn dates; this allows fish from different release times to be at similar sizes. Approximately 7 million eggs are collected annually and kept for production; additional eggs may be collected and culled based on genetic information.

In late December and early January, the first groups of fish are transferred to the raceways once their yolk sacs have been absorbed at approximately 1,200 fpp (1.4 inches; Table 2-9). By the end of February, fish from all spawn dates (approximately 5.57 million) have been split among six raceways at an average size of 190 fpp (2.6 inches). Fish are initially crowded into the upper ends of the raceways and given more space in the downstream sections as they grow. There are no fish in the downstream sections of raceways as young fish are stocked into the upstream sections and specific timing of expanding the rearing space is variable; therefore, the crowding of fish is not represented in the density index calculations in Table 2-9. This does not significantly affect the bioprogram because the limiting criteria in Table 2-3 is water flow, not rearing density.

In early March, tagging operations begin, and half of the fish are tagged directly in the rearing channel (Table 2-10) while others remain spread among four raceways (Table 2-9). The modeled size and populations in each production area (raceways and rearing channel) are identical. Typically, stocking operations for smolts begin in May and finish by the end of June; however, there are some fish groups that are released as unfed fry in January and February. It is difficult to predict the size at release because it is dependent on feed rationing practices and the specific egg lots to be stocked. Growth is modeled at a slower rate after marking to depict the average size of all egg lots; however, fish from early spawn dates are expected to be near 67 fpp (3.7 inches) at release. Total production from this bioprogram is approximately 5.25 million fall-run Chinook; however, actual production practices exceed the recommended flow index criteria and from 2018 onward have allowed for total fish releases over 6 million fish annually for mitigation requirements. In recent years, 10 million fish have been released including the release of swim-up fry and fish released at 170 fpp (2.7 inches) immediately after marking.

Table 2-9. End of Month Production Information for the Fall-Run Chinook Salmon Raceway Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Late Dec/ Early Jan	Raceways	6	1,200	1.4	1,500,000	1,250.0	24.0	0.01	0.08
Jan	Raceways	6	400	2.0	2,500,000	6,250.0	24.0	0.03	0.29
Feb	Raceways	6	190	2.6	5,579,000	29,363.2	24.0	0.10	1.05[a]
Mar	Raceways	4	150	2.8	2,719,750	18,131.7	16.0	0.09	0.90
Apr	Raceways	4	115	3.1	2,650,000	23,043.5	16.0	0.10	1.04[a]

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
May	Raceways	4	85	3.4	1,749,000	20,576.5	16.0	0.08	0.84
Jun	Raceways	4	67	3.7	874,500	13,052.2	16.0	0.05	0.49

[a] This is the maximum capacity of the raceways for fish at this size; additional fish production would exceed the established safety factor for the FI criteria.

Table 2-10. End of Month Production Information for the Fall-Run Chinook Salmon Rearing Channel Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Mar	Rearing Channel	1	150.0	2.80	2,719,750	18,131.7	16.0	0.05	0.90
Apr	Rearing Channel	1	115.0	3.10	2,650,000	23,043.5	16.0	0.06	1.04[a]
May	Rearing Channel	1	85.0	3.40	1,749,000	20,576.5	16.0	0.05	0.84
Jun	Rearing Channel	1	67.0	3.70	874,500	13,052.2	16.0	0.03	0.49

Note: Remaining fish are stocked out by the end of July.
[a] This is the maximum capacity of the rearing channel for fish at this size; additional fish production would exceed the established safety factor for the FI criteria.

The inland Chinook Salmon program uses adult broodstock that overlap between the spring- and fall-run populations; since these fish cannot be accurately assigned to a run, they are used for recreational fish allotments as opposed to conservation allotments. Approximately 172,000 eggs are collected in the first week of October. Eggs undergo triploid induction after fertilization and are transferred to the inland production area hatchery building where they are incubated in Heath stacks. In late December or early January, approximately 150,000 fish are transferred to eight fry tanks at 1,200 fpp (1.4 inches; Table 2-11). Fish are reared in the fry tanks until they reach approximately 300 to 400 fpp (2 to 2.2 inches long). Due to space limitations in early rearing, some fish may be transferred to the raceways in February prior to reaching 2 inches in length. Ultimately, approximately 132,605 fish are split between the two inland rearing raceways at the end of March.

Several different target stocking sizes were identified by the CDFW and DWR, ranging from 100 fpp to 4 fpp. Table 2-11 models the maximum production of fish at a target size of 4 fpp, which would be reached in October. In years where target stocking sizes are decreased, the total number of fish produced could be increased. Depending on stocking size preferences growth to the largest target size of 4 fpp. For this bioprogram, it is assumed that ideal conditions exist, and fish can be released as yearlings in October when they reach approximately 4 fpp (9.4 inches long). This bioprogram will result in approximately 125,000 fish stocked out but requires some manipulation by hatchery staff to alleviate rearing densities in the fry tanks in February.

Table 2-11. End of Month Production Information for the Inland Chinook Salmon Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Late Dec/ Early Jan	Fry Tanks	8	1,200	1.40	150,000	125.0	0.5	0.19	0.37
Jan	Fry Tanks	8	688	1.70	135,000	196.3	0.5	0.24	0.48
Feb	Fry Tanks	8	278	2.30	120,000	432.0	0.5	0.39[a]	0.78
Mar	Raceways	2	139	2.90	132,605	957.0	8.0	0.02	0.09
April	Raceways	2	67	3.70	129,553	1,941.8	8.0	0.03	0.15
May	Raceways	2	34.7	4.60	126,500	3,643.4	8.0	0.04	0.22
Jun	Raceways	2	19.2	5.60	125,500	6,521.6	8.0	0.06	0.32
Jul	Raceways	2	11.2	6.70	125,300	11,151.2	8.0	0.09	0.46
Aug	Raceways	2	6.9	7.90	125,200	18,265.5	8.0	0.13	0.64
Sep	Raceways	2	5.1	8.70	125,100	24,375.9	8.0	0.16	0.78
Oct	Raceways	2	4.1	9.40	125,000	30,721.2	8.0	0.18	0.91

[a] This is the maximum capacity of the fry tanks for fish at this size; additional fish production would exceed the established safety factor for the DI criteria. It is assumed that hatchery staff transfer fish to raceways to alleviate densities.

Steelhead production begins with spawning operations from mid-December to mid-February. Approximately 410,000 eggs are collected to complete the production modeled in this bioprogram. Eggs collected throughout the spawning operations move through the early rearing fry tanks like an assembly line. The bioprogram models the eggs collected from the first spawning dates as they move through the deep tanks. Approximately 100,000 fish are initially stocked into the deep tanks at 1,800 fpp (1.2 inches) in the beginning of March. At the end of March, 80,000 fish will be transferred into two raceways at approximately 800 fpp (1.5 inches). This coincides with fish from later spawn dates hatching and being transferred into the fry tanks in late March and throughout April. By the end of May, fish from all spawn dates will have been transferred to the raceways, and a total population of approximately 324,625 fish will be at an average size of 230 fpp (2.3 inches).

At the end of June, fish will reach approximately 150 fpp (2.7 inches) and be ready for marking operations to begin. As fish are marked, they are transferred to the rearing channel. Before this can occur, all fall-run Chinook Salmon held in the rearing channel must be released. Steelhead will remain in the rearing channel until the following January or February when they approach the target release size of 4 fpp (8.9 inches). This bioprogram models the production of approximately 265,000 steelhead smolts while maintaining the rearing criteria specified in Table 2-6. Annual operations at the facility produce approximately 450,000 smolts by exceeding the rearing criteria. Additionally, there is more flexibility in actual operations because fish are various sizes due to the wide spawning window; these nuances are not captured in this bioprogram.

Table 2-12. End of Month Production Information for the Steelhead Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Late Feb/ Early Mar	Fry Tank	4	1,800	1.2	100,000	55.6	0.4	0.19	0.29
Mar	Fry Tank	4	800	1.5	80,000	100.0	0.4	0.28[a]	0.42
Apr	Raceways	2	400	1.9	200,000	500.0	8.0	0.01	0.07
May	Raceways	2	230	2.3	324,625	1,411.4	8.0	0.02	0.17
Jun	Raceways	2	150	2.70	318,000	2,120.0	8.0	0.02	0.22
Jul	Rearing Channel	1	80	3.3	311,375	3,892.2	16.0	0.01	0.16
Aug	Rearing Channel	1	48.2	3.9	304,750	6,322.6	16.0	0.01	0.23
Sep	Rearing Channel	1	24.3	4.9	298,125	12,268.5	16.0	0.02	0.35
Oct	Rearing Channel	1	13.9	5.9	291,500	20,971.2	16.0	0.03	0.49
Nov	Rearing Channel	1	9.1	6.8	284,875	31,304.9	16.0	0.04	0.64
Dec	Rearing Channel	1	6.5	7.6	278,250	42,807.7	16.0	0.05	0.78

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Jan	Rearing Channel	1	5.0	8.3	271,625	54,325.0	16.0	0.05	0.91
Feb	Rearing Channel	1	4.0	8.9	265,000	66,250.0	16.0	0.06	1.04[b]

[a] This is the maximum capacity of the fry tanks for fish at this size; fish production in the fry tanks is balanced with fish constantly coming in and being transferred out to the raceways based on the spawning date.

[b] This is the maximum capacity of the rearing channel for steelhead at this size based on the FI safety factor.

The production schedule is controlled by the arrival of adult broodstock and the marking requirements for releases of these anadromous species. The occupancy of each production area (incubation, early rearing, raceways, and rearing channel) is depicted using different colored blocks in Figure 2-1. The water flow demand is expected to be highest in April and May of each year when the ladder is operating for next year's adult spring-run Chinook early arrivals (highlighted in red) and all production programs are underway. The lowest flow rate is expected in August of each year while the ladder is shut off and the only fish on station are the steelhead in the rearing channel. Nuances of weekly fish transfers to various production areas at the hatchery are not captured in Figure 2-1, but it provides a high-level view of the production cycle at the facility.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spring-Run Chinook Salmon																								
Eggs Recieved									■												■			
Egg Incubation									■	■	■										■	■	■	
Raceway Rearing	■	■	■	■	■	■						■	■	■	■	■	■	■						■
Fall-Run Chinook Salmon																								
Eggs Recieved										■	■											■	■	
Egg Incubation	■									■	■	■	■									■	■	■
Raceway Rearing	■	■	■	■	■	■	■						■	■	■	■	■	■	■					
Channel Rearing			■	■	■	■	■								■	■	■	■	■					
Inland Chinook Salmon																								
Eggs Recieved										■												■		
Egg Incubation										■	■	■										■	■	■
Early Rearing	■	■	■										■	■	■									
Inland Raceway Rearing			■	■	■										■	■	■							
Steelhead																								
Eggs Recieved	■	■										■	■	■										■
Egg Incubation	■	■	■									■	■	■	■									■
Early Rearing		■	■	■	■									■	■	■	■							
Raceway Rearing			■	■	■	■	■								■	■	■	■	■					
Channel Rearing	■	■					■	■	■	■	■	■	■	■					■	■	■	■	■	■
Fish Ladder																								
Operation (20 cfs)	■	■		■	■	■			■	■	■	■	■	■		■	■	■			■	■	■	■
Max. Flow Required (cfs)	69.6	68.9	64.9	76.4	72.4	64.0	56.0	16.0	36.3	36.9	37.6	45.3	69.6	68.9	64.9	76.4	72.4	64.0	56.0	16.0	36.3	36.9	37.6	45.3

Figure 2-1. Production Rearing Schedule Over 2 Years with Peak Water Demand Occurring Annually in April and May (as highlighted in the Max Flow Required row).

3.0 Climate Evaluation

3.1 Introduction

In this section, projections of air temperature conditions at the Feather River Hatchery are presented for the next 20 years (2024-2043) and the following 20 years (2044-2063) and will be compared against the reference period 1984-2003. These time horizons are referred to as the near-future period and the mid-century period, respectively. These projections inform the project team of potential needs for adaptive changes. Projections of air temperature extremes are included to inform of potentially hazardous working conditions.

3.2 Methodology for Projecting Air Temperature

This study uses future climatic and hydrologic projections based on global climate model (GCM) simulations associated with the data set known as CMIP5, which was part of the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2014). The projections in this report are based on results from 10 different global climate models under the Representative Concentration Pathway (RCP) RCP4.5 scenario of future greenhouse gas emissions, which represents a future with modest reductions in global emissions compared to current levels.

An ensemble of 10 global climate models (GCMs), listed in Table 3-1, is used for capturing a wide range of plausible climate projections. Since this project's future time horizon is limited to 40 years, the dominant source of uncertainty in climate projections is expected to be the natural variability of the earth's climate (and the variability present in every GCM model run), with the second major source of uncertainty being differences between GCMs. Using this ensemble will simultaneously address both uncertainty sources. The selection of 10 GCMs was based on tests of their ability to accurately simulate California climate, following the study of 35 CMIP5 models by (Krantz et al., 2021).

Table 3-1. List of Global Climate Models Used in This Study.

No.	GCM	Research Institution
1	ACCESS-1.0	CSIRO, Australia
2	CanESM2	Canadian Centre for Climate Modelling and Analysis, Canada
3	CCSM4	National Center for Atmospheric Research, United States
4	CESM1-BGC	National Science Foundation, Department of Energy, and National Center for Atmospheric Research, United States

No.	GCM	Research Institution
5	CMCC-CMS	Centro Euro Mediterraneo per Cambiamenti Climatici, Italy
6	CNRM-CM5	Centre National de Recherches Météorologiques / Centre Européen de Recherche et Formation Avancées en Calcul Scientifique, France/European Union
7	GFDL-CM3	NOAA Geophysical Fluid Dynamics Laboratory, United States
8	HadGEM2-CC	Met Office Hadley Centre, United Kingdom
9	HadGEM2-ES	Met Office Hadley Centre, United Kingdom
10	MIROC5	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies, Japan

The methodology used for obtaining projections of air temperature, which is summarized in Figure 3-1, was based on simulations by the 10 selected CMIP5 global climate models (GCMs). The GCM projections were statistically downscaled (using different methodologies) by a consortium of research institutions and made publicly available for all of California at a grid cell spatial resolution of 1/16° x 1/16° (about 5 km x 7 km) (Vano et al., 2020). In this report, the downscaling methodology named “Localized Constructed Analogs” (LOCA) is used. The choice of the LOCA data set was guided by its proven ability to represent extreme values of the downscaled climatic variables (important to this study) and because the hydrologic projections used for other California fish hatchery studies were based on the LOCA-downscaled climate projections. The difference between greenhouse gas emissions scenarios is small for a time horizon of 20 years; therefore, it is sufficient to use one greenhouse gas emissions scenario in this study, and the moderate scenario RCP4.5 is used.

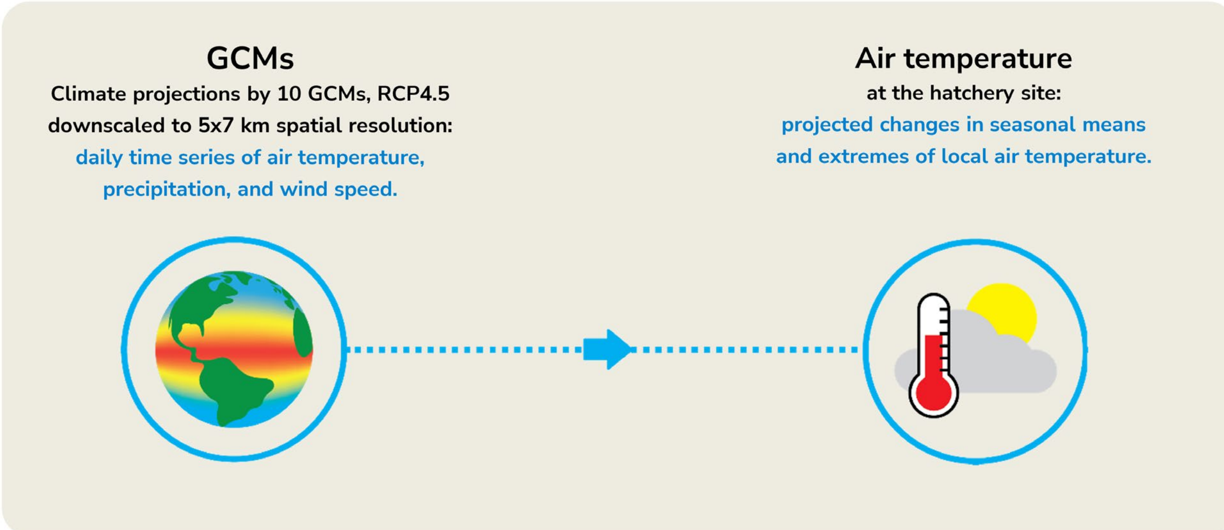

Figure 3-1. Methodology for Obtaining Air Temperature Projections.

3.3 Uncertainty and Limitations

It is important to acknowledge the large and unquantifiable uncertainty associated with these and any climate projections. The projections of air temperature presented here 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 air temperature over this hatchery area 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.

3.4 Projected Changes in Air Temperature at the Hatchery Site

Figure 3-2 displays the simulated mean daily air temperature (solid lines) and its range from minimum to maximum (shaded areas) for each day of the year, for the near-future time period (red) and the reference period (blue). All data are simulated by the ensemble of 10 GCMs for each time period. Higher peaks of daily temperature are seen for the near-future compared to the reference period, while the historical period has lower minima.

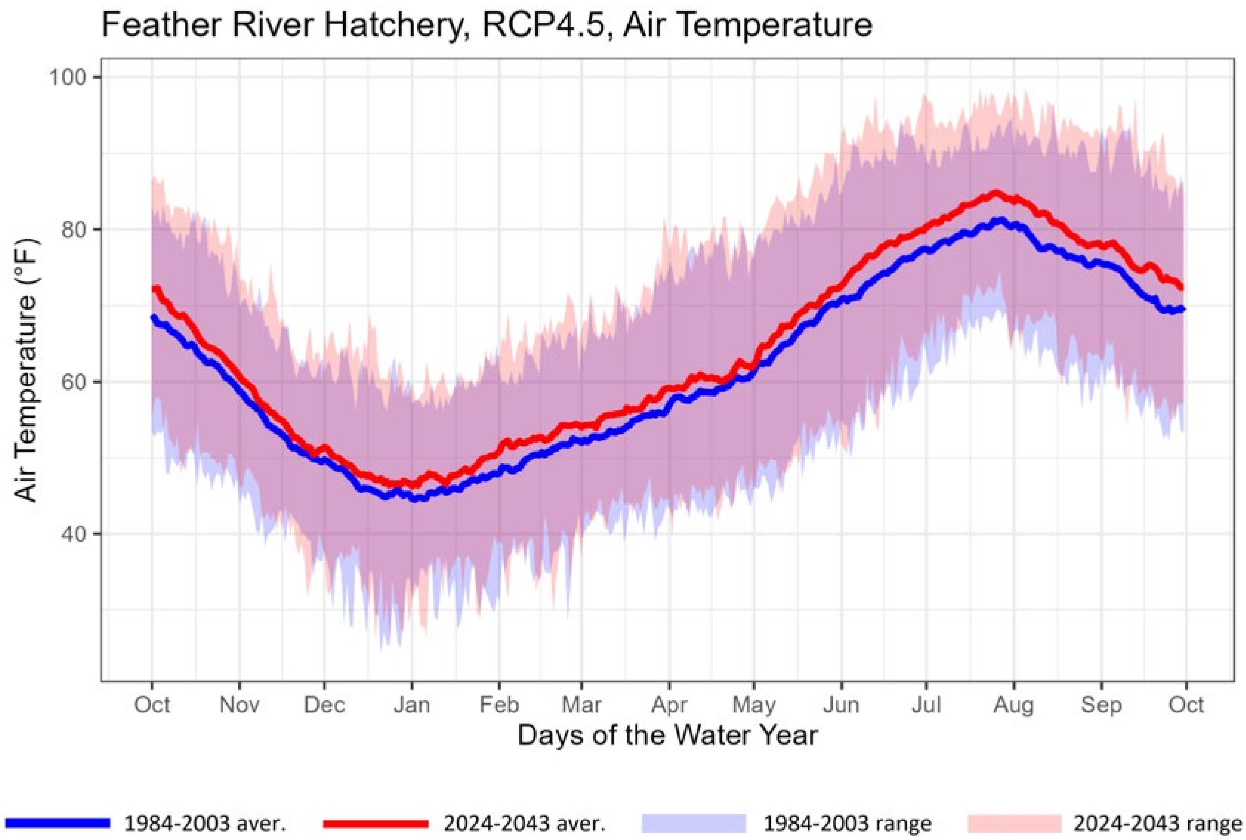

Figure 3-2. Mean Daily Air Temperature and Range for Each Day of the Water Year.

Table 3-2 and Table 3-3 list the projected mean seasonal air temperature for two future time periods, and the temperature change relative to the reference period. All time horizons, including the reference period, are simulated by the ensemble of 10 GCMs. The lowest and highest of the 10 GCM daily projections define the lower and upper limits of the shaded areas in Figure 3-2, and are given in Table 3-4 and Table 3-5.

Table 3-2. Projected GCM 2024-2043 Mean Seasonal Air Temperature at the Hatchery Site (change relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Ensemble mean	63.4°F (+2.4°F)	49.3°F (+2.0°F)	61.4°F (+1.9°F)	78.5°F (+3.3°F)	64.5°F (+2.5°F)
Lowest	63.0°F (+2.0°F)	48.6°F (+1.3°F)	60.8°F (+1.3°F)	77.2°F (+2.0°F)	63.3°F (+1.3°F)
Highest	63.9°F (+2.9°F)	49.9°F (+2.6°F)	62.6°F (+3.1°F)	79.5°F (+4.3°F)	65.4°F (+3.4°F)

Table 3-3. Projected GCM 2044-2063 Mean Seasonal Air Temperature at the Hatchery Site (change relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Ensemble mean	64.5°F (+3.5°F)	50.3°F (+3.0°F)	62.7°F (+3.2°F)	79.8°F (+4.6°F)	65.4°F (+3.4°F)
Lowest	63.9°F (+2.9°F)	49.4°F (+2.1°F)	62.0°F (+2.5°F)	78.3°F (+3.1°F)	63.9°F (+1.9°F)
Highest	65.3°F (+4.3°F)	51.2°F (+3.9°F)	63.6°F (+4.1°F)	81.3°F (+6.1°F)	66.5°F (+4.5°F)

Table 3-4 and Table 3-5 list the projected percentiles of highest air temperature in each day (T_{max}) for two future time periods, relative to the reference period. All time horizons, including the reference period, are simulated by the ensemble of 10 GCMs.

Table 3-4. Projected GCM 2024-2043 Percentiles of Highest Air Temperature in Each Day (T_{max}) at the Hatchery Site (change relative to 1984-2003).

GCM	3rd percentile	25th percentile	50th percentile	75th percentile	97th percentile
Ensemble mean	50.8°F (+1.8°F)	62.8°F (+1.8°F)	76.2°F (+2.1°F)	92.0°F (+3.0°F)	104.6°F (+3.5°F)
Lowest	50.2°F (+1.2°F)	62.4°F (+1.4°F)	75.6°F (+1.5°F)	91.5°F (+2.5°F)	103.3°F (+2.2°F)
Highest	51.8°F (+2.8°F)	63.3°F (+2.3°F)	76.7°F (+2.6°F)	92.9°F (+3.9°F)	106.3°F (+5.2°F)

Table 3-5. Projected GCM 2044-2063 Percentiles of Highest Air Temperature in Each Day (T_{max}) at the Hatchery Site (change relative to 1984-2003).

GCM	3rd percentile	25th percentile	50th percentile	75th percentile	97th percentile
Ensemble mean	51.7°F (+2.7°F)	63.9°F (+2.9°F)	77.5°F (+3.4°F)	93.3°F (+4.3°F)	105.6°F (+4.5°F)
Lowest	50.6°F (+1.6°F)	63.3°F (+2.3°F)	76.9°F (+2.8°F)	92.0°F (+3.0°F)	104.0°F (+2.9°F)
Highest	52.7°F (+3.7°F)	64.5°F (+3.5°F)	78.0°F (+3.9°F)	94.7°F (+5.7°F)	106.7°F (+5.6°F)

At the hatchery site, mean annual air temperature is projected to rise by 2.4°F in the near future period compared to the reference period (1984-2003), and by an additional 1.1°F in the mid-century period. The season with the most warming is the summer (Table 3-2, Table 3-3, and Figure 3-2) and the highest temperature rises are projected to occur in the hottest days (Table 3-4 and Table 3-5). Days with maximum daytime temperatures representing the 75^{th} percentile (i.e., the upper quartile of temperatures) are projected to warm by 3.0°F in the next 20 years, relative to the reference period. The 97^{th} percentile of the daytime maximum temperature is projected to rise by even more, 3.5°F, reaching 104.6°F. These projected temperatures represent potentially hazardous outdoor working conditions at the hatchery.

3.5 Fire Risk

Historical wildfires have been documented both in the immediate vicinity of the hatchery and less frequently within the watershed perimeter, as mapped in Figure 3-3. Most of the watershed area has not burned within the past century and therefore has relatively large amounts of fuel stores. The lack of fire is anomalous in the region, with adjacent basin areas of similar size having experienced large fires since 2010 (Figure 3-3). Vegetated land cover transitions from grasslands near the hatchery to mostly forested in the uplands, with anticipated fuel recovery rates ranging from 2 to 5 years in grasslands to more than 10 years in the uplands (depending on the type).

Expressing wildfire risk as a percent chance of occurring at least once in a decade (Westerling, 2018), the projected wildfire risk at the hatchery site is approximately 10% through mid-century (Figure 3-3). Across the uplands, the projected fire risk is higher, with local zones increasing to 60% towards the end of this century.

The primary risks to the hatchery operations include infrastructure impacts from local fires, as well as reservoir impacts from fires in the upper basin. Because the hatchery relies on intake from the diversion dam, the hatchery is shielded from most flooding and debris that can impact hatcheries along running rivers, except for catastrophic dam failure events. Wildfires can impact reservoirs by increasing runoff and turbidity along burn scars. Watersheds are most sensitive to flooding and suspended sediment impacts in the first five to ten years after the fire, or the time it takes for new vegetation to mature. Turbidity was not listed as an existing maintenance concern. Therefore, the largest potential risks are fire-related infrastructure hazards to the hatchery itself.

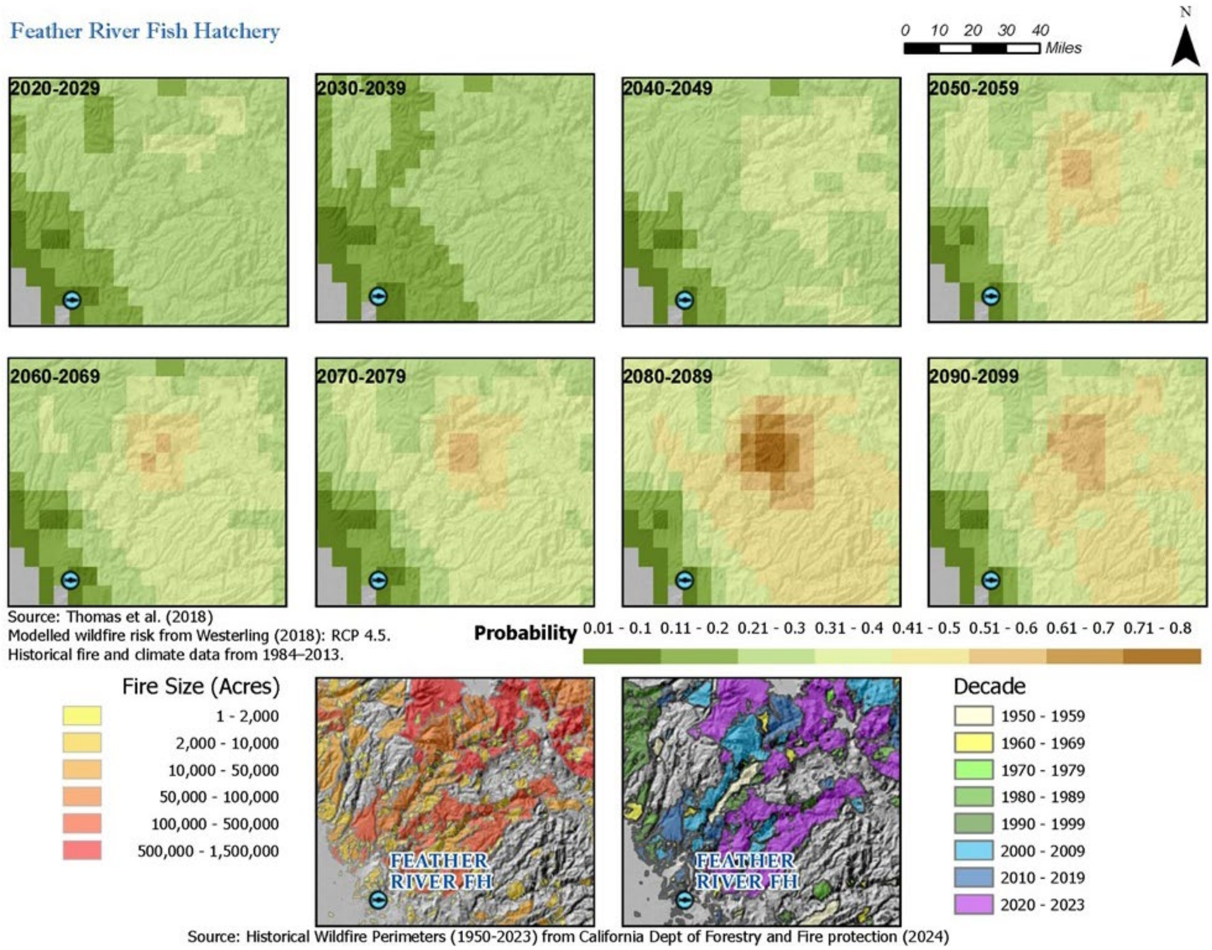

Figure 3-3. Wildfire Risk as Probability of Future Occurrence and Known Historical Fire.

3.6 Conclusions

The climate change evaluation for the Feather River Hatchery was restricted to air temperature projections given instructions by CDFW that streamflow or water temperature evaluations were not requested for this hatchery. DWR's future FERC license provisions would require DWR to provide water to the FRH at temperatures that are lower than the current water temperatures. The following are the water temperatures (these are Maximum Mean Daily Temps) expected to be required in the future FERC license:

- September 1-September 30: 56°F
- October 1 – May 31: 55°F
- June 1 – August 31: 60°F

The projected increases in seasonal means and extremes of air temperature are among the highest of all California hatcheries studied. Mean annual air temperature is projected to rise by

2.4°F in the next 20 years (2024-2043) and by an additional 1.1°F in the mid-century period (2044-2063), compared to the reference period (1984-2003). The summer will experience the most warming, and the largest temperature increases are projected to occur on the hottest days.

The distribution of daily air temperatures will change, and the upper end of this distribution is of most interest. Therefore, we looked at changes in the 75th and 97th percentiles of the daily temperature distribution and found that the 75th percentile will increase by 3.0°F and the 97th percentile will increase by 3.5°F in the next 20 years, relative to the reference period.

According to gridded air temperatures for the reference period 1984-2003, the 75th and 97th percentiles of peak daytime temperature (i.e., the temperature at the hottest time of day) were 89.0°F and 101.1°F. For the near-future period (2024-2043), these percentiles are projected to rise to 92.0°F and 104.6°F, respectively. Such an increase in the peak air daytime temperature requires adaptation measures for protection of hatchery workers against heat stroke and other health effects of heat exposure. Roads and roofs may also need to be replaced using more heat-resistant and reflective materials.

The hatchery is at moderate to high risk of wildfires. The projected chance of at least one wildfire occurring in a 10-year period at the hatchery site is estimated as 10% through mid-century. There is a history of fire both within the immediate vicinity of the hatchery, as well as frequent moderate to large fires in the watershed. Post-fire conditions also pose risks to the hatchery, including scar-induced flooding, turbidity, and debris.

4.0 Existing Infrastructure Deficiencies

The Feather River Hatchery is currently able to produce fish production goals to maintain its mitigation requirements. However, multiple deficiencies were identified during the site visit and are described in Section 4 of the Site Visit Report (Appendix A) that could limit the FRH's ability to maintain fish production under the pressure of climate change impacts. Section 5.4 of the Site Visit Report identified potential technologies and solutions available to address specific deficiencies that would allow the hatchery to provide protection against climate change and to better meet the production goals that are in addition to the mitigation goals for the facility. The main areas of concern for the hatchery included insufficient rearing space for the inland Chinook Salmon program, improper grading for the inland program's hatchery building affecting its water supply, and operational challenges associated with the rearing channel. Biosecurity deficiencies and potential solutions for addressing these concerns were identified in Sections 3.0 and 3.2 of the Site Visit Report, respectively. The details of these deficiencies are further expanded upon in Sections 4.1 and 4.2.

4.1 Water Process Infrastructure

The water process infrastructure at the Feather River Hatchery is in relatively good condition. The DWR performs regular maintenance every 5 to 10 years; historically during these maintenance periods, production was shifted to the Feather River Annex. There are no specific plans on how to approach the maintenance requirements now that the Feather River Annex is inoperable. A minor issue identified during the site visit was the repair or replacement of several shade-boards in the aeration tower. There is a scheduled improvement for the ultraviolet (UV) disinfection system for the inland production area; a new UV system has replaced the old system and increased treatment capacity to 16 cfs of water flow. The disinfected water can be diverted to the inland production area, or two production raceways used for anadromous fish. Other potential water process upgrades could include the oxygenation of water at the aeration tower. Currently, floating aerators are installed in raceways when densities and water temperatures increase; oxygenation of the water supply would reduce the need for this equipment and improve the rearing environment for fish.

4.1.1 Water Quality

In recent years, the water quality characteristics of the hatchery's source water have changed. This has led to slightly decreased water conductivity (from approximately 115 µs/cm in 2017 to approximately 85 µs/cm presently); timing correlates to issues with the spillway at the Oroville Dam upstream, but exact reasons for the change are unknown. Additionally, the dissolved oxygen levels have decreased slightly in 2023, from 11 mg/L at the aeration structure to 9 mg/L; the cause is unknown and has not resulted in any measurable differences in fish culture success to date.

4.2 Rearing Infrastructure

4.2.1 Inland Chinook Salmon Area

4.2.1.1 Hatchery Building

As constructed, the inland hatchery building sits approximately 2 feet above the grade specified in designs. This results in a loss of head pressure, which requires several operational changes by staff and limits the efficiency of this program. Fry tanks inside the building sit on the floor, leaving them more susceptible to damage and making the area more difficult to clean. The limited head pressure also requires staff to incubate eggs in Heath trays instead of upwelling jars, and air bubbles in the supply line have caused large egg mortality events when upwelling jars were used initially. The drain troughs inside the hatchery building are also undersized, staff cannot remove more than one standpipe before they overflow, flooding the floor of the building. Frequent flooding could cause other issues with electrical or structural systems, and limited tank flushing increases the time it takes for hatchery staff to clean tanks.

4.2.1.2 Raceways

As identified in the Site Visit Report, the rearing space in the inland production area is not sufficient to produce fish at the desired release size. In the past, inland Chinook were transferred to the Feather River Annex to finish grow-out, but since that facility is inoperable fish must be released in April before they reach the target size of 3 fpp (10.4 inches). The intake structure for the Feather River Hatchery can supply more water than is currently used for rearing, but water conveyance infrastructure would have to be upgraded, particularly for the inland production area. There is enough space on the property to expand the inland production area, allowing the hatchery to release fish at the desired size.

4.2.2 Rearing Channel

The rearing channel is a unique production space; originally constructed as a rock and earth bed natural spawning area, it was eventually covered with concrete and turned into a more traditional rearing area. This provides a significant amount of rearing space, approximately 120,000 ft^3, letting staff lower densities in the production raceways and accept more supplemental production goals. However, because the rearing channel was not originally designed for intensive fish culture, it can be difficult to work with. Access points are limited, and its curvature and size make it difficult to clean when in use. Additionally, because the rearing volume is so large, fish can be held at low densities, but the entire channel is limited by the available flow of 16 cfs. Retrofitting plumbing to allow for more water to discharge at the midway point of the channel would allow for increased production in the same space, maximizing efficiency. Alternatively, oxygenation could be included to supplement the rearing channel and allow for increased rearing densities without increases in flows.

5.0 Alternative Selected

5.1 Alternative Description

During the site visit and through meetings with hatchery staff, several deficiencies were identified that could be improved to meet production goals above and beyond mitigation. These deficiencies have been summarized in Section 4.0 of this report. Appendix E – Alternatives Development Technical Memorandum (TM) provides a discussion of alternative technologies that may be used to address the existing deficiencies and potentially expand production, improve biosecurity, and increase operational efficiencies. The following section presents a summary of the preferred alternatives to be further evaluated in a Comprehensive Facility Assessment that would be conducted by DWR, in collaboration with CDFW, under a new FERC license. These recommendations are for upgrades that would best utilize the alternative technologies to respond to the existing deficiencies, maximize fish production, and respond to the climate change projections described in Section 3.0. The conceptual layout of the alternative described below is shown in Appendix C.

5.1.1 Upgraded Water Treatment Systems

For the proposed upgrades in this report, water treatment systems are recommended for further evaluation at several points of use at the facility: the hatchery building, production raceways, and inland salmon program area. This was chosen because of the limited space throughout the existing hatchery's rearing infrastructure and the small amount of available head pressure for the water supply. However, DWR and CDFW are working together to evaluate potential water supply treatment alternatives, one of which is consolidating all treatment processes into a single location that would serve the entire hatchery.

5.1.1.1 Filtration

A course filtration screen is proposed for the facility's intake at the Thermalito Diversion Dam to prevent large debris and aquatic organisms from entering the hatchery system. Pressurized sand filtration is also proposed at the facility to provide clean water during high run-off events (reducing turbidity and sediment accumulation in rearing areas) and to maintain ultraviolet (UV) transmittance for disinfection systems. Filtered water would be supplied to the hatchery building with one 9-foot-diameter sand filter located near the existing aeration tower capable of processing up to 2.8 cfs of water flow. Filtration for the production raceways and the inland program area would be located north of the raceways (see Appendix C, FIG-1). The pressurized sand filtration proposed for the raceways will treat a total of 40 cfs and consist of twelve 10-foot-diameter sand filters (4 modules with 3 filters each). The inland salmon area would require six 10-foot-diameter sand filters (2 modules with 3 filters each).

Pumping would be required for the pressurized sand filtration; currently a 25 hp pump is called out for each filter in the estimate. This sizing is conservative; less pumping would be needed if a lower pressure differential is acceptable at the filters with more frequent flushing. This is feasible with the excess water the facility has available. Having pumps for the water supply in general is not ideal as CDFW would like to avoid pumping if they could. If the facility is selected for improvements, additional value engineering will be done for both the filtration method and water supply.

5.1.1.2 Disinfection

Both UV and ozone disinfection were considered for the hatchery's water treatment systems. After further discussion with CDFW and DWR, only a UV disinfection system is included in the proposed alternatives in this report.

Hatchery Building

Upgraded water treatment systems include upgrading the hatchery building with a larger UV disinfection system capable of treating the entire water demand of the building. Once the hatchery building's water supply is filtered per Section 5.1.1.1, it would be routed through an inline UV disinfection system. The UV system would be intended to treat for *Saprolegnia* spp., which has a recommended treatment dose ranging from 40 to 170 mJ/cm^2. A disinfection dose of 126 mJ/cm^2 was selected because it is effective against *Flavobacterium psychrophilum* (another common salmonid pathogen) and reduces operational costs relative to a 170 mJ/cm^2 dose. Prior to advanced designs, more comprehensive water quality testing is recommended to ensure that a dose of 170 mJ/cm^2 is not required for effective treatment. The UV system would be designed to accommodate up to 3 cfs of water flow at a dosage of 126 mJ/cm^2.

Raceways

Disinfection for the production raceways will be located north of the raceways and downstream of the raceway pressurized sand filtration (see Appendix C, Figure 1). Eight inline UV units will be housed in a PEMB with adequate space for the UV units, clearance for UV lamp replacement, and control panels and other appurtenances. The designed UV dose would be 126 mJ/cm^2 for 5 cfs of water flow per unit, providing a total UV treatment capacity of 40 cfs for the raceways.

5.1.1.3 Oxygenation

Recently, other CDFW hatcheries with water supplies connected to hydropower reservoirs have experienced sudden low dissolved oxygen levels. The direct causes of these changes are not well understood, but it is possible that climate change impacts within watersheds have significant effects. As climate impacts continue to alter watersheds throughout California in new ways, oxygenation equipment is proposed to ensure optimal water quality for fish rearing at the Feather River Hatchery.

As part of the piping modifications for the hatchery's water treatment system, a supersaturation oxygen loop is proposed. A side stream of incoming water will be routed through a Speece cone injected with pure oxygen. The oxygenated water will be directed back into the aeration tower chambers where it will be conveyed to the various production areas.

The oxygenation system would be designed to operate seasonally as required when fish densities or water temperatures are elevated, or if the source water becomes oxygen deficient due to environmental or anthropogenic effects on the watershed. Advanced designs would include the ability to adjust flow of supersaturated water to the desired rearing areas to achieve ideal dissolved oxygen levels at the point of use. This would be achieved through dissolved oxygen probes throughout the facility and associated controls and monitoring equipment.

For this report, it is assumed that oxygen will be generated on site. In future design phases, bulk liquid oxygen (LOX) storage and delivery will be evaluated and compared to oxygen generation on a feasibility and cost-benefit basis.

5.1.2 Aeration Tower Upgrades

Currently, weir boards are used to determine the total pool level in each rearing area's chamber in the aeration tower. Actual flow rates are adjusted at the point-of-use valves for raceways, tanks, etc. The inland Chinook Salmon production area and the production raceway area share a common chamber, with two separate valves controlling flow to each area. Adding additional weir boards to the production raceway chamber would increase the water pool depth and potentially resolve water pressure issues at the inland Chinook Salmon hatchery building. Further investigation of the potential effects this may have on available water flow to other rearing areas (hatchery building, rearing channel, adult facilities) is required before this approach can be determined as feasible. An additional alternative to resolve the head pressure issues at the inland Chinook Salmon production area is included in Section 5.1.4.1.

The aeration tower is in relatively good condition but requires some maintenance for optimal operation. The louvers, which act as shade slates, should be replaced to reduce the solar effects resulting in the undesirable heating of the water. Additionally, performing preventative maintenance on this structure will extend the life of this system. Protecting the concrete of the aeration tower with skim coating and epoxy paint or other products will reduce deterioration over time, and routine maintenance or replacement of valving in this structure will provide greater reliability and longevity of this system.

5.1.3 Replace Deteriorated Valves and Piping throughout the Hatchery

Various valves and pipes across the hatchery have aged and deteriorated over time. Inoperable valves and deteriorated piping increase risk to the hatchery operations and limit hatchery staff from adjusting flows to meet the flow requirements for the fish. Leaking valves results in water loss that could be directed towards fish production. The preferred alternative is to inspect valves and pipes throughout the hatchery and to replace infrastructure that is leaking, not operable, heavily aged/worn, or likely to fail in the near future. Replacing the valves and pipes would allow for better flow control and would allow for the hatchery to continue operating into the future.

5.1.4 Inland Salmon Program Upgrades

5.1.4.1 Modifications of Existing Inland Hatchery Building

The inland hatchery building was constructed two feet above the designed grade resulting in head loss and water flow issues for incubation and early rearing in the deep tanks. The preferred alternative is to install inline booster pumps to provide the necessary head pressure for normal operations. Additionally, it is proposed that the existing floor trench drains inside the hatchery building are expanded. This will allow for more efficient cleaning operations for fish culturists and prevent flooding of the building.

5.1.4.2 Construct Additional Inland Chinook Salmon Raceway

The preferred alternative is to add two additional raceways north of the existing raceways to provide the necessary space for inland Chinook Salmon production up to 3 fpp (10.4 inches). The facility currently operates two raceways for the inland Chinook Salmon program which do not provide the space or flow to meet the desired production for this program. The two existing raceways are 300 feet long, 10-feet wide with an operating water depth of 3 feet for a combined rearing volume of 18,000 ft^3. By adding another pair of raceways, the rearing volume is doubled to 36,000 ft^3. In previous years, final grow-out of the inland Chinook Salmon to a size of 3 fpp would occur at the Feather River Annex. The proposed pair of raceways would allow for all production to occur at the main Feather River Hatchery.

It is recommended that the existing inland program raceway is more closely evaluated and repaired by resurfacing the concrete, repairing expansion joints, and coating with an epoxy or polyurethane product to extend the usable life. Solid roof structures are proposed to cover both the existing and new pair of inland program raceways. The structures would include fencing and netting to improve predator exclusion and provide a more protected environment for both fish and staff as air temperatures are forecasted to increase. The roof structure would be designed to support a photovoltaic system to help offset energy costs for hatchery operations.

5.1.5 Production Raceway Upgrades

5.1.5.1 Concrete Refurbishment for Outdoor Rearing Areas

The concrete in the raceways is showing signs of aging after 40 years of service. The underlying aggregate in the floor and walls of the raceways is exposed due to wear which creates an abrasive surface that can be harmful to fish as well as a surface that promotes algae growth. The rough aggregate is difficult for hatchery staff to clean efficiently. Adding a skim coating to the concrete can help alleviate the present issues and reduce the rate at which the concrete surface deteriorates. Resurfacing of the raceways can add 5-15 additional years of service before additional maintenance is required; Appendix E explains raceway resurfacing approaches, processes, and considerations in more detail.

5.1.5.2 Add a Roof Structure to the Raceways

Covering the raceways with a roof eliminates direct sunlight and reduces the rate at which the water in the raceways warms, provides protection from avian predation, reduces risk of sunburn on the fish, and allows for a structure that is more easily enclosed to reduce predation.

5.1.6 Pilot Circular Tank Partial Recirculating Aquaculture System

Three partial recirculating aquaculture systems (PRASs) with circular tanks are proposed to provide additional rearing infrastructure to support future shifts towards reuse systems. This system would significantly reduce water use associated with fish production, therefore requiring less incoming water to be treated. As climate change impacts continue to worsen, it is possible that water temperatures in the Feather River could rise to unsafe levels in the next 30+ years. Incorporating an advanced circular tank PRAS will ensure that the hatchery has the familiarity and expertise of culturing anadromous fish in these cutting-edge systems.

The PRASs would also provide additional rearing space if the rearing channel or raceways require extended maintenance due to normal aging and wear. The sizing of the PRAS is based on the capacity for each species identified in Table 2-2 through Table 2-5 and a conservative DI of 0.2. The new circular tank system may be constructed on the far west side of the facility to allow for continued use of the rearing channel during construction. Tanks and equipment would be covered with a solid roof structure and surrounded with predator exclusion measures to maintain biosecurity. The PRAS equipment would include sumps, pumps, filtration, UV disinfection, and oxygenation. The system would also include chillers to maintain optimal water temperatures during the summer (steelhead) and fall (egg incubation) when ambient water temperatures may be elevated.

To maintain the rearing criteria for the desired capacity, 24 circular tanks are proposed, each 20 feet in diameter with a wall height of 7 feet and a water depth of 6 feet. This provides approximately 1,885 ft^3 of rearing volume per tank, or 45,240 ft^3 for the entire PRAS. Based on recommendations from Timmons et al. (2018), the flow rate for each tank should provide a hydraulic residence time (HRT) of no more than 45 minutes. That is, it should take less than 45 minutes for the water to completely be exchanged in the tank. This requires a process flow rate of approximately 325 gpm per tank, or 7,800 gpm (17.4 cfs) for the entire system.

The PRAS would be set up in three separate modules, each with eight tanks. Each module will require a process flow of approximately 2,600 gpm (5.8 cfs). Each module will have its own sump, pumps, filtration, UV disinfection system, chiller, and oxygenation system. For this report, oxygen is assumed to be sourced from on-site oxygen generation as opposed to bulk liquid oxygen (LOX) deliveries. During advanced design phases, LOX availability will be evaluated and compared to oxygen generation in a cost-benefit analysis.

It is recommended that operations begin with a recirculation rate of 50%; once staff are familiar with the equipment and operations of the PRAS, recirculation rates can increase to 75% without requiring a biofilter. The PRAS equipment will be sized to treat and recondition up to 1,950 gpm (4.3 cfs), while operating at a recirculation rate of 75%. The fresh make-up flow requirement (25% of process flow) will be 650 gpm for each module, or 1,950 gpm (4.3 cfs) for the entire PRAS.

5.1.7 Power Upgrades

5.1.7.1 Emergency Generator

It is important to ensure that backup power generators are appropriately sized to accommodate the permanent reuse equipment, and any other additional technology proposed. New propane-fed backup power generators would be installed to maintain production operations during periods of power outages. The generators would be chosen to meet current air quality standards required for this area and sized to meet the power needs of the hatchery during temporary outages. Standby emergency generators will be included to service all the proposed equipment. This includes the UV systems, pumps, and PRAS equipment.

5.1.7.2 Solar Panels

Any new structures proposed would be designed to support solar arrays. Supplemental solar power generation will help offset the power requirements of new equipment and provide operational resiliency as climate change continues to impact the California DWR's power generation systems.

5.2 Pros/Cons of Selected Alternative

Table 5-1 provides a high-level summary of the pros and cons for Feather River Hatchery's selected alternative.

Table 5-1. Pros/Cons of Selected Alternative - Feather River Hatchery.

Description	Pros	Cons
Repair aeration tower louvers.	• Reduces heating of water and provides some protection to the infrastructure.	• Increases capital cost.
Install an oxygenation system.	• Provides optimal fish rearing conditions. • Produces healthier fish in an improved rearing environment.	• Increases cost due to installation and continued cost for oxygen supply. • Increases complexity of operations.
Add filtration for raceways, hatchery building incubation, and inland program.	• Reduces negative impacts associated with increased turbidity.	• Increases capital cost. • Requires a significant footprint. • Requires pumping to maintain water pressure and flow rates.
Install UV disinfection for raceways, hatchery building incubation, and proposed RAS modules/Improve UV disinfection for inland program.	• Reduces pathogen abundance in water supply. • Increases fish survival.	• Increases cost due to installation and operation. • Increases maintenance.
Add booster pump for inland hatchery building.	• Provides appropriate flow to incubation and early rearing tanks. • Does not require reconstruction of existing building.	• Increases capital and operating costs. • Relies on the pump to maintain appropriate flows.

Description	Pros	Cons
Replace deteriorated valves and piping.	• Improves functionality and flow control. • Increases hatchery infrastructure lifespan.	• Increases capital cost. • Disrupts hatchery operations during construction.
Refurbish raceways.	• Is a low-cost solution. • Increases abrasion resistance. • Minimizes algae buildup. • Improves cleaning efficiency. • Extends the life of the infrastructure.	• Increases capital cost • Has a limited life span for skim coat (10-20 years). Correct application is critical to achieve this life span.
Add initial PRASs.	• Reduces total water required per fish produced and increases flexibility. • Improves water quality within rearing vessels. • Provides alternative to aging infrastructure. • Improves flow control.	• Increases cost due to installation and operation. • Requires additional training for staff.

5.3 Alternatives for Short-Term Improvements

In the event that funding is not available to construct the preferred alternative, the following short-term improvements are recommended for continued hatchery operation.

5.3.1 Water Treatment Upgrades

The recommended short-term improvements for the facility include some components of the preferred upgrades. A Speece cone near the aeration tower is included to maintain oxygen levels for rearing areas throughout the hatchery. Sand filtration is proposed for the hatchery building's water supply to provide the most sensitive life stages of fish high-quality water even during periods with increased turbidity.

Aeration tower improvements are also suggested as a short-term improvement, explained above in Section 5.1.2. A booster pump to provide the correct amount of water pressure to the inland program area is also proposed as a short-term improvement.

5.3.2 Add a Roof Structure to the Raceways

Covering the raceways with a roof eliminates direct sunlight and reduces the rate at which the water in the raceways warms, provides protection from avian predation, reduces risk of sunburn on the fish, and allows for a structure that is more easily enclosed to reduce predation.

5.3.3 Resurface Concrete Rearing Areas

Both the raceways and rearing channel would be resurfaced with an epoxy or similar coating to extend the life of the concrete. This work would include the cleaning and preparation of existing raceways, and skim coating or patching of any heavily damaged concrete surfaces. Multiple products would be considered based on McMillen and CDFW’s recent experience with fish-safe concrete coating systems.

5.3.4 Rearing Channel Upgrades

Access to the rearing channel is limited for staff performing daily fish culture tasks. There are limited walkways along the 2,000-foot-long rearing channel. Additional grating and handrails are proposed to provide more access points for staff along the rearing channel. This will allow them to perform routine fish culture in a safe and efficient manner. As part of these upgrades, it is recommended that the existing predator exclusion framework is completely replaced.

5.3.5 Add a Drain from the Sump Vault Directly to Effluent Ponds

The sump vault requires pumping of hatchery building effluent to move it to the percolating ponds. Modifying this structure by rerouting the hatchery building discharge pipe directly to the percolating ponds eliminates the reliance on pumping water from the sump. Alterations would still allow for the direct release of water from the hatchery building to the Feather River. This is allowed in the facility’s NDPES permit and would only be used in the event of an emergency.

5.4 Natural Environment Impacts

5.4.1 Fire and Flood Risk

The recommended changes to the Feather River Hatchery will change the existing infrastructure and the number of rigid structures on site. However, they are not expected to impact fire risk at the facility.

The recommended changes will slightly increase the total impervious surface area of the facility, but this is not expected to significantly affect the flood risk of the facility. Flood risk is related to the operation of dams along the Feather River, with the only recent example of potential flood stemming from the Oroville Dam spillway failure in 2017. Apart from 2017, hatchery staff did not indicate that flooding was a major concern for the facility. Additional structures as part of the proposed upgrades would be graded to carry water away from the facility towards designated stormwater collection points. Replacing worn valving and piping throughout the facility will help hatchery staff manage flows and avoid flooding of any rearing vessels. Upgrades to the inland hatchery building will resolve head issues and provide adequately sized drainage to avoid flooding the building during fish culture activities.

5.4.2 Effluent Discharge

The recommended changes to the hatchery do not include an overall increase in production outside of annual changes in production goals that are the result of coordination and consensus among multiple agencies. The proposed changes are not anticipated to trigger a change to the NPDES permit; however, other processes outside the scope of this report may require additional compliance efforts. The recommended alternatives will connect existing effluent infrastructure but will not add additional discharge points for the hatchery. Additionally, treatment of incoming water through filtration, disinfection, and oxygenation will result in an increase in the quality of water being discharged from the facility. No changes to the existing effluent percolation ponds were suggested because they are operating as intended and maintain compliance with the facility’s NPDES requirements.

It is important to note that changes to existing aquaculture programs (renovations, new construction) may trigger (administratively) the requirement for new and/or updated NPDES permits. Acknowledging even a modest increase in waste load (fish biomass) due to increased rearing flexibility provided by the proposed alternatives, we assume that the increase in effluent removal efficiencies provided by the PRAS systems will result in net effluent “gains” to the overall aquaculture program.

5.5 Hatchery Operational Impacts/Husbandry

Outside of variances associated with the natural environment and behavior of adult anadromous fish, there will be no changes to the production schedule for the Feather River Hatchery. Spawning and incubation procedures will be unchanged for all anadromous species raised at the hatchery.

The proposed upgrades for inland Chinook production will allow for hatchery staff to use upwelling jars for egg incubation, instead of Heath stacks. Additionally, early rearing of the inland Chinook can be conducted as normal; the upsized drainage system in the hatchery building will allow for multiple tanks to be drained simultaneously. The proposed addition of two more raceways also allows for hatchery staff to raise the fish allotment to the target size of 3 fpp.

The proposed pilot circular tank system will change the day-to-day operations of the facility. The system may be used for either steelhead or Chinook Salmon and will allow for significantly reduced water use to produce a similar number of fish relative to the water demand and fish production of the raceways or rearing channel. The Feather River Hatchery staff may choose to use it as grow-out for steelhead or Chinook Salmon after fish have been marked or tagged. The circular tank system would be located near the western end of the rearing channel; fish could transfer from the channel to individual circular tanks relatively easily with an appropriately sized fish pump. However, the circular tanks would be located more than 500 feet away from the nearest production raceways. Pumping fish these distances would require considerable amounts of hose and the space to store it. It is more feasible to pump the fish into a fish transfer tank equipped with an oxygen system and off-load them directly (via gravity) into the final rearing tanks which will be recessed into the ground. Once the fish are in the final rearing PRAS circular tanks, the fish will be grown to their target release size at which time they may maximize the capacity of the system. Truck loading for fish release will basically continue as the hatchery has operated in the past utilizing fish pumps and dewatering towers with a few minor adjustments unique to circular tanks relative to traditional raceways.

5.5.1 PRAS Circular Tank Operations

The pilot circular PRAS system will operate by reusing up to 75% of the water flow. The hydraulic self-cleaning characteristics of the circular tanks will reduce labor associated with tank cleaning. Additional tank sweeper systems are also available and can further reduce staff labor associated with maintaining tank hygiene. Staff time will be required for monitoring PRAS components including routine water quality checks, flow adjustments, and monitoring LHO and CO_2 systems to ensure a high-quality rearing environment. Seine nets, clamshell crowders or other crowder types can be used to concentrate fish for collection and handling.

Transfer of fish between tanks and for truck loading will utilize fish pumps and hosing to minimize handling and stress on the fish and decrease physical labor for staff transferring fish between tanks or loading trucks. For transferring fish into other rearing tanks requiring enumeration, a fish counter can be included at the receiving tank to obtain an accurate inventory of the fish. For fish being loaded onto a transport tanker for stocking, a dewatering tower will allow for the removal of the water through a screen prior to the fish entering the fish transport tanker. This is consistent with current CDFW hatchery practices as well as industry standards and practices and allows the hatchery to quantify fish biomass based on water displacement in the fish transport tanker. The return of the water from the dewatering tower to the PRAS module sump will be necessary to maintain the water balance within the PRAS module. Another option is to temporarily increase the fresh make-up water flow to compensate for this water loss in the module during the fish pumping process.

5.5.2 PRAS Equipment

The PRAS provides tremendous benefits in reducing the water flow requirements to produce large numbers/biomass of fish while maximizing water quality. However, these systems are more complex and require additional skillsets to monitor and maintain the equipment to ensure reliable system operations for successful fish production. Hatchery staff would determine the best use of the PRAS and whether it would be ideal for steelhead or Chinook Salmon production. The annual production cycle lends itself to providing maintenance windows and opportunities for cleaning and disinfection; all PRASs should be programmed into the facilities maintenance and management system to schedule, perform, and document preventative and corrective maintenance.

5.5.3 Feeding

Feeding will largely continue as usual, except for the PRAS tanks. Hatchery staff will need to transition away from the blower style feeding systems typically used for linear raceways to a feeding system designed for circular tanks. Fish can be fed in circular tanks utilizing the simplest of methods ranging from hand-feeding to automated systems and the techniques may vary depending on the size of the circular tanks and staff preferences. In addition to staff preferences, there are pros and cons associated with the various feeding options. Hand-feeding requires more staff time compared to automated feeding systems as it is labor intensive but allows staff to observe fish feeding and overall behavior and health. Hand-feeding allows the staff to feed the fish to satiation and minimizes overfeeding reducing wasted feed and maximizing water quality. Automated systems require an initial cost for the purchase and installation of the system. The automated feeding systems providing feed intermittently throughout the day including staff non-duty times to maximize growth, reduces staff labor (but reduces the staff's observations during feeding), requires adjustments to deliver the correct amount of feed, requires preventative and corrective maintenance and continued cost associated with these maintenance requirements. It should be noted that hand and automatic feeding systems are not mutually exclusive. Even with automatic feeding systems, culture operations should still involve regular monitoring of fish and their feeding response throughout the day.

5.6 Biosecurity

The goal of biosecurity measures is to minimize the risk of pathogens entering the facility and spreading between rearing areas at the facility. The Feather River Hatchery reported several pathogens of concern at the facility. This included Costia (*Ichthyobodo* spp.), bacterial gill disease (causative agent *Flavobacterium* spp.), ich (causative agent *Ichthyophthirius multifiliis*), bacterial coldwater disease (causative agent *Flavobacterium psychrophilum*), and whirling disease (causative agent *Myxobolus cerabralis*). The most likely pathways for pathogens to enter the hatchery and spread through the facility is through the incoming water supply or environmental exposure within the hatchery.

5.6.1 Incoming Water Supply

The Feather River Hatchery currently has limited measures to prevent pathogens from entering the facility. However, the recommended alternatives improve biosecurity by managing and treating the incoming water supply before entering the facility.

5.6.2 Environmental Exposure/Bio Vectors

The existing facility has several areas that are potential pathways for pathogens due to environmental exposure. The existing concrete raceways are enclosed by perimeter fencing and netting, but these structures do not completely exclude predators from accessing the raceways. The recommended alternatives reduce the risk of pathogens entering the rearing areas by reducing environmental exposure. Adding a permanent roof structure over the raceways will further reduce potential pathogen vectors, such as birds, otters, etc., from entering the rearing vessels. Predators can be a significant source of stress and they can transmit pathogens into the facility. Additionally, upgrading the existing predator exclusion frame for the rearing channel will provide similar benefits. The new PRAS would also be covered by a roof and surrounded by fencing, providing an additional secure rearing area.

5.7 Water Quality Impacts

The recommended alternatives will improve the water quality within the existing rearing vessels as well as the effluent leaving the facility. Adding PRAS with dual-drain circular tanks can improve the water quality of the rearing environment. Dual-drain circular tanks provide a completely mixed environment as opposed to a raceway that has a gradient of high to low dissolved oxygen (DO) along its length. This characteristic of circular tanks makes the entire tank volume available to the fish, instead of fish crowding at a raceway's head end, thereby not using the entire raceway volume. The dual-drain system in circular tanks aids in waste removal, allowing for more effective removal of solid waste and uneaten feed. This can contribute to better overall water quality.

The other PRAS equipment will also improve the water quality within the system. The microscreen drum filters will remove the solids in the water. The LHOs will ensure the dissolved oxygen levels enter the tanks at saturation or higher. The carbon dioxide strippers will remove dissolved carbon dioxide as well as other undesirable gases, and the UV unit will reduce the pathogen load of the water that returns to the tanks. Additionally, installing a rigid roof structure with bird netting will reduce heat gain during the summer months and algae growth in the rearing tanks. Each PRAS module will concentrate the fish waste into smaller flows from the center drain and drum filter backwash. The recommended alternatives include treating this effluent waste with a drum filter and settling pond. This will reduce the solids and improve the water quality of the effluent being discharged.

The recommended alternatives also include improving the incoming water quality. The water treatment infrastructure will reduce the debris and pathogen load of water entering the facility. This will improve the water quality in the hatchery building, production areas, and adult holding/collection.

6.0 Alternative Cost Evaluation

6.1 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. The appropriate overhead and profit markups have been included in the project pricing. The detailed cost estimates, including assumptions and inflation information are presented in Appendix F.

6.2 Estimate Classification

This OPCC estimate is consistent with a Class 5 estimate as defined by the Association for Advancement of Cost Engineering (AACE) classification system, as shown in Table 6-1 below. For purposes of this project, McMillen has utilized an accuracy range of -30% to +50% in the estimates presented in Table 6-2.

Table 6-1. AACE Class 5 Estimate Description (Source: Association for Advancement of Cost Engineering).

Criteria	Details
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.

Criteria	Details
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, Expressions, Synonyms:	Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of-thumb.

6.3 Cost Evaluation Assumptions

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

- All unit costs assume the total cost for installation including any applicable taxes.
- The cost estimate is at a Class 5 level with an accuracy range of -30% to +50% and includes a 25% contingency. This range accounts for current inflation variability within aquaculture projects, unforeseen conditions, and anticipated cost escalation leading up to the projected construction year.
- Prevailing wages are provided as a general increase based on past construction pricing.
- All Division costs are rounded up to the nearest $1,000.
- Length and area dimensions for the estimate were derived from scaled AutoCAD drawings of the facility and the property. Survey was not utilized for this initial estimate.
- Geotech investigation cost assumes seven bore holes (20 feet deep), material testing, piezometer installation, and a written report.
- Topographic survey cost assumed is based on $1,000/acre.

- Building joist/eave height will be 18 feet.
- Site geotechnical properties have not been evaluated but are assumed to be good for construction of the hatchery.
- Topographic survey has not been completed. Site survey will be required to establish elevations of all systems to ensure proper hydraulics can be achieved.
- A facility condition assessment was performed for the Feather River Hatchery in 2022 by Terracon (Terracon Consultants, Inc., 2022). The assessment included an inventory of all facilities and equipment, code evaluations, and upgrades required to meet the assessment for the main hatchery and the annex, including the detailed replacement value. The cost of all work items generated was approximately $552,331 in 2022 dollars. The work items in the Terracon facility condition assessment are not included within this report, costs, or evaluation of facilities. Some work items from the Terracon facility condition assessment may be resolved as part of the proposed upgrades at the Feather River Hatchery, while others may still need to be addressed. The upgrades in the Terracon reports may be included in future design efforts for each facility at CDFW direction.
- PRASs will be enclosed non-conditioned areas with sheet metal systems walls and doors. Ventilation for humidity will be included.
- A 500kW backup generator is proposed for new equipment; it is assumed that there is adequate backup power capacity for existing equipment and facilities.
- It is assumed that the existing abatement ponds will be maintained and are of adequate capacity to be used for the new facilities.
- Additional division specific cost evaluation assumptions may be found in Appendix F.

6.4 LEED Assessment

RIM Architects (RIM) and STŌK have reviewed and assessed this facility's location along with reviewing the combination of state law and Leadership in Energy and Environmental Building (LEED) eligibility requirements. From this review, it is determined that this location is not eligible or required under state law to pursue LEED due to the lack of human occupancy in the proposed structures and/or square footage requirements. There is insufficient scope to pursue LEED certification. Refer to Appendix H for more information.

6.5 Net Zero Energy Evaluation

A previously unaccounted, large parking lot, combined with the proposed shading structures and new buildings, provides more than sufficient PV space to achieve net zero energy. The surplus of available area (17,962 square feet) offers flexibility for future expansion or to serve as a buffer against potential increases in energy demand.

6.6 Alternative Cost Estimate

The following tables illustrate the estimated costs for the alternatives evaluated and depicted within the figures in Appendix C.

Table 6-2. Alternative Cost Estimate.

Item	Estimate ($)
Division 01 – General Requirements	6,690,000
Division 02 – Existing Conditions	168,000
Division 03 – Concrete	2,615,000
Division 05 – Metals	337,000
Division 13 – Special Construction	21,537,000
Division 23 – Mechanical & HVAC	148,000
Division 26 – Electrical	5,010,000
Division 31 – Earthwork	731,000
Division 32 – Exterior Improvements	155,000
Division 40 – Process Water Systems	2,205,000
Division 44 – Pumps	540,000
2024 CONSTRUCTION COST	**40,136,000**
Construction Contingency	10,034,000
Overhead	2,408,000
Profit	3,211,000
Bond Rate	402,000
2024 CONSTRUCTION PRICE	**56,191,000**
Design, Permitting, and Construction Support	8,429,000
Geotechnical	25,000
Topographic Survey	15,000
PROJECT TOTAL	**64,660,000**
Accuracy Range +50%	96,990,000
Accuracy Range -30%	45,262,000
Photovoltaic (Full kW Required)	9,795,600
Photovoltaic (Roof kW Available)	7,935,300

7.0 Feather River Hatchery Environmental Permitting

The proposed Project would involve the modification to the existing hatchery and associated infrastructure. A list of anticipated permits, agency review time, submittal requirements, and supporting documentation for the proposed project regardless of which alternative is selected are summarized in Table 7-1, Table 7-2, and Table 7-3. The review timeframes are estimated and are based on the recommendations presented in permit guidance documentation and experience with other permitting projects in California.

We reviewed the location through online mapping tools (U.S. Fish and Wildlife Service [USFWS] Information for Planning and Consultation [IPaC] and California Biogeographic Information and Observation System [BIOS]) to determine if species listed under the Endangered Species Act (ESA) and the California Endangered Species Act (CESA) potentially occur at the site. The results indicated that the site has the potential for species to be present identified as endangered or threatened. The site does not contain critical habitat. The results of these mapping tools indicate that a Biological Assessment of the area would need to be prepared prior to consultation with the USFWS, National Oceanic and Atmospheric Administration (NOAA), and other state agencies.

The list is developed at a high level and additional permits may need to be assessed as the project is advanced.

Table 7-1. Anticipated Federal Permits and Details for Proposed Upgrades.

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
USFWS National Environmental Policy Act (NEPA) Compliance	Environmental Assessment	Analysis of potential impacts on various natural resources, Design Package	12 – 18 months	Evaluation of the selected alternative to identify if there would be a significant impact
U.S. Army Corps of Engineers (USACE) Clean Water Act (CWA) Section 404 - Nationwide Permit Authorization	Pre-Construction Notification Application	Wetland and Stream Delineation, Design Package	3 months	Required if jurisdictional waters of the U.S. or wetlands are affected by the project area

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
USFWS ESA Section 7 Consultation	Biological Assessment	Field surveys of affected area, Design Package	4 months	The site has potential for species listed under the ESA to occur
National Oceanic and Atmospheric Administration (NOAA) Section 10(a)(1)(A) of the ESA	Application	Supplemental information to include description of proposed project, analysis of potential take and potential impact to species, proposed minimization and mitigation measures, and funding source	4 months	Authorization for scientific purposes or to enhance the propagation or survival of an endangered or threatened species

Table 7-2. Anticipated State of California Permits and Details for Proposed Upgrades.

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
Lead Agency TBD California Environmental Quality Act (CEQA)	Environmental Impact Report	Analysis of potential impacts on various natural resources, Design Package	12 – 18 months	Required for issuing State permits. Potential to be coordinated with the NEPA compliance for efficiency

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
California Department of Fish and Wildlife (CDFW) California Fish and Wildlife Code Section 2081 Incidental Take	Application	Supplemental information to include description of proposed project, analysis of potential take and potential impact to species, proposed minimization and mitigation measures, and funding source	4 months	Required for the authorization to take any species listed under the California Endangered Species Act
California Department of Fish and Wildlife (CDFW) California Fish and Wildlife Code Section 1600 Lake and Streambed Permits	Application/ Notification	Biological Resources Assessment, water quality information, mitigation information	1-3 months	Required for hatchery intake diversions
Central Valley Regional Water Quality Control Board (RWQCB) 401 Water Quality Certification	Application	Wetland and Stream Delineation USACE Review NEPA/CEQA Compliance	3 months	Required if jurisdictional waters of the US or wetlands are affected by the project area
California Office of Historic Preservation Section 106 Review	Concurrence Request Letter	Cultural Resources Survey, Design Package	3 months	Required as part of the NEPA/CEQA process
California Division of Water Rights Water Rights	Application or Transfer	N/A	4 months	N/A

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
California State Water Resources Control Board (SWRCB) National Pollutant Discharge Elimination System (NPDES)	Application	N/A	1 month	Required if hatchery effluent is discharged to a jurisdictional waterway
SWRCB Construction General Permit	Application	Stormwater Pollution Prevention Plan (SWPPP)	2 months	Required if construction activities disturb greater than one acre

Table 7-3. Anticipated Butte County Permits and Details for Proposed Upgrades.

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
Butte County Development Services	Grading, Building, Electrical, Mechanical, Pumping Applications	Project Summary and Design Package	2 months	N/A

7.1 National Pollutant Discharge Elimination System (NPDES) Permitting

The Feather River Hatchery is classified as a cold water Concentrated Aquatic Animal Production (CAAP) facility and is eligible to operate under General Order R5-2014-0161-032 issued by the Regional Water Quality Control Board, Central Valley (Region 5) and NPDES Permit No. CAG135001. This general order supersedes the previous NOA issued February 1, 2011.

The permit identifies formaldehyde and chlorine as potential pollutants from the hatchery. The following limitations for formaldehyde and chlorine effluent are specified:

- Formaldehyde: 0.65 mg/L (monthly average), 1.3 mg/L (daily maximum)
- Chlorine: 0.018 mg/L (daily maximum)

7.2 Water Rights

Water rights documentation can be obtained from the client if requested by an agency.

8.0 Conclusions and Recommendations

This report provides a summary of the state of the Feather River Hatchery, identifies and quantifies the impacts the hatchery could experience as a result of climate change, and provides proposed facility design modifications to increase the resiliency of the hatchery in conjunction with the associated costs and the potential impacts of the proposed modifications.

The in-depth analysis of the available hydrologic and climatologic data performed by NHC provides projections of forecast changes that may be experienced at the hatchery. In general, air temperature increases are expected at Feather River Hatchery. Regarding future water temperatures, the hatchery's water supply may be cooler if new temperature criteria are required for the new FERC license expected to be issued to DWR in the coming years.

To meet CDFW's goal of continuing to provide recreational fishing opportunities for the public and for the conservation of endangered or threatened species as the climate changes, the resiliency of existing hatcheries will need to be increased. Increasing resiliency will also require new facilities and updating existing infrastructure that is nearing the end of its effective lifespan.

If DWR receives its new FERC license, DWR will work with CDFW to complete a Comprehensive Facility Assessment of the Feather River Hatchery that will evaluate facility improvements and maintenance needs. The conclusions and recommendations from this hatchery's Climate Induced Upgrades Report will be evaluated as part of the Comprehensive Facility Assessment.

Some recommendations that would help to achieve the goals of this report include the following:

- Upgrading the water treatment system to provide a more secure and clean rearing environment and increased water quality for the facility.
- Improving the inland program hatchery building's facilities to allow staff to operate the system as originally designed. This would include adequate head pressure and drain system sizing.
- Covering the production raceways with a roof structure and improved predator exclusion fencing and netting. This will limit the warming of water caused by increased air temperatures and reduce the number of mortalities associated with predation.
- Repairing production raceway surfaces with skim coating, expansion joint repair, and a coating product to provide a smooth finish. This will protect the concrete, extending the usable life of the structure.

- Improving the rearing channel by replacing the predator exclusion system to reduce mortalities and increasing access points for the staff to allow for improved fish culture operations.
- Replacing deteriorated valving and piping throughout the hatchery. This will improve flow control allowing for more judicious use of water and preparing the hatchery for operations well into the future.
- Further evaluation should be conducted regarding the addition of a PRAS. Adding initial PRASs as a pilot program will allow hatchery staff to gain valuable experience working with systems that have lower water flow demands. Water supply for the facility (including both quantity and quality) may differ in the future due to factors outside of CDFW’s control. This could include reduced water availability from the Oroville Dam Complex and/or elevated water temperatures that require significant chilling to maintain year-round production (lower water use could result in reduced operational costs to maintain optimal temperatures).
- Further evaluation should be conducted regarding the installation of solar panels on new infrastructure to offset the power demand associated with new equipment.

The proposed upgrades to the Feather River Hatchery would have negligible impacts on the natural resources in the surrounding area. Most if not all improvements would occur within currently developed areas, which lessen the permit requirements. The total cost estimate of the proposed design modifications is $64,660,000.

9.0 References

California Department of Forestry and Fire Protection. 2023. *California Fire Perimeters (1950+).* http://gis.data.cnra.ca.gov/datasets/CALFIRE-Forestry::california-fire-perimeters-1950/explore.

IPCC, Intergovernmental Panel on Climate Change. 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.*

Krantz, W., D. Pierce, N. Goldenson, and D.R. Cayan. 2021. "Memorandum on Evaluating Global Climate Models for Studying Regional Climate Change in California." https://www.energy.ca.gov/sites/default/files/2022-09/20220907_CDAWG_MemoEvaluating_GCMs_EPC-20-006_Nov2021-ADA.pdf.

Piper, R G, I B McElwain, L E Orme, J P McCranen, L G Fowler, and J R Leonard. 1982. *Fish Hatchery Management.* Washington, D.C.: U.S. Fish and Wildlife Service.

Terracon Consultants, Inc. 2022. "Facility Condition Assessment Report Moccasin Creek Fish Hatchery."

Thomas et al. 2018. "Modelled wildfire risk from Westerling (2018): RCP 4.5, Historical fire and climate data from 1984-2013."

Timmons, M. B., T. Guerdat, and B. J. Vinci. 2018. *Recirculating Aquaculture 4th Edition.* Ithaca, NY: Ithaca Publishing Company LLC.

Vano, J., J. Hamman, E. Gutmann, A. Wood, N. Mizukami, M. Clark, D.W. Pierce, et al. 2020. "Comparing Downscaled LCOA and BCSD CMIP5 Climate and Hydrology Projections - RElease of Downscaled LCOA CMIP5 Hydrology." Techincal Memorandum.

Westerling, A. L. 2018. Wildfire Simulations for California's Fourth Climate Change Assessment; Projecting Changes in Extreme Wildfire Events with a Warming Climate. California's Fourth Climate Change Assessment, California Energy Commission. https://www.energy.ca.gov/sites/default/files/2019-11/Projections_CCCA4-CEC-2018-014_ADA.pdf