Climate Induced Hatchery Upgrades

Mokelumne River Hatchery

Alternatives Analysis Submittal

Final Report
Revision No. 4

February 2025

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Revision Log

Revision No.	Date	Revision Description
0	02/23/2024	65% Draft Internal Technical Review
1	03/01/2024	65% Draft for CDFW Review
2	08/30/2024	100% Draft Internal Technical Review / CDFW Review
3	10/31/2024	Final Submittal to CDFW
4	2/14/2025	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 Mokelumne River Hatchery was built in 1964 and has been operated and managed by CDFW and the East Bay Municipal Utility District (EBMUD) under a cooperative agreement. The facility underwent a major rebuild in 2002 funded by East Bay Municipal Utility District. That rebuild provided increased raceway capacity, a chiller unit, UV filtration, and many ancillary upgrades to improve egg incubation, production capacity, and survival. While EBMUD's mitigation targets remain fixed, CDFW has increased production targets for ocean enhancement and climate resilience over the years, due to the facility's track record of high egg-to-truck fished numbers, and high contribution to both the ocean fishery and inland fisheries. It now has an aging infrastructure and deficiencies related to anticipated future climate conditions that need to be addressed in the near future in order to meet current fish production goals. This evaluation and the proposed alternatives in this report represent a proactive effort to continue to build on the hatchery's success in the face of climate change while acknowledging the expanded use of the facility over time and the joint responsibilities of the two agencies.

The water source, Camanche Reservoir, can experience water temperatures in the upper range of tolerance for salmonids. Based on climate analyses, peak air and water temperatures are expected to increase in the next 40+ years. Recently, the hatchery has significantly increased its annual production numbers related to ocean enhancement and other CDFW production while mitigation responsibilities have remained constant; existing chilling equipment for the hatchery building is likely undersized due to non-mitigation fish production and higher water temperatures anticipated in the future. To meet increased production goals for non-mitigation fish, indoor rearing space was sacrificed for increased egg incubation space. The increased production goals of the hatchery did not include an increase in rearing space, making it difficult for hatchery staff to maintain optimal rearing densities. Spawning for steelhead takes place in a retrofitted shed, with adult fish held in production raceways instead of isolated areas designed to maintain pre-spawn fish. Additionally, the water supply head pressure changes continuously as reservoir levels fluctuate, making it difficult for staff to maintain appropriate flow rates to the rearing areas. During the rebuild in 2002, the facility was equipped with low-flow alarms which were decommissioned due to frequent false alarms. This resulted in three fish mortality events in the past 20 years that may have been prevented. The existing concrete raceways are over 20 years old and show some signs of deteriorating, including leaks at the expansion joints. Extremely high seasonal air temperatures, which are projected to increase, can be dangerous for both staff and the fish.

The preferred alternatives identified in this report include significant improvements to adult fish holding and production areas by constructing infrastructure specific to steelhead (*Oncorhynchus mykiss*) production. The steelhead production area includes adult holding, incubation, and grow-out spaces that capitalize on partial recirculating aquaculture systems (PRASs) to decrease water demand and make water treatment more economical. This would provide more flexibility to maintain biosecurity throughout the facility and comfortably accommodate the increased production goals. The concrete of the existing raceways would also be refurbished and repaired to extend the usable life. Additionally, raceways would be covered with a solid roof structure to mitigate the heat radiating from the dam face and improve conditions for staff and fish. A new research production area is proposed to facilitate anadromous fish research that currently uses existing production space. Dedicated research space would improve conditions for production fish by decreasing densities and allow for more flexibility of research activities. All proposed improvements would include low-flow alarms and power upgrades, including emergency generators, required for the operation of the new equipment and systems.

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
$82,354,000	$10,454,400

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 commercial and recreational fishing opportunities for the public, to support mitigation targets 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 for 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. In collaboration with CDFW and EBMUD, 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 and facility owners applicable, designs for climate change resiliency upgrades will be advanced for as many facilities as is feasible. The climate and infrastructure evaluation for the Mokelumne River Hatchery will be coordinated with EBMUD and is described in this report.

1.4 Project Location Description

The Mokelumne River Hatchery is located in Clements, CA, just downstream of the Camanche Reservoir approximately 35 miles southeast of Sacramento. Figure 1-1 shows the Mokelumne River Hatchery location map.

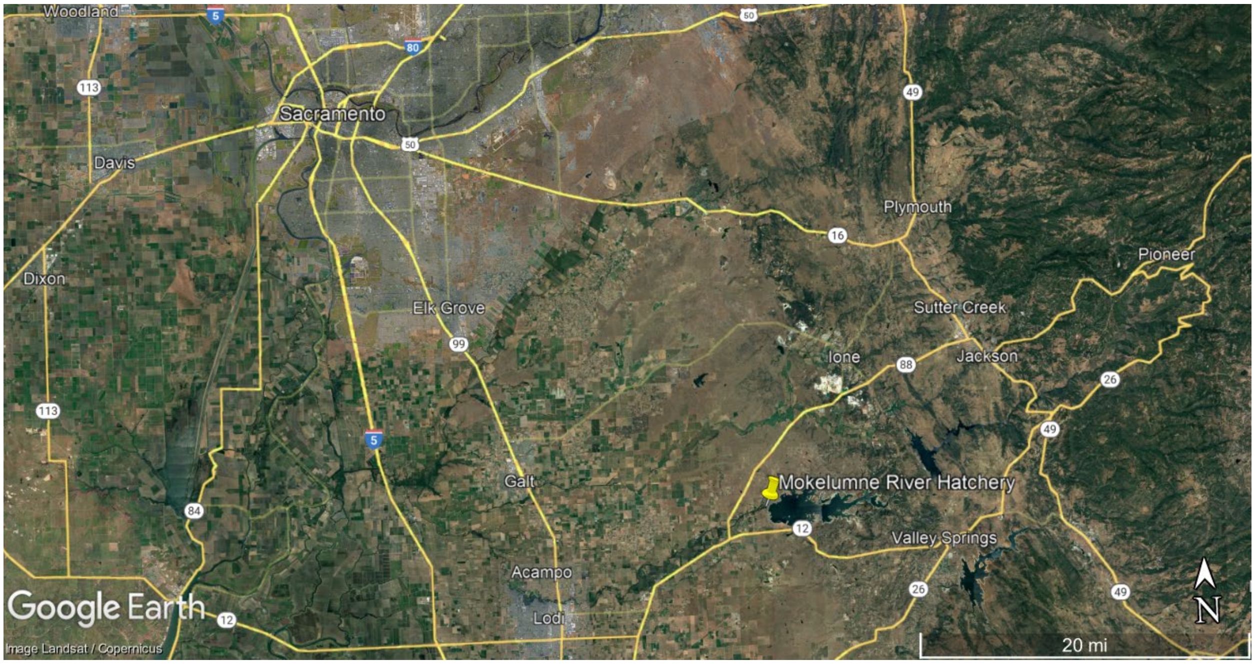

Figure 1-1. Mokelumne River Hatchery Location Map.

The Mokelumne River Hatchery was originally constructed in 1963 to offset the loss of fish spawning habitat due to the construction of the Camanche Dam by East Bay Municipal District (EBMUD). The hatchery was remodeled in 2002, enlarging the rearing space to promote fish health and fish survival rates while also making hatchery operations more efficient. The Mokelumne River Hatchery raises Central Valley fall-run Chinook Salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) with an annual production goal of 6.4 million Chinook smolts and 250,000 steelhead smolts and a combined biomass of approximately 185,000 pounds. The hatchery utilizes gravity-fed surface water from the Camanche Reservoir (via the Camanche Dam valve house), supplying water for all fish rearing activities. EBMUD provides water with temperatures typically ranging from 48-62°F seasonally. The general facilities are shown in Figure 1-2. More detailed descriptions and photos of the Mokelumne River Hatchery are described in the Site Visit Report (Appendix A).

Figure 1-2. Mokelumne River Hatchery Facility Layout.

2.0 Bioprogram

2.1 Production Goals and Existing Capacity

The Mokelumne River Hatchery was established to mitigate the loss of salmon and steelhead spawning and rearing habitat after the construction of Camanche Dam was completed in 1963. East Bay Municipal Utility District (EBMUD) initiated construction of the hatchery in 1964 and continues to provide funding as the facility's mitigator while CDFW operates the hatchery. Other production goals are undertaken regularly and have increased in recent years, including those for special studies requested by researchers and those to enhance commercial ocean fisheries, and designated 'climate resilience' production lots funded by CDFW. The hatchery produces Central Valley fall-run Chinook Salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*). The Chinook Salmon are listed by the federal government as a species of concern, while the California Central Valley steelhead is listed as threatened under the Endangered Species Act. The current production goals for the Mokelumne River Hatchery are shown in Table 2-1. Production is split to show the minimum production goals to meet mitigation requirements, and supplement production for special studies or ocean fisheries enhancement and climate resilience.

Table 2-1. Annual Production Goals at the Mokelumne River Hatchery.

Species/strain	Mitigation Requirements (EBMUD funded)	Supplemental Production (CDFW funded)	Total Production Goal
Fall-Run Chinook Salmon	3.4 million smolts (52 fpp[a]/4.0 inches)	3[b] to 5.6 million smolts (ocean enhancement) Sporadic requests for eggs and smolts, generally less than 100,000 fish	6.4 to 9 million smolts
Steelhead	250,000 yearlings (4 fpp, 8.9 inches)	Sporadic requests, generally very few fish	250,000 yearlings

[a] Fish per pound (fpp)

[b] The 'normal' production goal for ocean enhancement is 3 million smolts, but it has increased to 5.6 million based on additional enhancement initiatives.

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 preliminary bioprograms that address fish biomass (density index) and also encompass water temperature and elevation criteria to ensure oxygen levels appropriately align with production (flow index).

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) requirements identified. A summary of the rearing capacities identified in the Capacity Bioprogram is shown in Table 2-3 and Table 2-4. The fish production for each species is as follows:

- Fall Run Chinook Salmon: 6.4 to 9 million smolts
- Steelhead: 250,000 yearlings

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

Rearing Unit (max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
Deep tanks (550 fpp/1.8 inches)	415,704	Rearing volume[b]
Raceways (52 fpp/4.0 inches)	5,364,122 (14 out of 20 raceways)	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.
[b] Early rearing for Chinook Salmon is split, some are reared in deep tanks and others are transferred directly to raceways once they begin swimming up. Hatchery staff have not found a difference in survival between these groups. This limiting factor is based solely on increases in CDFW funded production lots in recent years.

Table 2-3. Steelhead Capacity of Various Rearing Units at the Mokelumne River Hatchery per the Capacity Bioprogram (Appendix A).

Rearing Unit (max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
Deep tanks (250 fpp/2.2 inches)	230,947	Rearing volume
Deep tanks (150 fpp/2.7 inches)[b]	170,061	Rearing volume
Raceways (4 fpp/8.9 inches)	346,032 (6 out of 20 raceways)	Rearing volume

[a] This is an estimate of 90% production capacity to allow for a buffer in circumstances where more flexibility is needed for hatchery operations.
[b] This is the ideal size that steelhead could be held indoors. It would reduce handling because fish could be transferred into the marking trailer then directly into the raceways. Currently, fish are transferred to raceways, grown, and handled again once they reach marking size.

2.2 Bioprogram Summary

The Capacity Bioprogram in the Site Visit Report (Appendix A) demonstrates the total capacity of each rearing area at the Mokelumne 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, is shown in Table 2-3 and Table 2-3. At a high level, the total capacity for the Mokelumne River Hatchery falls short of the Chinook Salmon production goals shown in Table 2-3, due to recent increases in CDFW-funded production lots, though nuances of the timing of egg collection, raceway use, and fish releases allow for more flexibility. Ultimately, the capacity of the hatchery is strained with an increased production goal of 9 million fish. The low-end production goal of 6.4 million smolts is readily attainable and provides more flexibility during fish stocking, marking, and tagging, allowing for more efficient and biosecure operations. With current operations, the Mokelumne River Hatchery does have sufficient capacity to meet steelhead mitigation goals. Details about the various rearing areas and infrastructure are discussed in the Site Visit Report in Appendix A.

In this current report, we developed an initial Production Bioprogram (Appendix B) to illustrate the potential maximum production that the facility is capable of while remaining within the limits set by the Capacity Bioprogram.

2.2.1 Criteria

The methods and reasoning used to determine the criteria associated with biological programming for the Mokelumne River Hatchery can be found in Appendix A. For reference, the established criteria are shown in Table 2-4. To model the production cycle schedule for the Production Bioprogram, survival assumptions are made and included in Table 2-5. This bioprogram also assumes optimal egg development and fish growth given the water temperatures experienced at the facility. Additionally, the high-level approach of this bioprogram does not model individual egg-takes. Instead, it is assumed that all eggs are collected near the beginning of the spawning window and fish are produced to the capacity of the available rearing systems. Survival rates and information to calculate growth rates were provided by Mokelumne River Hatchery staff.

A Fahrenheit Temperature Unit (FTU) is the equivalent to 1° F over freezing (32° F) for 24 hours. The growth rate for fall-run Chinook Salmon is 0.001 inches per FTU. For early-rearing Steelhead, the growth rate at 1,800 fpp to 250 fpp is 0.00055 inches per FTU. During grow-out, the growth rate at 250 fpp to 4 fpp is 0.0009 inches per FTU.

Table 2-4. Criteria Used for the Production Bioprogram and Discussed in Detail in Appendix A.

Criteria	Value
Density index (DI)	0.3
Flow index (FI)	1.50
Water temperature	Egg incubation: constant 52 to 54 °F Raw supply: variable between 48 and 62 °F

Table 2-5. Survival Assumptions Used for the Production Bioprogram.

Species	Survival
Fall-Run Chinook Salmon	Egg-to-fry: 95% Fry-to-juvenile (250 fpp): 95% Juvenile-to-outplant (52 fpp): 99%
Steelhead	Egg-to-fry: 75% Fry-to-juvenile (150 fpp): 90% Juvenile-to-outplant (4 fpp): 93%

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 egg collections, grading, or sorting. The model is meant to show an example of how production may occur given the criteria and assumptions outlined in the previous section. The bioprogram does not break down individual egg collection efforts and potential size differences of the family groups (based on the spawning date) during the production cycle.

2.2.2.1 Chinook Salmon

The Mokelumne Hatchery collects Chinook Salmon eggs from October through December; eggs collected early in the run (on which this model is based) will hatch and swim up for first feeding in mid to late December. Fish ready to accept starter feeds are assumed to be approximately 1,200 fpp (1.4 inches). Operations at Mokelumne are unique because a portion of fish are started in the indoor troughs at this size, while others are placed directly into raceways. This division is required because there is not enough space indoors or outdoors to rear all groups of Chinook Salmon; the hatchery building is space-limited, and some of the raceways are occupied by steelhead, preventing all Chinook from being started outdoors. The production numbers for Chinook Salmon started indoors are shown in Table 2-6; the production is limited by available rearing volume shown by a DI of 0.27 at the end of January. At this point, fish are transferred to the raceways.

Table 2-6. End of Month Production Information for Chinook Salmon Reared in Indoor Troughs Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs[a])	DI	FI
Dec/Early Jan	Troughs	36	1,200	1.4	437,579	364.6	4.7	0.17	0.12
Jan	Troughs	36	550	1.8	415,700	755.8	4.7	0.27	0.20

[a] Cubic feet per second (cfs).

Other Chinook are transferred directly to the raceways when they can swim up and begin feeding (approximately 1,200 fpp, 1.4 inches). Fish are spread out among available raceways to avoid excess handling and stress throughout the production cycle. Fish are started at the head end of the raceways, and screens are continually moved downstream to provide more rearing area. Flows are also restricted early on and increased as fish grow. Anticipated flow requirements for all raceways at the end of each month are shown in Table 2-7. Chinook Salmon are initially stocked into 13 raceways, but in February, the remaining fish raised in troughs will be included in the raceway inventory.

At the end of February, the total population will be split across 14 raceways. Marking and tagging operations occur over March and April. The marking process requires an entire raceway of fish to be transferred out of the raceway, through the marking trailer, and into an empty raceway. At the end of March, 17 raceways are occupied by Chinook Salmon. By the end of April all steelhead are stocked out and all 20 raceways are available for Chinook rearing. Chinook Salmon are tagged directly into raceways that previously held steelhead. Even though 20 raceways are available for Chinook Salmon, only 19 raceways are used for the final grow-out because marking operations require one empty raceway. In conjunction with the last marking and tagging effort, earlier groups of Chinook are stocked out in April totaling approximately 3 million fish. Another 6 million fish are released in May and June. Table 2-7 models the anticipated number of fish stocked out in each month and the associated reduction in raceway use. It is assumed that as fish reach the target size of 55 fpp, staff reduce feed rates to maintain remaining populations instead of promoting growth. This high-level model demonstrates a capacity to produce approximately 9 million Chinook Salmon smolts while maintaining DI and FI criteria throughout the production cycle. Overall production is limited from going beyond current production goals by the timing of marking/tagging and balancing raceway use with steelhead releases. However, this bioprogram does not provide significant time for raceway disinfection prior to changing the species of fish in each raceway. Additionally, if stocking needs to be postponed for environmental or other unplanned circumstances, the hatchery may have difficulty maintaining a quality rearing environment in the available rearing space. This bioprogram also does not account for differences in weekly egg collection groups throughout the entire spawning season, which does provide some additional flexibility during operations. Production of 6.4 million fish is readily attainable using only 14 raceways based on previous hatchery operations. This allows for complete disinfection of raceways prior to changing the species raised in each raceway.

Table 2-7. End of Month Production Information for Chinook Salmon Reared in Raceways 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
Dec/Early Jan	Raceways	14	1,200	1.4	8,959,103	7,466	9.4	0.05	1.27
Jan	Raceways	14	550	1.8	8,644,885	15,718	15.6	0.08	1.25
Feb	Raceways	14	220	2.5	9,031,930[a]	41,054	31.2	0.16	1.17
Mar	Raceways	17	100	3.2	9,015,965	90,160	44.5	0.22	1.41
Apr	Raceways	19	55	3.9	9,000,000	163,636	57.8	0.29	1.62[b]
May	Raceways	15	55	3.9	6,000,000	109,091	45.6	0.25	1.37
Jun	Raceways	7	55	3.9	3,000,000	54,545	21.3	0.27	1.46

[a] Fish reared indoors are added to the raceway inventory in February.

[b] This exceeds the recommended Flow Index but more accurately models the hatchery's production strategies.

2.2.2.2 Steelhead

Steelhead broodstock collection occurs simultaneously with Chinook Salmon collection. Adult steelhead are held in raceways instead of adult holding ponds to allow more time for ripening and genetic testing. Steelhead arrival at the Mokelumne Hatchery typically peaks in December and ends in early March. Fish from early egg collections will begin hatching and swim-up in late February or early March. Steelhead are initially stocked into the troughs and ideally raised to 250 fpp (2.2 inches) before being transferred to the raceways. To avoid exceeding the DI criteria of 0.3, only 231,000 steelhead are raised in the troughs to 250 fpp. Fish will reach 250 fpp at the end of May, and transfer of steelhead to the raceways will align with the release of some Chinook Salmon to ensure there is enough space and flexibility in the raceways for steelhead production. Ideally, staff reserve 14 raceways for Chinook production and six raceways for steelhead production (two raceways per release group). Steelhead will be released in February, March, and April. Table 2-8 shows the associated reduction in raceways for these release months. Like Chinook production, it is expected that staff will reduce feed rates once steelhead approach the target release size of 4 fpp (8.9 inches). The bioprogram illustrates a maximum production of approximately 218,000 yearling steelhead.

Production is limited by the available space in the troughs if operations adhere to a DI of 0.3. At the end of May, the DI approaches 0.3, limiting the total number of fish in the troughs when they reach a size of 250 fpp. However, eggs are collected over several weeks, and not all fish will reach 250 fpp at the same time. Flexibility in the timing of transfers to the raceways allows staff to meet the production goal of 250,000 yearling steelhead and exceed the capacity modeled in this bioprogram.

Table 2-8. End of Month Production Information for Steelhead 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
Feb/early Mar)	Troughs	36	1,800	1.2	256,668	143	3.3	0.08	0.08
Mar	Troughs	36	850	1.5	248,112	292	3.3	0.13	0.13
Apr	Troughs	36	500	1.8	239,556	479	4.7	0.17	0.13
May	Troughs	36	250	2.2	231,000	924	4.7	0.27[a]	0.20
Jun	Raceways	6	120	2.9	229,383	1,912	1.3	0.02	1.10
Jul	Raceways	6	60	3.6	227,766	3,796	2.7	0.03	0.88
Aug	Raceways	6	33	4.4	226,149	6,853	4.0	0.04	0.87
Sep	Raceways	6	21	5.1	224,532	10,692	5.3	0.06	0.87
Oct	Raceways	6	14	5.9	222,915	15,923	6.7	0.07	0.90
Nov	Raceways	6	9.5	6.7	221,298	23,295	8.0	0.10	0.97
Dec	Raceways	6	7.3	7.3	219,681	30,093	9.4	0.11	0.98
Jan	Raceways	6	5.8	7.9	218,064	37,597	10.7	0.13	0.99
Feb	Raceways	3	4.8	8.4	143,922	29,984	6.0	0.20	1.32
Mar	Raceways	1	4.0	8.9	60,000	15,000	3.0	0.28	1.24
Apr	Raceways	1	4.0	8.9	60,000	15,000	3.0	0.28	1.24

[a] This DI requires fish to be transferred to the outdoor raceways and limits the overall production of this model.

This bioprogram shows an example of production for a single cohort of each species—Chinook Salmon and steelhead—at the Mokelumne Hatchery. Total Chinook Salmon production is limited to approximately 9 million fish, which meets current production goals. Because of the flow rates in available raceways; the FI criteria is exceeded as the population approaches the target stocking size of 55 fpp (Table 2-7), Steelhead production is limited to approximately 218,000 yearlings (average of 4 fpp across all release months) by the total available rearing volume in the hatchery troughs. The DI criteria are reached as the population approaches a size of 250 fpp and are stocked out into the raceways (Table 2-8). The production schedule, shown in Figure 2-1, demonstrates the overlap between each species and the various rearing areas. The maximum monthly flow rate for the facility is shown at the bottom of Figure 2-1. Note that the different colored blocks in Figure 2-1 correspond to the months in which each species (Chinook Salmon and Steelhead) is in the troughs, the raceways, or the early tanks, along with noting when eggs are received and incubated.

It is expected that flow demand will be highest in March (up to 70 cfs). Maximum demand may not reach this, as hatchery operations will involve managing flows in the ladder at the end of the steelhead run as flows are increased to accommodate Chinook Salmon in the raceways. Facility operations will involve managing flows on an individual tank level with reduced flows for young fish or tanks with lower stocking densities. The flow rates shown for each month are maximum estimates based on the bioprogram. The high-level bioprogram in this section does not capture the nuances of production week-by-week and the differences among family groups and egg-collection dates. It is important to understand that actual facility operations allow for additional flexibility for fish transfers, and that size is not uniform for an entire species population 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
Chinook Salmon																								
Eggs Received																								
Egg Incubation																								
Rearing in Troughs																								
Rearing in Raceways																								
Steelhead																								
Eggs Received																								
Egg Incubation																								
Early Rearing in Deep Tanks																								
Rearing in Raceways																								
Fish Ladder																								
Operation (20 cfs)																								
Max. Flow Required (cfs)	51.2	60.7	71.0	65.5	50.3	22.6	2.7	4.0	5.3	28.7	30.0	45.5	51.2	60.7	71.0	65.5	50.3	22.6	2.7	4.0	5.3	28.7	30.0	45.5

Figure 2-1. Production Rearing Schedule Over 2 Years (as highlighted in the Max Flow Required row).

3.0 Climate Evaluation

3.1 Introduction

In this section, climatic and hydrologic projections of conditions at the hatchery are presented for the next 20 years (2024-2043) and the following 20 years (2044-2063). 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. Air temperature projections inform of potentially hazardous working conditions, and water temperature projections inform of risks to fish rearing.

3.2 Water Sources

The hatchery receives water from the Camanche Reservoir through two outlets located at 202.5 feet and 102.6 feet at reservoir levels. Most supply is from the lower-level outlet, with the upper-level outlet being able to provide only 10-15 cfs. The upper-level outlet provides warmer water, and when water is very cold in the spring, some of this warmer water is used to temper the lower-level water. Seasonal water temperatures range from 48°F to 62°F, and water quality is suitable for salmonid production. The highest water temperature observed within the last 20 years is approximately 64°F. Temperatures peak in October when egg collection begins. Chillers are utilized in the fall for the incubation of Chinook Salmon eggs when incoming temperatures reach their peak, and this equipment maintains incubation water temperatures between 52°F and 54°F.

Flow to the hatchery building is filtered through sand media filters and can be chilled by up to 6.3°F cooler than ambient water temperatures. All water is used on a single pass basis. The colder water from the deeper Pardee Reservoir is released into Camanche Lake to contribute to cold water pool volume. EBMUD actively manages these systems to maintain sufficiently cool temperatures for the hatchery.

Operational needs vary from month to month, with spawning and incubation operations using up to 6 cfs and the rearing facilities up to 65 cfs. The hatchery typically operates with 39 cfs of water flow but has operated as high as 71 cfs.

3.3 Methodology for Climate Change Evaluation

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 2013). 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
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

Hydrologic projections utilize daily timestep results from the Variable Infiltration Capacity (VIC) hydrologic model (Figure 3-1) that was driven by the projected daily climate time series. VIC divides the watershed into grid cells (about 5 km x 7 km in this study) where properties of the soil column and land cover and all major fluxes of water and energy are represented. Soil infiltration capacity is spatially variable within each grid cell, and baseflow is represented as a non-linear function of soil water storage.

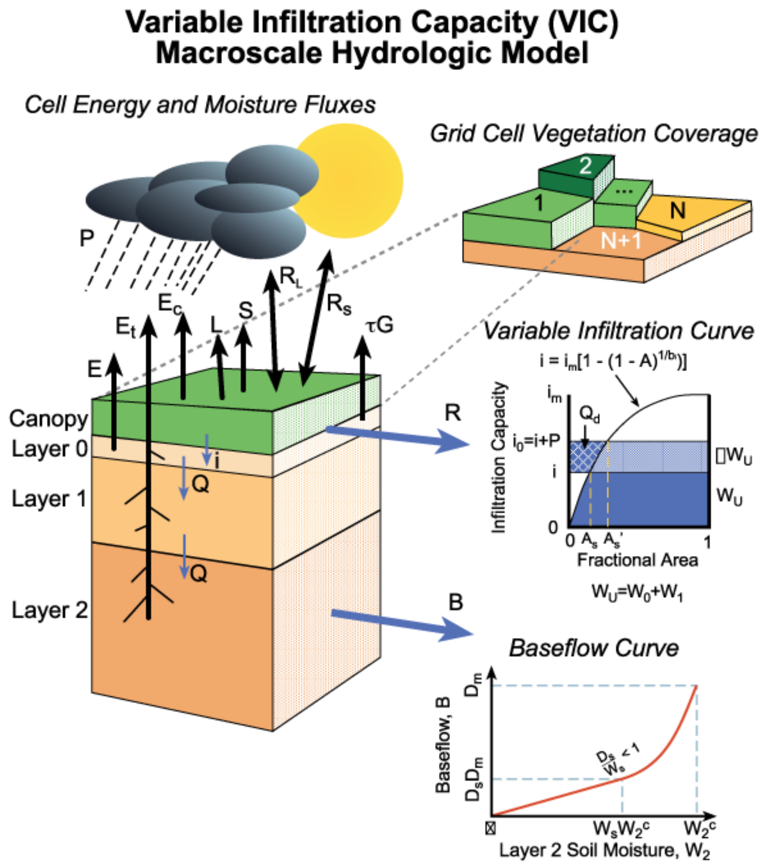

Figure 3-1. The VIC Hydrologic Model (University of Washington Computational Hydrology Group, 2021)

The methodology used for obtaining projections of climate, water temperature, hydrology and flood risk is summarized in Figure 3-2. The sections below provide additional detail, as well as a discussion of fire risk:

1. **Projections of climatic variables** (air temperature and precipitation) were 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 made available by the same research

consortium (item 2 below) used 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.

2. **Projections of daily and seasonal snow accumulation over the Mokelumne watershed, and stream flows in the Mokelumne River, as it enters the Pardee-Camanche reservoir system,** were obtained by aggregating over the watershed the grid cell-based snowpack and streamflow projections made available by the same research consortium as in item 1 above (Vano et al., 2020). These publicly available projections were obtained by driving the VIC hydrologic model with the CMIP5 daily climate projections.
3. **Projections of wildfire risk** at each hatchery site were evaluated at a high level based on the projections by Westerling (2018), which are available through the California government Cal-Adapt.org website (Cal-Adapt, 2023). In addition to the risk that fire poses to the facility, it has the effect of reducing soil permeability, increasing peaks of runoff and stream flows that impact flooding and water quality, and potentially decreasing groundwater recharge.

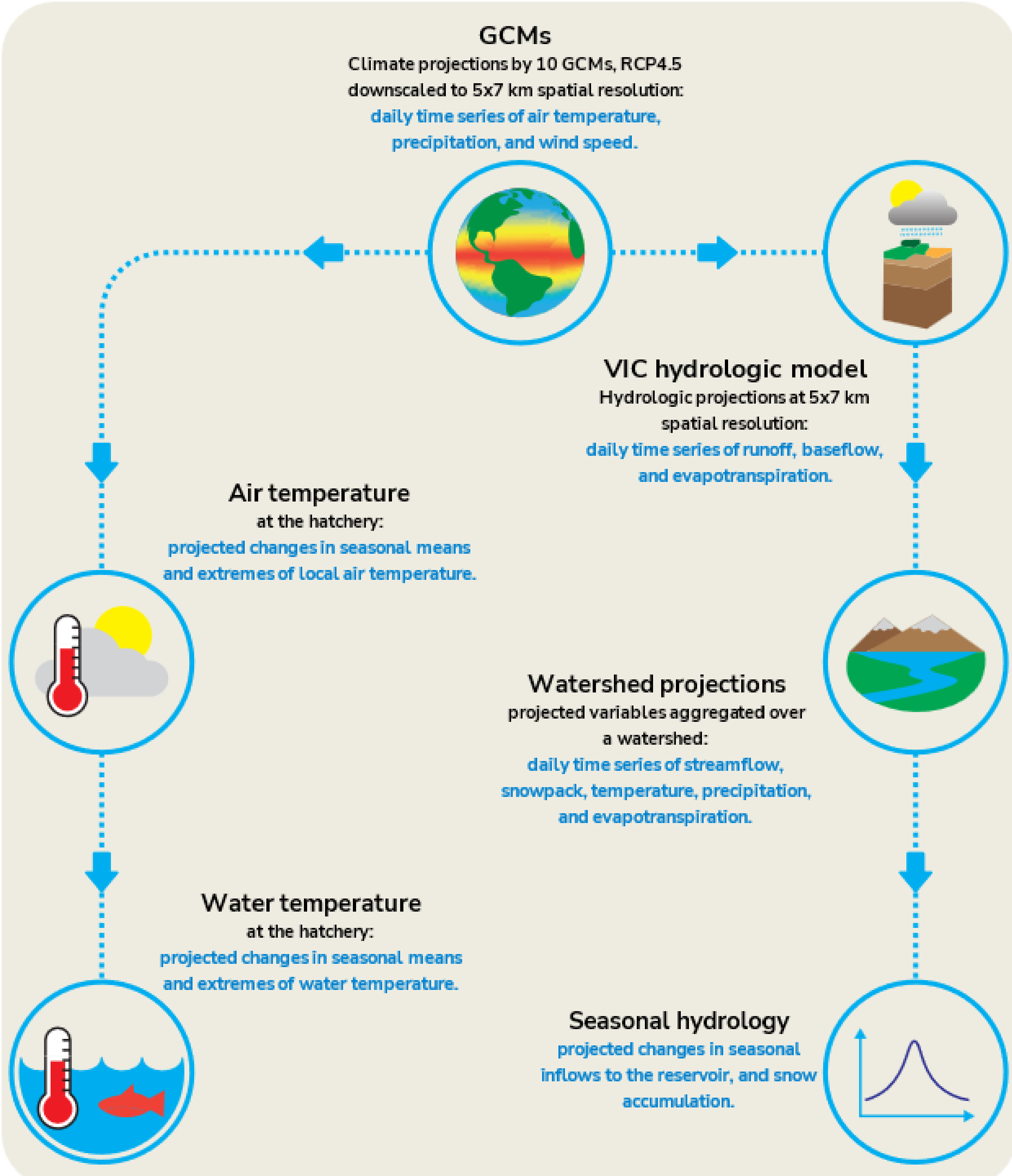

Figure 3-2. Methodology for Obtaining Projections.

3.4 Uncertainty and Limitations

It is important to acknowledge the uncertainty associated with these and any projections of climate and hydrology. While there is a need to provide climate projections for a variety of planning purposes, the underlying projections of climate change are subject to large and unquantifiable uncertainty.

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

3.5 Projected Changes in Climate at the Hatchery Site

3.5.1 Air Temperature

Figure 3-3 displays the simulated mean daily air temperature (solid lines) and its range from minimum to maximum (shaded areas) for each day of the year at the hatchery site (top panel) and averaged over the watershed upstream from the reservoirs. The near-future time period and the reference period are represented in red and blue, respectively. 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.

The projected temperature rise for the hatchery site (top panel of Figure 3-3) indicates potentially hazardous outdoor working conditions. The projected temperature rise averaged over the watershed (bottom panel of Figure 3-3) explains the projected decline in snow accumulation, and in snowmelt timing, that will be seen in Section 3.5.3.

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 3-3, and are given in Table 3-2 and Table 3-3. 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.

At the hatchery site, mean annual air temperature is projected to rise by 2.5°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 (Figure 3-3, Table 3-2, and Table 3-3) 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 75th percentile (i.e., the upper quartile of temperatures) are projected to warm by 3.2°F in the next 20 years, relative to the reference period. The 97th percentile of the daytime maximum temperature is projected to rise by even more, 3.8°F, reaching 105.7°F.

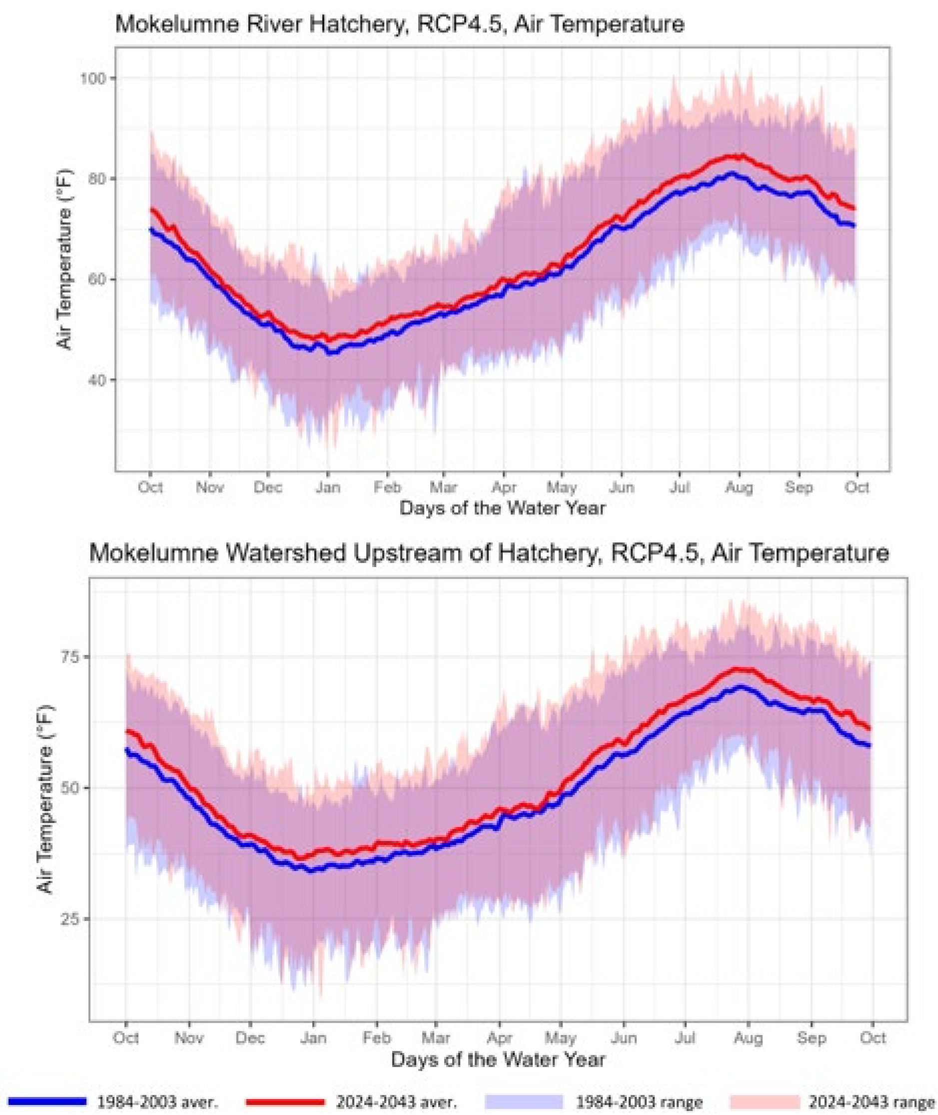

Figure 3-3. Mean Daily Air Temperature and Range for Each Day of the Year.
Top: **At the hatchery site.** ***Bottom:*** **Averaged over the watershed. The period means are represented by solid color lines, while the range is covered by the color shades.**

Table 3-2. Projected 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	65.0°F (+2.5°F)	50.8°F (+2.2°F)	62.6°F (+1.8°F)	79.3°F (+3.4°F)	68.0°F (+2.6°F)
Lowest	64.5°F	50.1°F	61.9°F	78.6°F	67.0°F
Highest	65.9°F	51.5°F	63.5°F	80.4°F	68.7°F

Table 3-3. Projected 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	66.1°F (+3.6°F)	52.0°F (+3.4°F)	63.6°F (+2.8°F)	80.6°F (+4.7°F)	69.0°F (+3.6°F)
Lowest	65.6°F	51.1°F	63.0°F	79.2°F	67.8°F
Highest	67.0°F	52.8°F	64.3°F	82.2°F	70.2°F

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	52.5°F (+2.0°F)	64.0°F (+1.9°F)	77.5°F (+1.9°F)	92.4°F (+3.2°F)	105.7°F (+3.8°F)
Lowest	51.6°F	63.3°F	77.2°F	91.5°F	103.9°F
Highest	54.2°F	64.3°F	78.1°F	93.2°F	106.8°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	54.0°F (+3.5°F)	65.0°F (+2.9°F)	78.7°F (+3.1°F)	93.6°F (+4.4°F)	106.7°F (+4.8°F)
Lowest	52.9°F	64.2°F	78.2°F	92.2°F	104.8°F
Highest	55.5°F	65.7°F	79.4°F	94.7°F	108.1°F

3.5.2 Water Temperature

Daily water temperature was provided by the hatchery for the period from 9/2018 through 8/2022, and daily air temperature was provided for the same period. Instead of varying with air temperature, water temperature likely rises with declining reservoir storage, increasing steadily through the summer as storage declines, and peaking in the fall season (Figure 3-4), therefore the two variables show little correlation (Figure 3-5). Modeling reservoir storage is beyond the scope of this project; hence, water temperature projections are not presented. The projected decline in summer streamflow (Section 3.5.3), due principally to the earlier depletion of the snowpack, is likely to lead to decreasing reservoir summer storage and higher water temperatures in late summer and fall.

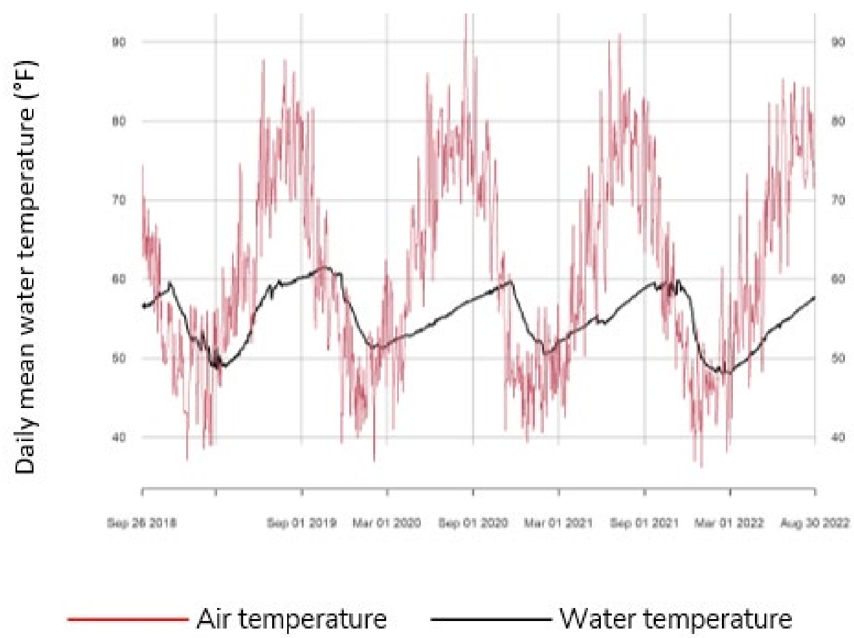

Figure 3-4. Seasonality of Observed Daily Mean Water Temperature and Air Temperature.

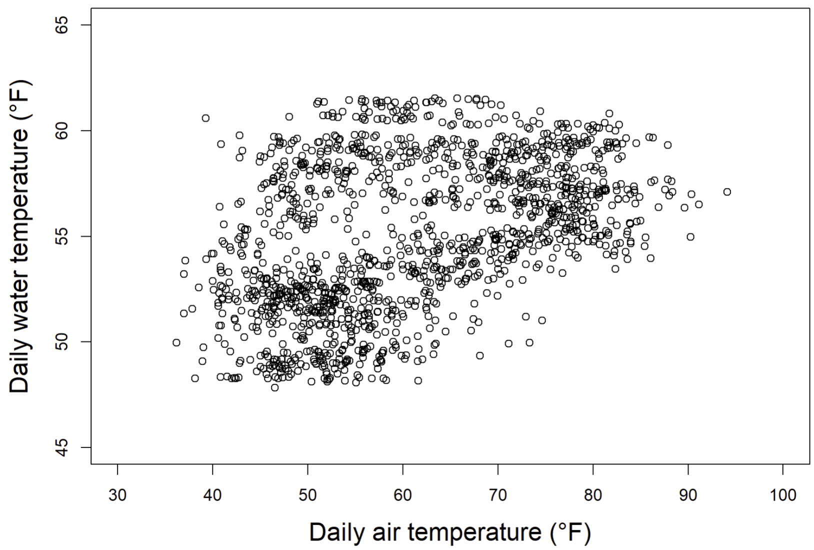

Figure 3-5. Observed Daily Mean Water Temperature Versus Air Temperature.

3.5.3 Snowpack and Streamflow for the Mokelumne River Watershed

Rising air temperatures result in projected changes in the hydrologic regime of the Mokelumne River watershed. Figure 3-6 displays the projected mean daily snowpack (solid lines) and range from minimum to maximum (shaded areas) for each day of the year averaged over the watershed, for the near future (red) and the reference time period (blue). Figure 3-7 displays the projected streamflow in a similar manner to Figure 3-6. Data in both figures are simulated by the ensemble of 10 GCMs for each time period, including the reference period. The Mokelumne River watershed upstream of the hatchery site has an estimated 628 square miles, according to StreamStats (USGS, 2019).

The differences in snow accumulation and streamflow between the near-future period and the reference period seen in Figure 3-6 and Figure 3-7 occur as a result of the projected air temperature increase. Projected seasonal changes are summarized in Table 3-6, Table 3-7, Table 3-8, and Table 3-9. On a mean annual basis, it is projected that snowpack will decline by one-third in the near-future period, and by one-half in the mid-century period, relative to the reference period. In the near-future period, snowmelt is projected to occur about 3 weeks earlier on average.

Averaging the air temperature over the Mokelumne River watershed (shown in Figure 3-3, bottom panel), the number of days in winter (December-February) with below-freezing mean daily temperatures was 22% in the reference period (1984-2003) but is projected to decline to

13% in 2024-2043, and to 8% in 2044-2063. This is a result of the projected winter warming by an average of 2.2°F in 2024-2043 and 3.4°F in 2044-2063 relative to 1984-2003.

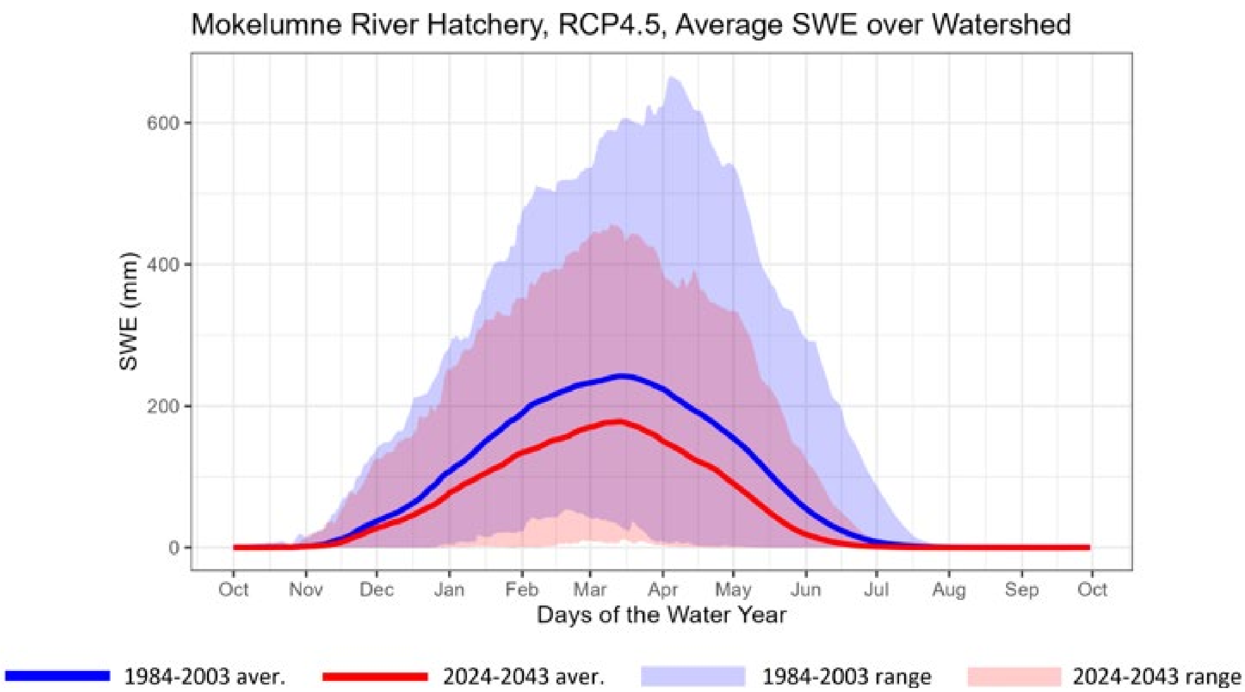

Figure 3-6. Mean Daily Snow Water Equivalent and Range for Each Day of the Year for Mokelumne River Watershed.

Table 3-6. Projected GCM 2024-2043 Mean Change in the Seasonal Snowpack (change relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Ensemble mean	-34%	-29%	-35%	-74%	-33%

Table 3-7. Projected GCM 2044-2063 Mean Change in the Seasonal Snowpack (change relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Ensemble mean	-51%	-42%	-55%	-92%	-61%

The mean daily streamflows (solid lines) displayed in Figure 3-7 show increases in the colder months (November through March) and declines in summer (June-August). Seasonal streamflow changes are summarized in Table 3-8 and Table 3-9, the largest being an increase by 29% of mean winter streamflow and a decline of -60% in mean summer streamflow in the near future period (2024-2043) relative to the reference period (1984-2003). For the mid-century period (2044-2063), these changes are even larger, equal to +49% and -80%, for winter and summer, respectively. Projected winter streamflows show higher peaks due to increase of rainfall relative to snowfall (Figure 3-7). There is also a projected increase in total winter precipitation for 2024-2043 compared to 1984-2003, but it is small (+3%), contributing little to the higher winter peak flows. Projected summer low flows start about two weeks earlier (Figure 3-7).

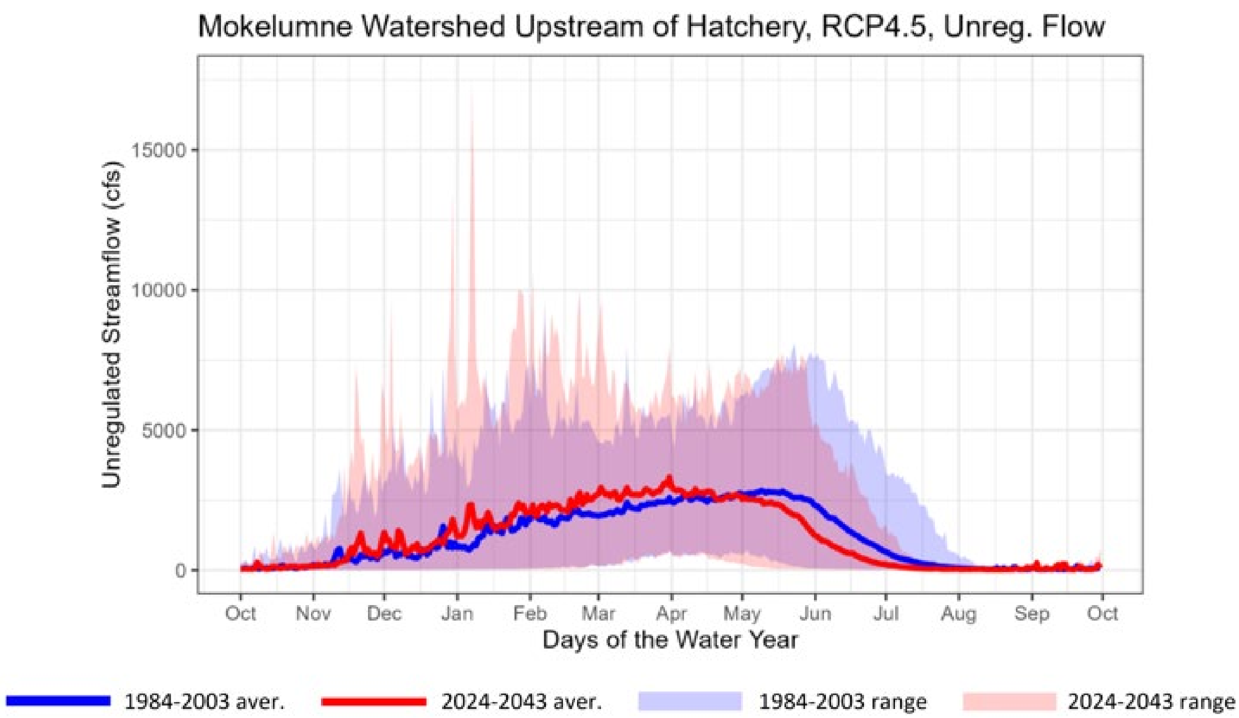

Figure 3-7. Mean Daily Streamflow and Range for Each Day of the Year for Mokelumne River Upstream of the Dams.

Table 3-8. Projected GCM 2024-2043 Change in the Seasonal Streamflow (change relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Ensemble mean	+3%	+29%	+3%	-60%	+28%

Table 3-9. Projected GCM 2044-2063 Change in the Seasonal Streamflow (change relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Ensemble mean	+1%	+49%	-6%	-80%	+1%

3.5.4 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 3-8. Most of the watershed area has not burned within the past century and therefore has relatively high 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 3-8). 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 per Westerling (2018), the projected wildfire risk at the hatchery site is approximately 15% through mid-century (Figure 3-8). Across the watershed, the projected fire risk is higher, at 30% mean probability and local zones increasing to 40% towards the end of this century.

The primary risks to the hatchery operations include local infrastructure impacts from local fires, as well as reservoir impacts from fires in the upper basin. Because the hatchery relies on reservoirs, the hatchery is shielded from potential flooding and debris that can impact hatcheries along running rivers. Fires can impact reservoirs by increasing runoff and turbidity along burn scars. The effects will likely be greatest in the upstream reservoirs furthest from the hatchery. Staggered placement of reservoirs along the Mokelumne River is expected to attenuate any upstream impacts from the fire, such as turbidity and high runoff volumes. Therefore, the largest potential risk is fire-related infrastructure hazards to the hatchery itself.

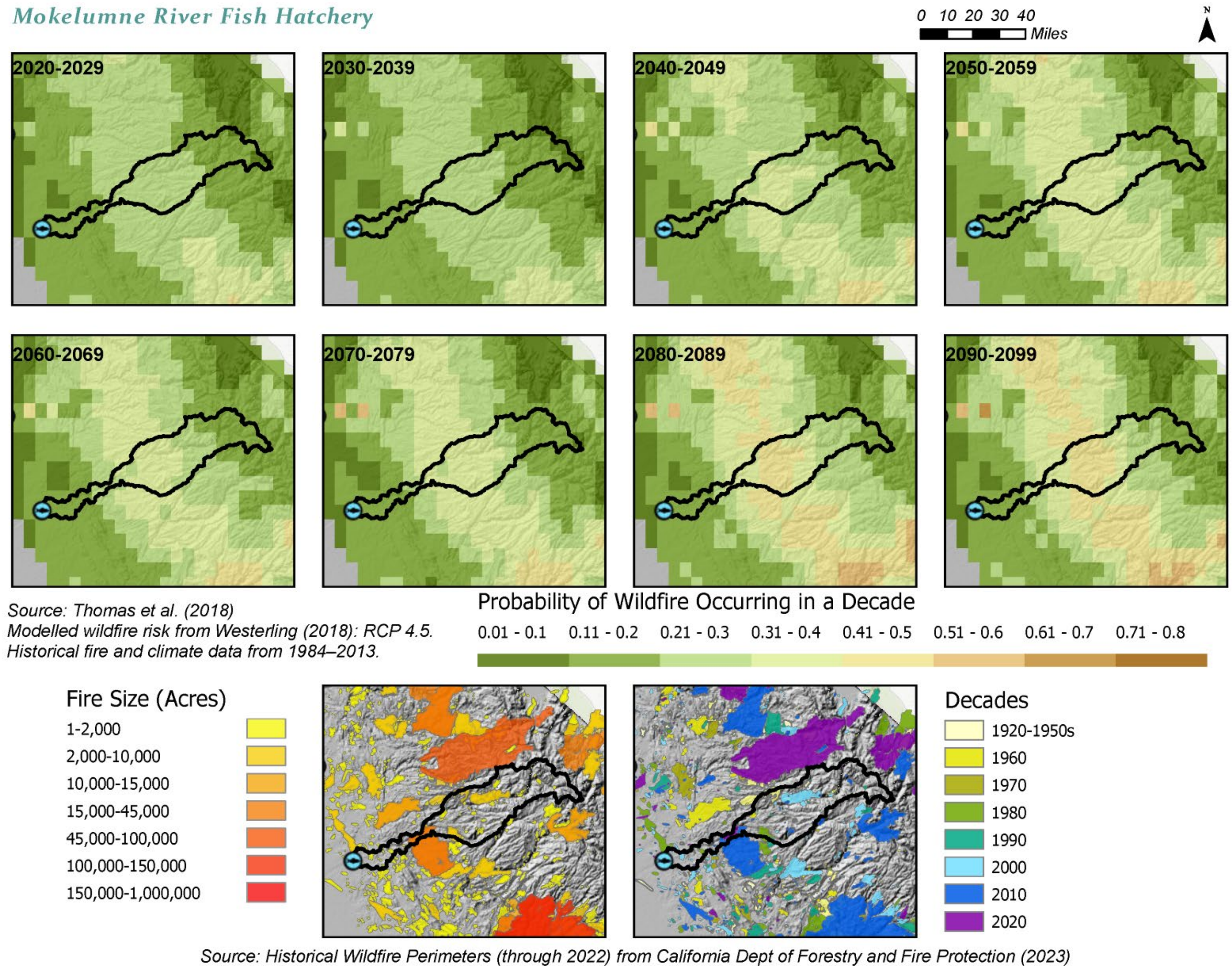

Figure 3-8. Wildfire Risks as Probability of Future Occurrence and Known Historical Fires.

3.6 Conclusions

Significant increases in air temperature are expected for the Mokelumne River Hatchery. Mean annual air temperature is projected to rise by 2.5°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. Days with temperatures representing the 75th percentile and 97th percentile of daily temperatures are projected to warm by 1.8°F and 3.4°F, respectively, in the next 20 years, relative to the reference period.

According to the observations-based gridded air temperature dataset used in this study (Livneh et al., 2013), the 75th and 97th percentiles of peak daytime temperature (i.e., the temperature at the hottest time of day) at the hatchery site in the reference period (1984-2003) were 89.2°F and 101.9°F. For the near future period (2024-2043), these percentiles are projected to rise to 92.4°F and 105.7°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.

Observations show that mean daily water temperature has only weak dependence on air temperature. Instead, water temperature increases steadily through the summer as reservoir storage declines, peaking in the fall season. Modeling reservoir storage is beyond the scope of this project; therefore, water temperature projections are not presented. The projected decline in summer streamflow, due principally to the earlier depletion of the snowpack under warmer conditions, is likely to lead to decreasing reservoir summer storage and higher water temperatures in late summer and fall.

The projected winter air temperature rise by 2.2°F in 2024-2043 and 3.4°F in 2044-2063 relative to 1984-2003 will alter the hydrologic regime of the Mokelumne River watershed. In particular, the number of winter days (December-February) with below-freezing mean daily watershed-averaged temperatures, which is projected to decrease from 22% in the reference period (1984-2003) to 13% in the near future period (2024-2043) and to 8% in mid-century (2044-2063), will lead to an increased rain-to-snow ratio, resulting in lower snow accumulation (only partially offset by a small projected increase in total winter precipitation).

Rising temperatures will cause large declines in snowfall and snow accumulation, with the watershed losing a projected one-third of its mean annual snowpack in the near-future period relative to the reference period, and snowmelt occurring about 3 weeks earlier in the year on average. Low summer streamflows will initiate earlier by about 2 weeks in the near future period relative to the reference period, and there is also a projected small decline in mean summer precipitation. Mean winter streamflow is projected to increase by 29%, while mean summer streamflow is projected to decrease by 60% in the near future period relative to the reference period.

The hatchery is at moderate risk of wildfires. While there is a lack of large historical fires in the basin, observations of past large fires in adjacent basins are more common. The lack of large fire in the Mokelumne basin is therefore anomalous, with large stores of fuel present in the basin ready to burn. The projected chance of at least one wildfire occurring in a 10-year period at the hatchery site is estimated as 15% through mid-century. Across the watershed, this risk is estimated as 30-40%. Post-fire conditions risks to the hatchery, including scar-induced flooding, turbidity, and debris, is less likely to affect the hatchery due to upstream reservoir storage. Local impacts to infrastructure from nearby fires is more likely.

4.0 Existing Infrastructure Deficiencies

While the Mokelumne River Hatchery is an operational facility, multiple deficiencies were identified during the site visit and described in Section 4 of the Site Visit Report (Appendix A). Section 5.4 of the Site Visit Report identified potential technologies and solutions available to address specific deficiencies that would allow the hatchery to meet current production goals and provide protection against climate change. The main areas of concern for the hatchery included undersized water treatment for egg incubation in the hatchery building due to recent increases in CDFW funded, non-mitigation production lots, a lack of alarms for life-support systems, insufficient steelhead adult holding and spawning infrastructure, and deteriorating raceway conditions. 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

4.1.1 Source Water Quality

Water in the Camanche Reservoir is treated by the East Bay Municipal Utility District (EBMUD) with liquid oxygen via a Speece cone to control hydrogen sulfide formation in the hypolimnion zone of the reservoir. This increases dissolved oxygen levels to ensure they do not drop below approximately 4 mg/L in the hypolimnion eliminating historic fish kills due to hydrogen sulfide gas. The potential reintroduction of anadromous fish above Camanche Dam may result in increased pathogen loads in the source water. Additionally, temperatures of the source water can already rise as high as 64°F even with EBMUD's adaptive management of their reservoirs. Based on projections of lower snowpack and streamflow (Section 3.5.3), it is expected that peak temperatures in the reservoir will continue to rise and pose an increasing risk to salmonid production at the facility.

4.1.2 Hatchery Building Water Treatment

The hatchery building's water treatment system consists of filtration, ultra-violet (UV) disinfection, and a 165-ton chilling unit. The system is designed to operate with up to 2 cfs of water flows and has worked as intended. However, this system may be undersized to reliably chill water for the hatchery if its production goals increase significantly. Additionally, as climate change continues to affect water temperatures in California's Central Valley, the chilling system may experience increased demand for longer periods of use. Further evaluation of this system may or may not be warranted.

4.1.3 Hatchery Building Water Supply Head Pressure

Hatchery staff identified concerns with head pressure of the water flowing into the hatchery building. Head pressure is constantly changing due to reservoir levels and water demand. This causes flow rates to individual tanks and incubation units to change throughout the day. EBMUD staff notify hatchery staff when flow changes are planned to address the need for staff to monitor and adjust flows.

4.1.4 Alarm Systems

During the site visit, staff identified three separate occasions in the past 20 years where there have been significant fish losses due to a lack of functioning low-flow alarms at the facility. Inadvertent fish losses due to infrastructure malfunctions are especially important for mitigation hatcheries that are part of conservation efforts for threatened species such as the steelhead raised at the Mokelumne River Hatchery. Mass mortality events impact the total production of the hatchery but also affect the subsequent years of adult returns potentially impacting the hatchery's ability to collect eggs.

4.2 Rearing Infrastructure

4.2.1 Steelhead Spawning and Early Rearing

Spawning operations for steelhead at the Mokelumne River Hatchery are confined to a small shed placed near the production raceways. There is limited space in the shed and its location requires eggs to be transported to the hatchery building for incubation. In the hatchery building, rearing space has become more limited because several deep tanks have been recently removed to add more egg incubation space for increased CDFW funded Chinook Salmon production goals. Currently, adult steelhead are held in the production raceways for ripening and genetic testing prior to spawning. This reduces operational flexibility and restricts overall production while adults are held.

4.2.2 Limited Indoor Rearing Space in Existing Hatchery Building

CDFW staff identified a concern with the amount of indoor rearing space available in the existing hatchery building not meeting production goals of up to 10 million eggs in some years due to increased drought production. This can lead to competition for space in the raceways due to extended steelhead rearing.

4.2.3 Raceway Deterioration

There are twenty (20) 300-foot-long raceways at the Mokelumne River Hatchery which were constructed in 2000. There is some normal wear and deterioration of the concrete after over 20 years of use, including leakage between expansion joints.

Though there is bird netting and fencing enclosing the raceways, river otter and raccoon predation is still a normal occurrence. Predation directly results in lost production, but the presence of predators also increases the risk of pathogen introduction and transmission. The 75th and 97th percentiles of peak daytime temperature (i.e., the temperature at the hottest time of day) at the hatchery site in the reference period (1984-2003) were 89.2°F and 101.9°F. For the near future period (2024-2043), these percentiles are projected to rise to 92.4°F and 105.7°F. Ambient air temperatures can warm raceway water in these conditions. Staff currently manage these conditions by feeding fish only in the morning and reducing contact with fish in the afternoon to avoid stressful conditions for both staff and animals. As mean and maximum ambient temperatures continue to rise in the future, solar effects on hatchery water temperatures are expected to worsen.

5.0 Alternative Selected

During the site visit, deficiencies were identified that currently limit the hatchery's ability to meet fish production goals. 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, improve biosecurity, and increase operational efficiencies. The following section presents a summary of the preferred alternative that would best utilize the alternative technologies to respond to the existing deficiencies, optimize current 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 Alternative Description

5.1.1 Steelhead Spawning and Adult Holding System

A dedicated building would provide space for adult holding, spawning, and reconditioning of adult steelhead. According to Mokelumne River Hatchery's Spawning and Release Protocol for steelhead, the annual broodstock collection goal is 270 fish (1:1 male to female ratio). The proposed adult holding system will allow for up to 300 adult steelhead to be held, each with an average size of 3 pounds and 20.5 inches long. A maximum holding density of 0.67 ft^3/lb of fish was used, based on National Marine Fisheries Service (NMFS) recommendations for long-term adult holding (NMFS 2022) and an average December water temperature of 55°F. For 300 adult fish (900 pounds), a total volume of approximately 603 ft^3 is required. This volume will be split among four circular tanks, to provide flexibility to separate fish by sex, ripeness, or other indicators used by hatchery staff. Adult steelhead will be trapped and sorted in the existing broodstock collection building based on current operations; instead of holding them in raceways, fish will be transferred to the circular tanks until they are ready to spawn. The circular tanks will be 10-feet in diameter with a water depth of 5 feet and a wall height of 6 feet, each tank with a volume of 392 ft^3. Each tank will be outfitted with protection (nets or covers) to prevent fish from jumping out. The total volume of the combined adult holding tanks will be approximately 1,570 ft^3; excess volume will allow for fish to be held in two tanks if spawning and sorting operations require. Required flow rates for steelhead adult holding are also based on the NMFS long-term holding guideline of 1.34 gpm per adult fish held; for 300 adult fish a total flow rate of 402 gpm is required, or approximately 100 gpm per tank. The water supply and drain lines for each tank would be sized to accommodate up to 200 gpm of flow to allow operational flexibility in the event where 150 fish may be held in a single tank.

Water treatment for adult holding is proposed to limit mortality associated with handling and stress of spawning operations. This would include filters and a UV disinfection system. The equipment would be sized to treat a flow rate up to 675 gpm (1.5 cfs) to provide flexibility and increase flow rates if needed. Additionally, the water supply would be diverted through a chiller to cool water as needed. The proposed chiller would be 170-tons, capable of chilling the water demand (~1 cfs) approximately 7°F.

Details about specific spawning equipment will be developed as designs progress, but it will include anesthesia equipment, rinsing tables, and other miscellaneous equipment to aid operations. The area will also include adequate space for handling and spawning steelhead, as well as egg rinsing and disinfection. The adult holding tanks would be positioned near the existing adult holding ponds and spaced to provide direct forklift access to each individual tank. This will allow staff to easily transfer steelhead from the existing adult capture ponds to the new steelhead holding and spawning area.

5.1.2 Steelhead Production System Building

5.1.2.1 Incubation and Early Rearing

The proposed steelhead production system would provide space for egg incubation and early rearing. It is assumed that a maximum of 400,000 eggs will be incubated in a single spawning season, which would be collected from approximately 150 females. To maintain family groups, one tray will be allocated for each female spawned, requiring 150 Heath trays. Assuming a full Heath stack holds 15 usable trays (with the top tray reserved for treatment mixture or sediment settling), 10 full Heath stacks would fulfill incubation requirements for the program. Each Heath stack requires a maximum flow rate of up to 6 gpm, for a total of 60 gpm for the incubation system. Filtration and UV disinfection is proposed capable of treating the required flows to operate the incubation area.

The building will also include deep tanks to provide adequate rearing space for steelhead fry. Deep tanks will be identical to those in the current hatchery building, each is 1.5 feet wide, 16 feet long, with a water depth of approximately 22 inches for a tank volume of 44 ft^3. The steelhead building would provide rearing space to hold approximately 270,000 steelhead up to 150 fpp (2.7 inches) in the deep tanks. This would require 55 total deep tanks (2,370 ft^3 total volume), with each tank holding up to 4,910 fish. This would allow the hatchery to raise steelhead fry and provide a 5% buffer from the DI threshold of 0.3. To maintain the FI criteria of 1.5, each tank would require a minimum flow rate of approximately 10 gpm and a total flow rate of 550 gpm (1.2 cfs) for the early rearing system.

It is recommended that the supply water for the proposed incubation and early rearing system is treated by filtration and UV disinfection. The treatment equipment should be sized to treat

2 cfs of water flow. Water chilling would be available to the building and would service all rearing areas, including the grow-out system discussed below.

The incubation and early rearing systems proposed for the steelhead building would be outfitted with appropriate flow meters and low-flow alarms. These upgrades will aid staff in efficiently using water for each system and help to avoid significant mortality events associated with malfunctioning equipment and infrastructure.

5.1.2.2 Grow-Out System

Installing a circular tank system for steelhead smolt grow-out would free up more raceway space for the Mokelumne River Hatchery to achieve the new production goal of 9 million Chinook Salmon smolts. Circular tanks also have several advantages over raceways including self-cleaning tendencies, promoting uniform water quality throughout the tank, ease of adjusting water velocities, and more modular organization for separating family or release groups. However, circular tanks in a PRAS do not perform well if fish are less than 2 inches in length and are fed crumbled feed; the fine particles are difficult to filter and can foul reuse equipment. Building an early rearing system for the 9 million Chinook Salmon would require a substantial footprint, which is why the proposed alternative of circular grow-out tanks is proposed only for steelhead.

The new circular tank system for steelhead grow-out would be sized to accommodate 250,000 smolts at 4 fpp (8.9 inches). This would require 16 tanks, each with a 20-foot-diameter, 6-foot water depth, and 7-foot wall height for a total volume of approximately 30,000 ft^3. The tanks would be organized into four modules each with four tanks. To provide a hydraulic residence time (HRT) of at least 45 minutes (tank water is completely exchanged every 45 minutes), a flow rate of 325 gpm is required for each tank. Each module (four tanks) would require a flow rate of 1,300 gpm (2.9 cfs), or 5,200 gpm (11.6 cfs) for the entire steelhead grow-out system.

It is recommended that early operations begin with a recirculation rate of 50% or less. As culturists gain knowledge of the equipment and systems the rate can be increased up to 75% without the need for a biofilter. Recirculation equipment including pumps, filtration, degassing, oxygenation, chilling, and UV disinfection systems would be sized to accommodate a range of flow rates to operate up to a recirculation rate of 75%. Each module’s recirculation equipment would be sized to treat and recondition a flow rate up to 975 gpm (2.2 cfs), with 325 gpm of fresh make-up water added to the module for a process flow rate of 1,300 gpm.

Two (2) 250-ton chillers are proposed for the Steelhead Grow-out Building to chill the incoming make-up water by approximately 3.5°F at 50% recycle (2,600 gpm, 5.8 cfs) or by 7°F at 75% recycle (1,300 gpm, 2.9cfs). These chillers will also be used for any chilling required for egg incubation or early rearing water flows. Table 5-1 presents a summary of the proposed systems for steelhead. Note that the total water demand is 2,312 gpm, which is 5.15 cfs.

Table 5-1. Summary of Proposed Steelhead Systems

System	Rearing Vessel	Culture Dimensions	Total Units	Water Demand (gpm)
Incubation	Heath stack	NA	10	60
Early rearing	Deep tank	16' x 1.5' x 1.83'	55	550
Grow-out	Circular tank	20' dia x 6' depth	16	1,300
Adult holding	Circular tank	10' dia x 5' depth	4	402

5.1.3 Research and Special Release System

To assist the Mokelumne Hatchery with various special requests to hold additional fish for research purposes, a new rearing system is proposed in the current footprint of southern settling pond located west of the raceways. The system would have eight circular tanks: four large 20-foot diameter, 6-foot water depth, and 7-foot wall height tanks and four smaller tanks with a 12-foot diameter, 4-foot water depth and a 5-foot wall height. The large tanks would have an operating volume of approximately 1,885 ft^3 (total volume of 7,540 ft^3), the small tanks would have an operating volume of approximately 452 ft^3 (total volume of 1,808 ft^3).

To maintain an HRT of 45 minutes, each large (20-foot diameter) tank would require a flow rate of 325 gpm and all four tanks would require 1,300 gpm. The large tank system would be designed as a single PRAS module, with necessary equipment to recirculate up to 75% of the water used. It is recommended that early operations begin with a recirculation rate of 50% or less. As culturists gain knowledge of the equipment and systems the rate can be increased up to 75% without the need for a biofilter. Recirculation equipment including pumps, filtration, degassing, oxygenation, chilling, and UV disinfection systems would be sized to accommodate a range of flow rates to operate up to a recirculation rate of 75%. The system's recirculation equipment would be sized to treat and recondition a flow rate up to 975 gpm (2.2 cfs), with 325 gpm of fresh make-up water added to the module for a process flow rate of 1,300 gpm.

For the small (12-foot-diameter) tank system, a process flow rate of 120 gpm is required for each tank to achieve a minimum HRT of 30 minutes. The small tanks would be designed as an independent PRAS that would require approximately 480 gpm of total process flow. The recirculation equipment would be designed to process up to 360 gpm for operation at a 75% reuse rate, which would require approximately 120 gpm of fresh make-up water added to the system. This provides some buffer for equipment recirculation rates and make-up water requirements while achieving the required process flow rate of 480 gpm.

A 250-ton chiller is proposed, if both PRASs were operating at 50% reuse (890 gpm [2 cfs]), the chiller would be capable of decreasing the incoming water temperature by approximately 5.5°F.

5.1.4 Raceway Improvements

5.1.4.1 Outdoor Rearing Shade Structure

In order to address some existing issues with the predator netting, as well as to mitigate warming due to solar radiation, an outdoor shade structure is proposed over the production raceways. The shade structure would cover the raceways and proposed PRAS equipment, an approximate area of 420-feet by 390-feet, and would consist of a solid roof with open sides that would retain the existing fencing as both predator exclusion and public access restriction. Predator netting would tie the fence into the roof structure in order to provide a complete enclosure around the production raceway facilities. The shade structure would comprise a pre-engineered metal fabrication, and would require columns at intervals, which would protrude from the edges of the raceways slightly to maintain access between the raceways for hatchery equipment. The shade structure would additionally provide an opportunity for offsetting future operational energy expenditures with the installation of solar panels. The structure would also reduce the impact of radiative heating from the face of the dam, which can significantly increase air temperatures at the hatchery and negatively impact worker safety.

5.1.4.2 Raceway Refurbishing

Raceways would be cleaned and resurfaced to seal exposed aggregate and pitting below the water line as needed. Expansion joints will be serviced and repaired as well, including the removal of existing material. Finally, an epoxy coating, or similar product, will be used to seal the concrete and help maintain its condition. This will allow for continued use of the raceways for 10-15 years before additional maintenance is required.

5.1.5 Existing Hatchery Building Improvements

To mitigate the potential for increased water temperatures, the existing chiller is proposed to be replaced with a larger 250-ton chiller. Increasing chilling capacity is important to maintain optimal water temperatures for egg incubation and allow for slower development of eggs, spreading out hatching and early fry rearing.

As noted in Section 4.1.3, the hatchery building currently has problems with fluctuations in delivery water pressure to the points of use, due to changes in the Camanche Reservoir levels, as well as changes to the demand at the production raceways. To maintain constant pressure to the hatchery buildings a new pilot-actuated control valve in a precast concrete valve vault is proposed on the line coming into each of the hatchery facilities. The control valve will modulate its opening based on a pilot-system regulator to introduce hydraulic losses across the valve. These losses will maintain a set-point pressure on the downstream side of the valve regardless of the upstream head pressure condition or the total demand for all facilities. The valve would be equipped with a strainer, isolation gate valves, and bypass pipe and valve, such that the valve could be taken offline for maintenance.

The set-point pressure would be determined as required to provide design flows under some worst-case condition of reservoir level and hatchery demands. Under those conditions, the valve would be fully open and would meet the hatchery demands. For all pressures greater than the worst-case condition, the valve would modulate to maintain this constant pressure such that downstream adjustments to throttling valves are minimized. Final determinations of the set-point pressures and valve sizes will vary by facility and will depend on the proposed infrastructure and layout.

5.2 Pros/Cons of Selected Alternative

Table 5-2 provides a high-level summary of the pros and cons for Mokelumne River Hatchery's selected alternative.

Table 5-2. Pros and Cons of Selected Alternative – Mokelumne River Hatchery.

Description	Pros	Cons
Construct a building for a steelhead spawning and adult holding system.	• Provides dedicated space for steelhead adult holding and spawning. • Provides a water supply treatment system that includes chilling. • Provides a climate-controlled indoor space.	• Increases cost due to construction. • Requires handling and transport of fish from trap to building. • Additional water supply needs.

Description	Pros	Cons
Construct a steelhead production building.	• Allows for more increased production of both species. • Improves biosecurity and prevents predation. • Reduces water use with PRASs and makes water treatment options more feasible. • Provides a climate-controlled indoor space.	• Increases cost due to construction. • Increases operation costs to run PRAS equipment. • Additional water supply needs.
Add a research production system.	• Allows for research without sacrificing production space.	• Increases cost due to construction and increased operation. • Distance from all other fish production/rearing areas. • Additional water supply needs.
Refurbish raceway and shade structure .	• Provides a cooler environment for staff and fish. • Improves biosecurity. • Provides an opportunity for cost recuperation with solar panels. • Maintains existing raceway condition for 10+ years.	• Increases cost due to construction.
Improve the existing Hatchery Building's water supply using pilot-actuated control valves.	• Maintains consistent head pressure and flow rates and makes it easier to operate.	• Adds mechanical complexity. • Increases cost due to construction.

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 Additional Water Treatment for Incubation

To provide resiliency to impacts from climate change, and to control production timing at the facility, additional water chilling for egg incubation is proposed. This would involve upsizing the existing 165-ton chiller to provide chilling for a larger temperature differential. The current estimated change in water temperature for a 165-ton chiller operating with a 2.0 cfs flow rate is 4.4°F. An upgrade to a 250-ton chiller is proposed and this would result in a temperature differential of 6.6°F, or a 50% relative increase in chilling capacity. This would help control egg development and allow the hatchery to maintain optimal water temperatures for incubation as water temperatures in Camanche Reservoir are expected to increase due to reduced snowpack and streamflow described in Section 3.5.2.

5.3.2 Skim and Epoxy Coating of Raceways

A mortar skim-coat is proposed to repair the concrete where pitting and exposed aggregate are present. Expansion joints would be serviced and repaired as well, including the removal of existing material. This would be performed prior to using an epoxy coat, or similar product, to seal the concrete for extended protection. This type of resurfacing maintenance will be required periodically (every 10 to 15 years) to maintain the current raceway operations for the next several decades. Resurfacing the concrete will provide a smoother rearing environment for fish and make it easier for staff to maintain a clean rearing environment.

5.3.3 Predation Netting

The current bird netting is in a state of disrepair; complete replacement of the structure is proposed. If a permanent roof structure is not the selected alternative, the predator exclusion system would be replaced with a similar structure, open-air with mesh covering over the top and chain link fencing along the sides framed with metal supports. This structure would require regular maintenance, repair, and replacement of netting sections to maintain its condition for several decades.

5.3.4 Demolish Unused Tanks and Equipment

Removal of existing round tanks to the east of the adult holding ponds is proposed. Existing water supply lines for this system may be assessed and capped in place if conditions are acceptable. These supply lines may be used for potential hatchery building or adult holding expansion in the future.

There is an irrigation tank and associated equipment located south of the hatchery building. Removal is proposed to allow for more flexibility in site layout and organization for hatchery operations and future projects.

5.3.5 Install Low-Flow Alarms

Low-flow alarms are proposed for all rearing areas to avoid catastrophic mortality events that have occurred in the past. Alarms would be incorporated into the existing hatchery building and raceway infrastructure to notify staff of temporary water loss to the facility.

5.4 Natural Environment Impacts

The proposed upgrades to the Mokelumne River Hatchery should have negligible impacts on the natural resources in the surrounding area. All improvements would occur within currently developed areas except for the proposed public parking area which would be located on an already cleared area adjacent to the existing parking lot at the base of the dam. It is not anticipated that improvements would require additional environmental or cultural permits not identified in Section 7.0. An exception may occur if any existing structures fall under the jurisdiction of California’s Office of Historic Preservation (OHP).

5.4.1 Fire and Flood Risk

The recommended changes to the Mokelumne River Hatchery will change the existing infrastructure and increase the number of rigid structures onsite. This will increase the defensible area that the facility must maintain to protect its infrastructure during fires. The risk of fire is expected to increase, and the lack of recent fires within the watershed has potentially caused a buildup of fuel storage (Section 0). Aside from expected fire damage associated with current infrastructure, the proposed upgrades would include equipment with more failure points. Increased use of pumps, filters, and disinfection systems rely on electrical power; if fires disrupt the electrical supply infrastructure the hatchery may have to rely on backup generators for extended periods of time. Additionally, proposed oxygenation equipment creates a more dangerous situation in the event fire spreads to the facility. Staff must regularly check oxygenation equipment to ensure any potential leaks are promptly addressed.

Fire and flood risk are related, with flooding more probable in burn scarred watersheds with less vegetation to absorb rainfall. Occasionally, day use areas on the Mokelumne River near the hatchery are closed to the public because of dangerously high-water levels. Camanche Dam provides flood protection for the area below the dam, which limits some flood risk. The proposed upgrades do not include any additional structures that would be closer to the Mokelumne River relative to other existing structures. The steelhead adult holding and spawning system would be located near the raceways and existing adult holding area, but the steelhead production system and research tanks would be constructed further away from the river, slightly reducing the risk of flood damage. The implementation of pressure-regulated valves for the hatchery building will also provide staff with consistent flow into the building.

This will reduce the risk of tanks overflowing or running at dangerously low flows as the reservoir level fluctuates.

5.4.2 Effluent Discharge

The proposed alternatives for the hatchery do not include an overall increase in production goals, which are tied to salmon restoration programs and multiple stakeholders. The hatchery does not use all the existing effluent ponds, which currently occupy nearly 4 acres. As part of the recommended upgrades, the southernmost effluent pond would be filled in to provide space for extra research rearing. The research system would require only a small fraction of the space, providing more area for potential future developments or expansion. Since the effluent pond that would be demolished is unused, it would not affect the hatchery's ability to maintain its current NDPES 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 that waste load (fish biomass) is not anticipated to change with 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

The proposed upgrades should help alleviate spacing issues and logistics for the fish production cycle at the hatchery. Providing a dedicated space for all steelhead operations will allow the raceways to be used exclusively for Chinook Salmon. This would allow staff to more efficiently reach the 9 million smolt production goal for Chinook Salmon, without constraints related to the timing of steelhead releases. This would also benefit the marking and tagging operations, allowing for more raceways to be used and increased flexibility. The alternatives would not significantly impact any other stage of the production cycle for Chinook Salmon.

Steelhead production strategies would be significantly altered due to the recommended upgrades. Designs would strive to not impact the existing procedures used to transfer adult steelhead from the existing adult holding ponds, the only change would be their destination in the proposed adult holding circular tanks. Once in the adult holding tanks, staff would need to use seines or clamshell crowders to handle fish. Sorting and spawning operations would have significantly more space, as opposed to the current shed set up near the raceways. Steelhead egg incubation and early rearing would continue as normal, except for additional early rearing space for steelhead. This will provide hatchery staff more flexibility to raise steelhead to larger sizes before transitioning them to the grow-out tanks.

5.5.1 Circular Tank Operations

The adult holding and grow-out tanks for steelhead will have similar operations, with the exception that the grow-out system will operate as a PRAS. 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. Staff must monitor the water velocity in each circular tank to avoid over-exercising fish while maintaining the self-cleaning benefits of the tanks. Based on experiences of other producers (Peterson et al. 2024), the maximum target water velocity is approximately 2 fish body lengths per second (BL/s). Seine nets, clamshell crowders or other crowder types can be used to concentrate fish for collection and handling.

Loading fish for release will utilize fish pumps and hosing to minimize handling and stress on the fish and decrease physical labor for staff. 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 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 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

PRASs 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. The normal production cycle provides 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

Early rearing feeding techniques in the deep tanks can continue using the hatchery’s standard feeding practices. 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 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 provide 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 Mokelumne River Hatchery does not currently have significant disease issues except normal pathogens found at nearly all fish hatcheries, primarily *Flavobacterium* spp. that cause bacterial coldwater disease and Columnaris disease. The most likely pathways for pathogens to enter the Mokelumne River Hatchery are through the incoming water supply or environmental exposure within the hatchery. The proposed steelhead early rearing system would include filtration and UV disinfection of the incoming water supply. This will reduce the risk of pathogens affecting steelhead during the early life stages, including egg incubation and hatching.

5.6.1 Environmental Exposure/Bio Vectors

The existing facility has several areas that are potential pathways for pathogens due to environmental exposure. The existing raceways are enclosed by perimeter fencing with bird netting overtop, but these structures still allow for some instances of predation. All new proposed fish holding and rearing systems would be covered with solid roof structures and chain link fencing along the sides, completely excluding predators. Additionally, the existing raceways would be covered with a solid roof structure, to include fencing and netting along the sides. These improvements would significantly reduce the risk of predation and limit the potential for pathogen introduction into the rearing areas.

5.7 Water Quality Impacts

The recommended alternatives will maintain good water quality for all existing and proposed rearing areas. The circular tanks will provide a quality environment with equal dissolved oxygen levels throughout the tanks. Circular tanks also excel at flushing solids from fish waste or uneaten feed from the rearing environment, further improving water quality. The steelhead PRAS will maintain exceptional water quality from the filtered, disinfected, and oxygenated water, with only a fraction of the water consumption required for the raceways. There may be a slight reduction in water demand during various times of the year, but this will depend on CDFW's management of flows to individual rearing areas. The PRAS will concentrate solids into a smaller waste stream which has the potential to overwhelm effluent systems designed for specific flow rates and solids concentrations. However, the hatchery does not rely on its entire effluent pond system and even accounting for the demolition of the southernmost effluent pond, there should be adequate space to maintain effluent water quality in accordance with NPDES requirements.

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 estimate, 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 Class 5 cost estimates for this alternatives analysis:

- All unit costs assume 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.
- Geotechnical investigation is included in the project costs, assuming 7 bore holes (20 feet deep), material testing, and a written report, as well as piezometer installation.
- Topographic survey cost was assumed 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. Sute 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 Mokelumne Fish 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 including the detailed replacement value. The cost of all work items generated was $1,194,036 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 Mokelumne Fish 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.
- PRAS equipment for the raceways and the effluent treatment equipment will be enclosed in non-conditioned areas with sheet metal systems for walls and doors. Ventilation for humidity will be included.
- Two 500kW backup generators are proposed for new equipment; it is assumed that there is adequate backup power capacity for existing equipment and 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

The site offers substantial photovoltaic (PV) potential, particularly if the proposed public parking area is incorporated into a PV shading system. The strategic use of space ensures that the site not only meets but exceeds its energy needs, creating an area surplus of approximately 38,163 square feet that can be used to enhance energy resilience.

6.6 Alternative Cost Estimate

The following tables illustrate the estimated costs for each of the proposed improvements evaluated and depicted in Appendix C.

Table 6-2. Alternative Cost Estimate

Item	Estimate	
Division 01 – General Requirements (Includes Mobilization/Demobilization)	$	8,520,000
Division 02 – Existing Conditions	$	118,000
Division 03 – Concrete	$	4,002,000
Division 05 – Metals	$	220,000
Division 07 – Thermal and Moisture Protection	$	20,000
Division 08 – Openings	$	100,000
Division 13 – Special Construction	$	29,443,000
Division 23 – Mechanical & HVAC	$	450,000
Division 26 – Electrical	$	4,380,000
Division 31 – Earthwork	$	1,571,000
Division 32 – Exterior Improvements	$	208,000
Division 40 – Process Water Systems	$	2,091,000
2024 CONSTRUCTION COST	**$**	**51,123,000**
Construction Contingency	$	12,781,000
Overhead	$	3,067,000
Profit	$	4,090,000
Bond Rate	$	512,000
2024 CONSTRUCTION PRICE	**$**	**71,573,000**
Design, Permitting and Construction Support	$	10,736,000
Geotechnical	$	25,000
Topographic Survey	$	20,000
PROJECT TOTAL	**$**	**82,354,000**
Accuracy Range +50%	$	123,531,000
Accuracy Range -30%	$	57,648,000
Photovoltaic Required (3,872 kW)	$	10,454,400
Photovoltaic Available Roof space (2,943 kW)	$	7,946,100

7.0 Mokelumne River Hatchery Environmental Permitting

7.1 Anticipated Permits and Supporting Documentation

The proposed Project would involve the modification to the existing hatchery or construction of a new hatchery facility 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 (USFWS IPAC and California 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, 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 Approvals for Selected Location

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 US 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 Permits and Approvals for Selected Location

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	N/A	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

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
California Division of Water Rights Water Rights	Application or Transfer	N/A	4 months	N/A
California State Water Resources Control Board (SWRCB) National Pollutant Discharge Elimination System (NPDES)	Application (Note facility renovation/construction may trigger “New Source” permit for NPDES)	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 San Joaquin Permits and Approvals for Selected Location

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

7.2 National Pollutant Discharge Elimination System (NPDES) Permitting

The Mokelumne River Hatchery is classified as a cold water Concentrated Aquatic Animal Production (CAAP) facility and is eligible to operate under General Order R5-2019-0079-007 issued by the Regional Water Quality Control Board, Central Valley (Region 5) and NPDES Permit No. CAG135001. This general order supersedes the previous NOA (R5-2014-0161-017) issued January 15, 2015.

Wastewater is discharged through three outfalls:

- Outfall 001: Latitude: 38° 13' 34.22" N; and Longitude: 121° 01' 32.42" W
- Outfall 002: Latitude: 38° 13' 34.17" N; and Longitude: 121° 01' 32.24" W
- Outfall 003: Latitude: 38° 13' 34.49" N; and Longitude: 121° 01' 25.12" W

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)

7.3 Water Rights

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

8.0 Conclusions and Recommendations

This report provides valuable information on the impacts that the Mokelumne River Hatchery could experience as a result of climate change and provides modifications that can be made to increase the resiliency of the hatchery. The in-depth analysis of the available hydrologic data performed by NHC provides projections to forecast changes that may be experienced. In general, air temperatures are expected to increase, and snowpack is expected to decrease leading to lower reservoir levels and warmer water temperatures during some periods relative to historic averages. Additionally, the hatchery will remain at risk of being impacted by wildfires in the watershed, potentially near the hatchery property.

To meet CDFW’s goal of continuing to provide commercial and recreational fishing opportunities for the public, support mitigation targets, and for the conservation of endangered or threatened species as the climate changes, the resiliency of existing hatcheries will need to be increased. Hatchery upgrades require updating existing infrastructure that is nearing the end of its effective lifespan.

Some recommendations that would help to achieve this goal include the following:

- Constructing a new steelhead adult holding area, compliant with NMFS criteria, to include work areas for spawning activities.
- Constructing a new steelhead production building to maintain separation between species at the facility. Increased rearing space will allow the hatchery to meet increased production goals while maintaining optimal rearing conditions and densities.
- Demolishing unused effluent ponds and constructing an isolated research rearing area to provide flexibility for research activities without compromising fish production goals.
- Refurbishing the raceways to extend the usable life and covering them with a permanent roof structure to provide protection against high air temperatures for staff and to reduce predation of fish in raceways.
- Upgrading the existing hatchery building by installing a control valve to allow for constant water pressure and increasing the size of the water chiller to account for increasing water temperatures.
- Installing solar panels atop new structures will offset some of the power demands associated with new hatchery equipment.

The proposed upgrades to the Mokelumne River Hatchery would have negligible impacts on the natural resources in the surrounding area. All improvements would occur within currently developed areas, which lessen the permit requirements. The total cost estimate of the proposed design modifications is $82,354,000.

9.0 References

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