Climate Induced Hatchery Upgrades

Moccasin Creek Hatchery

Alternatives Analysis Submittal

Final Report
Revision No. 4

February 2025

This page intentionally left blank.

Table of Contents

List of Tables

List of Figures

Distribution

To: Daniel Niederberger, PE
CDFW

Kenneth Kundargi, Hatchery Program Manager
CDFW

From: Noah Hornsby, PE
McMillen, Inc.

Prepared By: Noah Hornsby, PE
Mike Boo, PE
Evan Jones
Megan Wilmott
McMillen, Inc.

Reviewed By: Derek Nelson, PE
Jeff Heindel
Mark Drobish
McMillen, Inc.

Revision Log

Revision No.	Date	Revision Description
0	3/22/2024	65% Draft Internal Technical Review
1	3/29/2024	65% Draft for CDFW Review
2	8/30/2024	100% Draft for CDFW and Internal Technical Review
3	10/31/2024	Final Submittal to CDFW
4	2/19/2025	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).

Moccasin Creek Hatchery has an aging infrastructure and deficiencies that need to be addressed in the near future in order to meet fish production goals. The leaking intake water distribution structure, lack of incoming water treatment, abandoned Moccasin Creek diversion structure, exposed HDPE piping, low oxygen levels in the raceways, aged plumbing with insufficient flow control, truck fill station, predation issues in the raceways, deteriorating concrete raceways, and limited backup power generation are all items that have been noted to hinder current production. The effects of which will magnify with climate change.

The preferred alternative for hatchery upgrades includes the replacement of the intake water distribution structure and truck fill station, burial of the exposed HDPE recirculation pipe, valving and piping upgrades to minimize leakage, increased flow monitoring and control, incorporation of additional water reuse and treatment, concrete raceway cover structures and resurfacing, increased backup power generation, and centralized monitoring.

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 may need to update feeding, harvesting, and water quality monitoring protocols to accommodate partial recirculating aquaculture systems. 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
$49,211,000	$6,326,100

1.0 Introduction

1.1 Project Authorization

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

1.2 Project Background

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

A total of 21 hatcheries were visited by McMillen to evaluate the existing infrastructure and fish production operations. During these visits, McMillen assessed the existing hatchery infrastructure deficiencies and replacement needs. The assessment was used to aid in determining the potential upgrades for each hatchery that would maintain the 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. 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 those CDFW hatcheries and the existing infrastructure conditions that are most susceptible to reduced fish production attributable to climate change and provide a prioritization of the hatcheries for improvements. With input from CDFW, designs for climate change resiliency upgrades will be advanced for as many facilities as is feasible.

1.4 Site Location Description

The Moccasin Creek Hatchery is located in the town of Moccasin, CA in the Mother Lode foothill region of the Western Sierra-Nevada Mountain Range and approximately 52 miles from Modesto, CA (Figure 1-1).

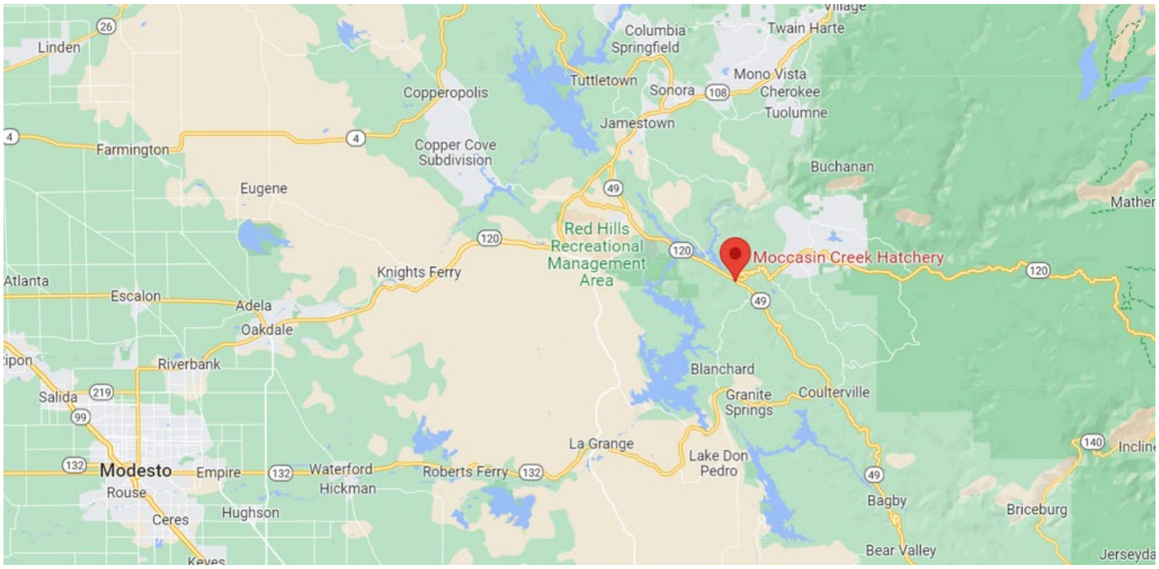

Figure 1-1. Moccasin Creek Hatchery Location Map.

In 1954, the Moccasin Creek Hatchery opened with 24 dirt ponds. Over the years, the hatchery has expanded to include eight concrete raceways, including forty-eight 100-foot-long ponds. The hatchery building originally consisted of 88 troughs and six round redwood tanks. In 2011, 10 deep tanks replaced 20 troughs, and in 2012, the round redwood tanks were replaced by six round fiberglass tanks. The Moccasin Creek Hatchery raises two strains of Rainbow Trout (*Oncorhynchus mykiss*), Brown Trout (*Salmo trutta*), and Golden Trout (*O. aquabonita*) with a combined fish production goal of approximately 400,000 pounds. The hatchery regularly operates as a flow-through system with recirculation capabilities required during periods of maintenance that limit their water supply and production. During normal operations and during maintenance periods, surface water is supplied from Moccasin Reservoir. Water can be provided directly from the powerhouse, but not during maintenance periods. The general facilities are shown in Figure 1-2. See the Site Visit Report (Appendix A) for additional details regarding the existing facilities.

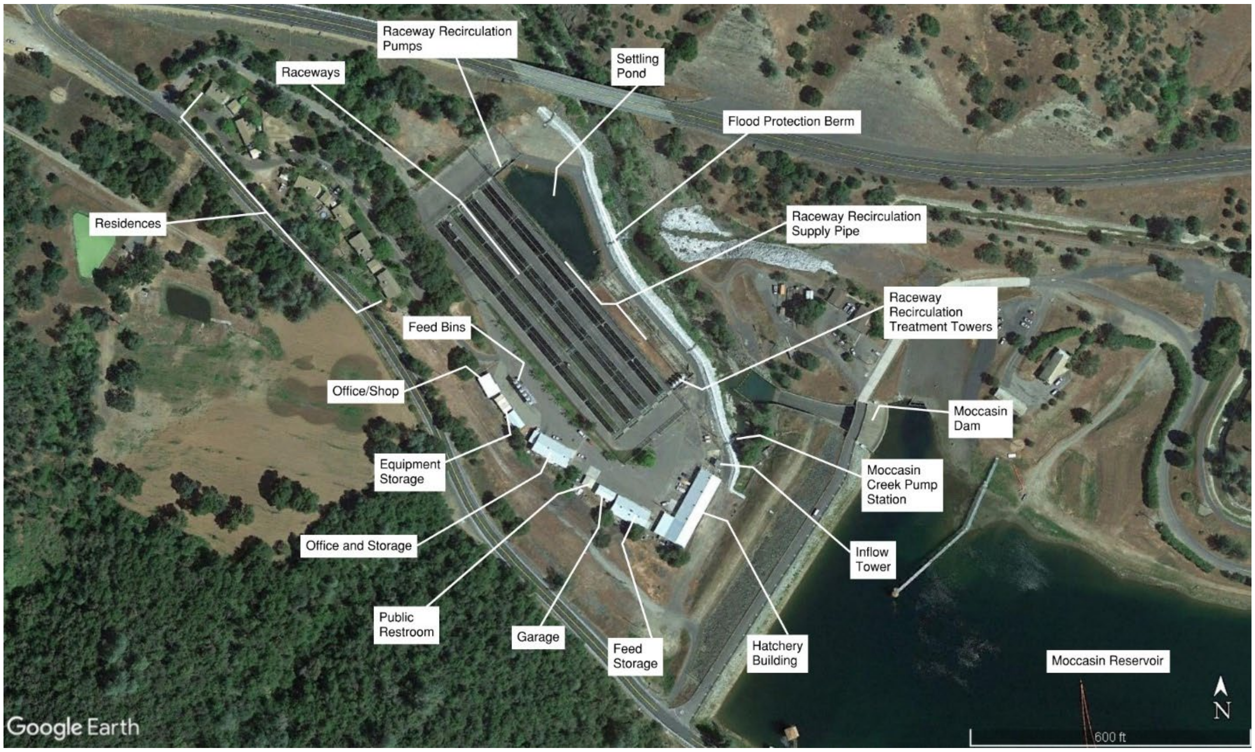

Figure 1-2. Moccasin Creek Hatchery Facility Layout. Google Earth Image Date: Apr. 2021.

2.0 Bioprogram

2.1 Production Goals and Existing Capacity

2.1.1 Inland Fisheries

California's hatchery production goal for inland trout is based on sport fishing licenses sold in the previous calendar year. This requirement sets a production goal for CDFW hatcheries to produce and release 2.75 pounds of trout per sport fishing license sold. The requirement stipulates that the majority of released fish be of a catchable size (2 fish per pound) or larger and requires CDFW to achieve this goal in compliance with certain policies, including the Strategic Plan for Trout Management. Currently, CDFW achieves approximately 35% of the required production based on sport fishing license sales. CDFW is also required, to the extent possible, to establish and maintain native wild trout stocks and protect native aquatic and nonaquatic species. CDFW currently utilizes a trout triploid program (sterile trout) to avoid genetic impacts to native trout populations through the stocking program.

The Moccasin Creek Hatchery produces Rainbow Trout, Brown Trout, and a small number of Golden Trout. The Capacity Biological Program (Capacity Bioprogram) for the facility was developed for the Site Visit Report (Appendix A) and provides the total numbers of fish and biomass that can be produced for all rearing tanks based on tank volume, operational water flows, and size of the fish. The calculations utilize the density and flow indices previously identified for the preliminary bioprograms which encompass water temperature and elevation criteria to ensure oxygen levels appropriately align with production. This information is available in the Site Visit Report (Appendix A). The calculations include a 10% safety factor to provide a 90% maximum capacity based on both the density index (DI) and flow index (FI) requirements identified. The annual production goal at the Moccasin Creek Hatchery is 400,000 pounds of fish released. However, ongoing maintenance of the Moccasin Reservoir, the water supply for the hatchery, has reduced annual production goals to 200,000 pounds of fish. The rearing capacity determined by the Capacity Bioprogram, assuming that dam maintenance is completed in 2026, and the full water right is restored, is shown in Table 2-1, Table 2-2, and Table 2-3. The production goal for each species is as follows:

- Rainbow Trout: 700,000 fish weighing 350,000 lbs
- Brown Trout: 60,000 fish weighing 4,000 lbs
- Golden Trout: 50,000 fish weighing 50 to 100 lbs

Table 2-1. Production Capacity of the Rainbow Trout Rearing Unit at the Moccasin Creek Hatchery per the Capacity Bioprogram (Appendix A).

Rearing Unit (max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
Troughs (180 fpp[b]/2.40 inches)	72,755 (404 lbs)	Rearing volume
Raceways (2 fpp/10.8 inches)	534,117 (267,059 lbs)	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] fpp = fish per pound

Table 2-2. Production Capacity of the Brown Trout Rearing Unit (Appendix A).

Rearing Unit (max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
Troughs (300 fpp/2.0 inches)	101,049 (337 lbs)	Rearing volume
Deep tanks (180 fpp/2.40 inches)	92,425 (513 lbs)	Rearing volume
Raceways (15 fpp/5.5 inches)	42,509 (2,833 lbs)	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.

Table 2-3. Production Capacity of the Golden Trout Rearing Unit (Appendix A).

Rearing Unit (max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
Troughs (1,000 fpp/1.36 inches)	235,781 (236 lbs)	Rearing volume
Circular Tanks (500 fpp/1.71 inches)	153,956 (308 lbs)	Water flow

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

2.2 Bioprogram Summary

The Capacity Bioprogram in the Site Visit Report (Appendix A) demonstrates the total capacity of each rearing area at the Moccasin Creek 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 2-1, Table 2-2, and Table 2-3. The total capacity for the Moccasin Creek Hatchery falls short of the production goal, although nuances of the timing of egg arrivals, fish stocking, and early rearing strategies allow for annual production to exceed the capacity. Details about the various rearing areas and infrastructure are discussed in the Site Visit Report, found in Appendix A.

In this current report, McMillen 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 Moccasin Creek 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, growth rate and survival rate assumptions were made and included in Table 2-5 and Table 2-6. Additional assumptions include the following:

- CDFW will have the ability to have Rainbow Trout eggs available throughout the year by either purchasing eggs from private vendors or through CDFW's own photoperiod programs.
- There will be optimal conditions for egg development and fish growth given the existing water temperatures at the facility.

Klontz (1991) provided optimal growth rates for Rainbow Trout at designated water temperatures, and survival rates were provided by Moccasin Creek Hatchery staff.

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

Criteria	Value
Density index (DI)	0.3
Flow index (FI)	1.61
Water temperature	Varied 44-55°F

Table 2-5. Growth Rate Assumptions Used for the Production Bioprogram.

Species	Value
Rainbow Trout	Approximately 0.66 inches per month
Brown Trout[a]	Approximately 0.28 inches per month from February to May Approximately 0.50 inches per month from May to December
Golden Trout	Approximately 0.30 inches per month

[a] Brown Trout early rearing takes place exclusively during cooler water temperatures (<50° F); for simplicity Rainbow Trout were modeled with a constant growth rate because of the various Pulse timings and water temperatures experienced over their production cycle.

Table 2-6. Survival Rate Assumptions Used for the Production Bioprogram.

Species	Value
Rainbow Trout	Egg-to-Juvenile (300 fpp): 70% Juvenile-to-outplant (2 fpp): 75%
Brown Trout	Egg-to-outplant (15 fpp): 65%
Golden Trout	Hatch-to-outplant (500 fpp): 80%

2.2.2 Production Bioprogram

This bioprogram (Appendix B) is meant to view hatchery operations at a high level and does not capture the nuances of specific timing of fish transfers, grading, sorting, or stocking. The model is meant to show an example of how production may occur given the criteria and assumptions outlined in the previous section. This program uses four groups of Rainbow Trout eggs delivered at specific times to maximize production. Each of these groups of Rainbow Trout eggs is referred to as a “Pulse” (i.e., Pulse 1, 2, 3, and 4) in the following narrative.

2.2.2.1 Rainbow Trout Pulse 1

Pulse 1 will arrive at the hatchery in October and will include approximately 170,000 Rainbow Trout eggs (Table 2-7). Approximately 140,000 fish will survive to first feeding at the beginning of November at an approximate size of 3,000 fpp (0.9 inches). These fish will be split among all 64 troughs. Fish will reach 300 fpp (2 inches) in early January and approximately 120,000 fish will be evenly split into two raceways and kept in the upper 100-foot section of each. Ideally, fish would be held indoors in the hatchery troughs through the end of January to a size of 160 fpp (2.5 inches), but rearing volume is limited in the hatchery building. Moving fish to raceways earlier increases production potential and frees space for incoming egg lots while maintaining the established DI criteria.

The current year's Rainbow Trout pulse will overlap with the previous brood year's pulse. This becomes apparent when fish are transferred from the troughs into the raceways and is shown in the production schedule (Figure 2-1). As fish are transferred from the troughs into the upstream section of two raceways, fish from the previous brood year will remain in the downstream sections of the same raceways. The bioprogram models the use of the upper 100-foot sections of two raceways through the end of February for the current brood year's cohort (Table 2-7). This provides flexibility for the previous brood year's cohort in the downstream raceway sections to be held longer if necessary. In March, fish from the current brood year's cohort will occupy the entire length of the raceway and the previous brood year's cohort will be completely stocked out. Fish will continue to grow for approximately one year until they reach 2 fpp (10.8 inches) at the end of January. Some fish must be stocked out at this time to make room for the next brood year's cohort of Pulse 1 fish. As mentioned previously, some fish may be held in the lower sections of the raceways until March, or potentially later, given that the established DI and FI criteria are maintained for both overlapping cohorts.

Table 2-7. End of Month Production Information for the Rainbow Trout Pulse 1 Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Early Nov	Troughs	64	3,000	0.90	140,000	46.7	0.7	0.08	0.16
Nov	Troughs	64	900	1.40	130,000	144.4	0.7	0.16	0.32
Dec	Troughs	64	350	1.90	120,000	342.9	0.7	0.29[a]	0.56
Jan	Raceways	2[b]	160	2.50	117,700	735.6	7.2	0.08	0.09
Feb	Raceways	2[b]	76	3.20	115,400	1,518.4	7.2	0.12	0.15
Mar	Raceways	2	42	3.90	113,100	2,692.9	7.2	0.04	0.21
Apr	Raceways	2	25.6	4.60	110,800	4,328.1	7.2	0.05	0.29
May	Raceways	2	16.8	5.30	108,500	6,458.3	7.2	0.06	0.38
Jun	Raceways	2	11.5	6.00	106,200	9,234.8	7.2	0.08	0.48
Jul	Raceways	2	8.3	6.70	103,900	12,518.1	7.2	0.10	0.58
Aug	Raceways	2	6.1	7.40	101,600	16,655.7	7.2	0.12	0.70
Sep	Raceways	2	4.7	8.10	99,300	21,127.7	7.2	0.14	0.81
Oct	Raceways	2	3.6	8.80	97,000	26,944.4	7.2	0.16	0.95
Nov	Raceways	2	2.9	9.50	94,700	32,655.2	7.2	0.18	1.06
Dec	Raceways	2	2.3	10.20	92,400	40,173.9	7.2	0.21	1.22
Jan	Raceways	2	2.0	10.80	90,000	45,000.0	7.2	0.22	1.29

[a] In late December and early January, fish reach the DI criteria of 0.3 and must be transferred to the raceways.

[b] Fish are kept in only the uppermost 100 ft sections of each of these raceways.

2.2.2.2 Rainbow Trout Pulse 2

Pulse 2 fish will arrive at the facility in July (Table 2-8) and follow a similar path as the Pulse 1 fish. Approximately 170,000 eggs will be incubated and result in 140,000 first feeding fry (3,000 fpp, 0.9 inches) in early August. These fish will be split among 64 available troughs. The Rainbow Trout Pulse 2 group will be reared in the troughs until early October, when approximately 120,000 fish (300 fpp, 2 inches) will be split into two raceways. The same constraints that affect Pulse 1 remain for Pulse 2 fish (early transfers to raceways to make space in the hatchery building and coordinating raceway transfers and raceway stocking). Approximately one year later, Pulse 2 fish will be ready to stock out at 2 fpp at the end of October. Some fish must be stocked out in October to make space for the next cohort of Pulse 2 but there is flexibility to hold some fish for longer if necessary.

Table 2-8. End of Month Production Information for the Rainbow Trout Pulse 2 Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Early Aug	Troughs	64	3,000	0.90	140,000	46.7	0.7	0.08	0.16
Aug	Troughs	64	900	1.40	130,000	144.4	0.7	0.16	0.32
Sep	Troughs	64	350	1.90	120,000	342.9	0.7	0.29[a]	0.56
Oct	Raceways	2[b]	160	2.50	117,700	735.6	7.2	0.08	0.09
Nov	Raceways	2[b]	76	3.20	115,400	1,518.4	7.2	0.12	0.15
Dec	Raceways	2	42	3.90	113,100	2,692.9	7.2	0.04	0.21
Jan	Raceways	2	25.6	4.60	110,800	4,328.1	7.2	0.05	0.29
Feb	Raceways	2	16.8	5.30	108,500	6,458.3	7.2	0.06	0.38
Mar	Raceways	2	11.5	6.00	106,200	9,234.8	7.2	0.08	0.48
Apr	Raceways	2	8.3	6.70	103,900	12,518.1	7.2	0.10	0.58
May	Raceways	2	6.1	7.40	101,600	16,655.7	7.2	0.12	0.70
Jun	Raceways	2	4.7	8.10	99,300	21,127.7	7.2	0.14	0.81
Jul	Raceways	2	3.6	8.80	97,000	26,944.4	7.2	0.16	0.95
Aug	Raceways	2	2.9	9.50	94,700	32,655.2	7.2	0.18	1.06
Sep	Raceways	2	2.3	10.20	92,400	40,173.9	7.2	0.21	1.22
Oct	Raceways	2	2.0	10.80	90,000	45,000.0	7.2	0.22	1.29

[a] In late September and early October, fish reach the DI criteria of 0.3 and must be transferred to the raceways.
[b] Fish are kept in only the uppermost 100 ft sections of each of these raceways.

2.2.2.3 Rainbow Trout Pulse 3

Rainbow Trout in the Pulse 3 group will share early rearing space in the hatchery building with both Brown Trout and Golden Trout. As a result, only 111,000 eggs will be received in April which should result in approximately 91,500 hatched fry ready to feed in early May (Table 2-9). These fish will be split into 24 troughs initially and will reach approximately 900 fpp (1.4 inches) around the end of May. In early June they will be split into 48 total troughs. Splitting into additional troughs cannot occur until the Brown Trout are relocated from the troughs to the deep tanks in early June (Table 2-11). In the beginning of July, approximately 77,077 fish will be relocated to two raceways because fish from Pulse 2 are arriving and will soon occupy all available troughs in the hatchery (Table 2-8). Pulse 3 fish will reach approximately 2 fpp the following year at the end of July and be ready for stocking. The Pulse 3 group of fish will not require the entire length of both raceways because of the reduced population size relative to Pulses 1 and 2. This is shown in Table 2-9 by the final DI of 0.15 once fish reach a catchable size. Having open sections of raceways allows staff to balance production and increase their flexibility to hold some cohorts of fish for extended growth, as necessary.

There is additional flexibility within the Pulse 3 production schedule to hold fish for a longer period indoors by splitting them into more troughs. Up to 62 troughs can be used, which would provide more flexibility to keep the previous years' Pulse 3 fish in the raceways for longer if necessary. Two troughs must be reserved in June and July for the Golden Trout program (Table 2-12).

Table 2-9. End of Month Production Information for the Rainbow Trout Pulse 3 Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Early May	Troughs	24	3,000	0.90	91,500	30.5	0.3	0.14	0.28
May	Troughs	24	900	1.40	85,000	94.4	0.3	0.29[a]	0.56
Jun	Troughs	48	350	1.90	78,500	224.3	0.5	0.25[a]	0.49
Jul	Raceways	2[b]	160	2.50	77,077	481.7	7.2	0.05	0.06
Aug	Raceways	2[b]	76	3.20	75,654	995.4	7.2	0.08	0.10
Sep	Raceways	2	42	3.90	74,231	1,767.4	7.2	0.02	0.14
Oct	Raceways	2	25.6	4.60	72,808	2,844.1	7.2	0.03	0.19
Nov	Raceways	2	16.8	5.30	71,385	4,249.1	7.2	0.04	0.25
Dec	Raceways	2	11.5	6.00	69,962	6,083.7	7.2	0.05	0.31
Jan	Raceways	2	8.3	6.70	68,539	8,257.7	7.2	0.06	0.38
Feb	Raceways	2	6.1	7.40	67,116	11,002.6	7.2	0.08	0.46

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Mar	Raceways	2	4.7	8.10	65,693	13,977.2	7.2	0.09	0.53
Apr	Raceways	2	3.6	8.80	64,270	17,852.8	7.2	0.11	0.63
May	Raceways	2	2.9	9.50	62,847	21,671.4	7.2	0.12	0.71
Jun	Raceways	2	2.3	10.20	61,424	26,706.1	7.2	0.14	0.81
Jul	Raceways	2	2.0	10.80	60,000	30,000.0	7.2	0.15	0.86

[a] In late May and late June, densities in the troughs approach the DI criteria of 0.3 and must be split into additional tanks and transferred to the raceways. This is exacerbated by the overlap with Brown Trout in the hatchery troughs.

[b] Fish are kept in only the uppermost 100 ft sections of each of these raceways.

2.2.2.4 Rainbow Trout Pulse 4

The egg receival of Pulse 4 will coincide with eggs arriving for Brown Trout production. To create space for Brown Trout, the Rainbow Trout Pulse 4 population will be roughly half of that in Pulses 1 and 2. Approximately 94,000 Rainbow Trout eggs will arrive in January, making up the Pulse 4 group. Approximately 85,000 fish will survive to first feeding in early February and will occupy 34 troughs (Table 2-10). Fish will reach approximately 300 fpp (2 inches) in early April and 66,000 will be transferred to a single raceway. Fish will be reared in the raceway for approximately one year until they reach a catchable size (2 fpp) at the end of April yielding approximately 50,000 fish for stocking.

Table 2-10. End of Month Production Information for the Rainbow Trout Pulse 4 Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Early Feb	Troughs	34	3,000	0.90	85,000	28.3	0.4	0.09	0.19
Feb	Troughs	34	900	1.40	80,000	88.9	0.4	0.19	0.37
Mar	Troughs	34	350	1.90	66,000	188.6	0.4	0.30[a]	0.58
Apr	Raceways	1[b]	160	2.50	64,770	404.8	3.6	0.08	0.10
May	Raceways	1[b]	76	3.20	63,540	836.1	3.6	0.14	0.16
Jun	Raceways	1	42	3.90	62,310	1,483.6	3.6	0.04	0.24
Jul	Raceways	1	25.6	4.60	61,080	2,385.9	3.6	0.05	0.32
Aug	Raceways	1	16.8	5.30	59,850	3,562.5	3.6	0.07	0.42
Sep	Raceways	1	11.5	6.00	58,620	5,097.4	3.6	0.09	0.53
Oct	Raceways	1	8.3	6.70	57,390	6,914.5	3.6	0.11	0.64
Nov	Raceways	1	6.1	7.40	56,160	9,206.6	3.6	0.13	0.77

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Dec	Raceways	1	4.7	8.10	54,930	11,687.2	3.6	0.15	0.89
Jan	Raceways	1	3.6	8.80	53,700	14,916.7	3.6	0.18	1.05
Feb	Raceways	1	2.9	9.50	52,470	18,093.1	3.6	0.20	1.18
Mar	Raceways	1	2.3	10.20	51,240	22,278.3	3.6	0.23	1.35
Apr	Raceways	1	2.0	10.80	50,000	25,000.0	3.6	0.24	1.43

[a] In late March densities in the troughs approach the DI criteria of 0.3 and must be transferred to the raceways.

[b] Fish are kept in only the uppermost 100 ft sections of each of these raceways.

2.2.2.5 Brown Trout

Approximately 88,000 Brown Trout eggs will arrive in January with 84,000 fish surviving to first feeding in early February (Table 2-11). These fish will initially be split among 30 available troughs, limited by overlapping production with the Rainbow Trout Pulse 4 group. Once Brown Trout reach 740 fpp (1.45 inches) in late March, they will be split into an additional 10 troughs to occupy 40 total troughs in early April. These transfers will be coordinated with the movement of Rainbow Trout Pulse 4 to the raceways in early April (Table 2-10).

Brown Trout will reach 300 fpp (2 inches) in late May, in early June they will be split into 10 deep tanks to provide additional rearing space and to allow for more trough rearing space for the Rainbow Trout Pulse 3 (Table 2-9). Brown Trout will reach 90 fpp (3 inches) at the end of July and will then be transferred to a single raceway in the uppermost 100-foot section. Fish will be held in the upper 100-foot section until early November when they will be given an additional 100-foot of rearing space in the raceway (200 feet total). Brown Trout should reach the target stocking size of 15 fpp (5.5 inches) at the end of December and will be ready to stock out; approximately 57,500 fish will be harvested.

Brown Trout and the Rainbow Trout Pulse 4 will share the same pair of raceways to stock small fish adjacent to other small fish. This provides some biosecurity best practices by reducing the risk of large fish splashing water or jumping over the wall into the adjacent raceway.

Table 2-11. End of Month Production Information for the Brown Trout Bioprogram Including Realized DI and FI Values.

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Early Feb	Troughs	30	3,000	0.90	84,000	28.0	0.3	0.11	0.21
Feb	Troughs	30	1,500	1.18	80,000	53.3	0.3	0.15	0.30
Mar	Troughs	30	740	1.45	76,000	102.7	0.3	0.24[a]	0.47
Apr	Troughs	40	500	1.73	72,000	144.0	0.4	0.21	0.42
May	Troughs	40	300	2.00	68,000	226.7	0.4	0.29[b]	0.57
Jun	Deep Tanks	10	160	2.50	64,000	400.0	0.4	0.20	0.80
Jul	Deep Tanks	10	90	3.00	60,000	666.7	0.4	0.28[c]	1.11
Aug	Raceways	1[d]	58	3.50	59,500	1,025.9	3.6	0.15	0.18
Sep	Raceways	1[d]	39	4.00	59,000	1,512.8	3.6	0.20	0.23
Oct	Raceways	1[d]	27	4.50	58,500	2,166.7	3.6	0.25	0.30
Nov	Raceways	1[e]	20	5.00	58,000	2,900.0	3.6	0.15	0.36
Dec	Raceways	1[e]	15	5.50	57,500	3,833.3	3.6	0.18	0.43

[a] In late March densities in the troughs approach the DI criteria of 0.3 and must be split into additional troughs once Rainbow Trout Pulse 4 are moved to raceways.
[b] In late May, densities approach the DI threshold again and must be transferred to deep tanks.
[c] In late July, densities approach the DI threshold and fish must be transferred to raceways.
[d] Fish are held in the first 100 feet of the raceway during these months.
[e] Fish are spread to 200 feet of the raceway during the final two rearing months.

2.2.2.6 Golden Trout

The Golden Trout production program at the Moccasin Creek Hatchery is relatively small, and fish are released as fingerlings as opposed to catchable or sub-catchable sizes. Golden Trout are also sourced from a wild broodstock population, which is not conducive to a constant production schedule. As such, there is variation on the number of eggs received, the arrival timing of eggs, and the availability of staff and equipment to stock the fish by airplanes.

Typically, Golden Trout eggs arrive in June and will hatch in July. There are typically two egg collections from the wild fish source, each egg take will be incubated and hatch into its own deep tank. A maximum of 150,000 green eggs will be received by the hatchery, and approximately 105,000 eggs will reach the eyed stage prior to hatch. It is assumed that 100,000 fish will hatch. At the end of August, Golden Trout will reach approximately 1,900 fpp (1.1 inches) and will be split among eight deep tanks (four tanks per egg take; Table 2-12). The fish will be held in the deep tanks until CDFW is able to stock them, they should reach the minimum stocking size of 500 fpp (1.7 inches) by the end of October. However, if logistics require the fish to be held past October, they should be split to occupy all 10 available deep tanks. The Golden Trout can be held in 10 deep tanks until early February; at the end of February fish will reach an approximate size of 100 fpp (2.9 inches) and would exceed the DI criteria of 0.3 in the deep tanks. If extended grow-out for Golden Trout at the Moccasin Creek Hatchery is required, staff would transfer fish to the 15-foot diameter circular tanks. The circular tanks are not modeled in this bioprogram because of their irregular and sporadic use in rare cases such as extended holding of Golden Trout.

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

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
early Aug	Deep Tanks	2	5,000	0.80	100,000	20.0	0.1	0.16	0.63
Aug	Deep Tanks	2	1,900	1.10	94,667	49.8	0.1	0.29	1.13
Sep	Deep Tanks	8	900	1.40	89,334	99.3	0.4	0.11	0.44
Oct	Deep Tanks	8	500	1.70	84,000	168.0	0.4	0.16	0.62
Nov	Deep Tanks	10	300	2.00	82,000	273.3	0.4	0.17	0.68
Dec	Deep Tanks	10	200	2.30	80,000	400.0	0.4	0.22	0.87
Jan	Deep Tanks	10	160	2.60	78,000	487.5	0.4	0.24	0.94
Feb	Deep Tanks	10	100	2.90	76,000	760.0	0.4	0.33[a]	1.31

[a] Fish must be stocked out in early February or be transferred to circular tanks if extended holding is necessary.

The staggered arrival of Rainbow Trout eggs allows for production to be maximized at the facility while maintaining the DI criteria during the early rearing stages inside the hatchery building. There is limited flexibility inside the hatchery building because of the low volume of rearing space, tightly spaced pulses of Rainbow Trout eggs, and the relatively large populations of each of the Rainbow Trout pulses. However, in the raceways there is flexibility to hold fish for longer than is shown in this bioprogram, though partial stocking should occur to avoid exceeding the DI and FI criteria. The final production of each species and Rainbow Trout pulse are shown in Table 2-13. The total production falls short of the hatchery's goals but remains within the established DI criteria during early rearing which limits overall production. Operations of the facility and variable growth rates among fish in a single pulse may allow for week-to-week changes in rearing strategies that allow for potentially increased production relative to what is shown in this bioprogram.

Table 2-13. Annual Bioprogram Production Totals for the Moccasin Creek Hatchery.

Group and Harvest Month	Fish	Pounds
Brown Trout: December	57,500	3,833
Golden Trout: October - February	84,000 – 76,000	168 - 760
Rainbow Trout – Pulse 1: January	90,000	45,000
Rainbow Trout – Pulse 2: October	90,000	45,000
Rainbow Trout – Pulse 3: July	60,000	30,000
Rainbow Trout – Pulse 4: April	50,000	25,000
Rainbow Trout – Total Production	**290,000**	**145,000**

Each raceway can receive up to 5 cfs of flow, however, not all raceways could receive the entire 5 cfs of available flow without exceeding the intake plumbing and water right for the facility of 30 cfs. Assuming troughs operate at 5 gpm and deep tanks operate at 20 gpm to meet the DI and FI criteria (Appendix B), the hatchery building requires approximately 1.2 cfs to simultaneously run all tanks. This leaves approximately 28.8 cfs of flow spread among eight raceways, or 3.6 cfs (1,615 gpm) per raceway. The maximum available flow was used as a guide to develop the bioprogram, however it will not be required for each raceway throughout the year. Small fish will initially require lower flow rates, and the small Brown Trout population will also require less flow relative to the larger Rainbow Trout groups. It is expected that water demand will remain relatively constant throughout the year and be near the 30 cfs water right for the facility. Additionally, the facility has a temporary recirculation system for the raceways to accommodate reduced flows during dam maintenance periods. The recirculation equipment can pump and recondition up to 10 cfs of water back to the head of the raceways. Continued use of this system after the maintenance period has ended would reduce makeup water demand in the raceways and free up more water for use in the hatchery building if needed.

The months of January, April, July, and October will be the most important in terms of balancing rearing volume and flow rates. These months represent overlaps of each Rainbow Trout pulse with the next year’s group (Figure 2-1). There will be a minimum of seven raceways in use throughout the year, with eight raceways required from August to December to accommodate Brown Trout production. The full raceways are not required for the Brown Trout or the Rainbow Trout Pulse 3, allowing for flexibility to hold other Rainbow Trout pulses for extended periods, as necessary. Note that the different colored blocks in Figure 2-1 correspond to the months in which each species is in either the raceways or the troughs, along with noting when eggs are received and incubated.

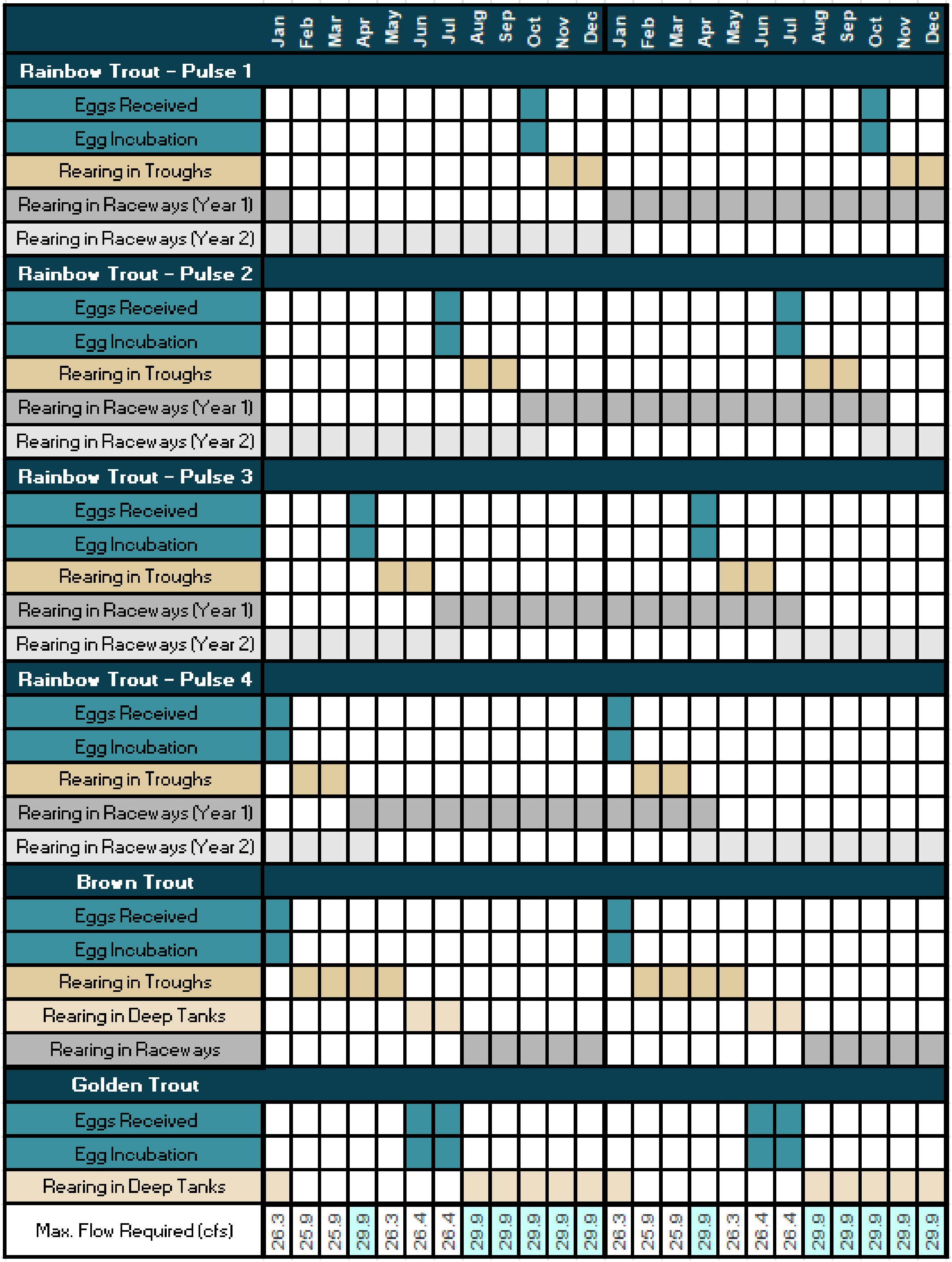

Figure 2-1. Production Rearing Schedule Over 2 Years with Peak Water Demand Occurring Annually in April and from August through December (as highlighted in the Max Flow Required row).

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 the 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 primary water source is the Moccasin Reservoir. From the intake at Moccasin Reservoir, water is piped to the hatchery's intake tower, which provides head pressure for the hatchery building.

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 2014). The projections in this report are based on results from 10 different global climate models under the Representative Concentration Pathway (RCP) RCP4.5 scenario of future greenhouse gas emissions, which represents a future with modest reductions in global emissions compared to current levels.

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

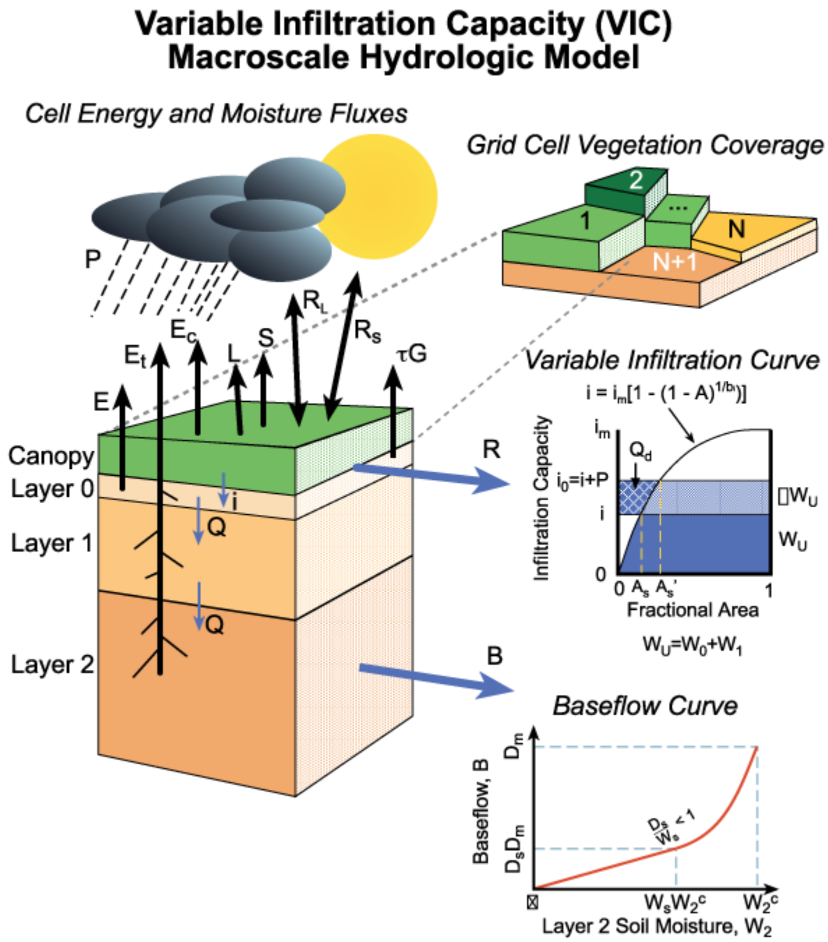

Figure 3-1. The VIC Hydrologic Model (University of Washington Computational Hydrology Group, 2021).

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 stream flows entering Moccasin Reservoir** were obtained by aggregating, over the watershed, the grid-cell-based 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 water temperature** were obtained using empirical relationships developed in this project between daily observations of air temperature and water temperature. The observed water temperature data were provided by the hatchery, while the air temperature was extracted from the publicly available Livneh gridded data set (Livneh et al., 2013) for the grid cell where the hatchery is located. The empirical relationship specific to this hatchery site was used to obtain projected water temperatures from the projected air temperature increases determined from item 1. above. Uncertainty is considerable given that water temperature in the Moccasin Reservoir depends not only on-air temperature but also on the unknown reservoir storage volume.
4. **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 and increasing peaks of runoff and stream flows that impact flooding and water quality.

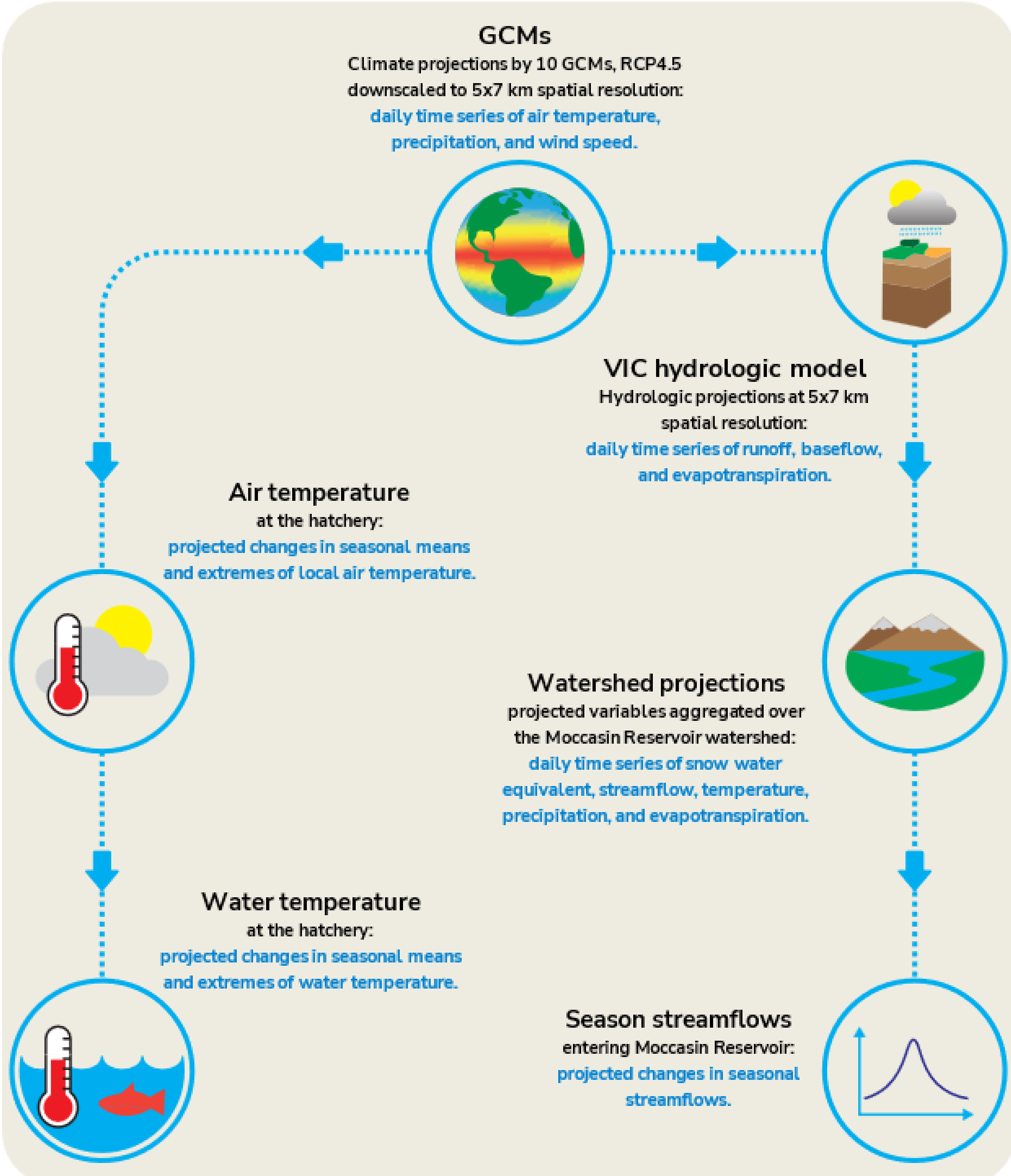

Figure 3-2. Methodology for Obtaining Projections.

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 it's range from minimum to maximum (shaded areas) for each day of the year, for the near-future time period (red) and the reference period (blue). All data are simulated by the ensemble of 10 GCMs for each time period. Higher peaks of daily temperature are seen for the near future compared to the reference period, while the historical period has lower minima.

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 the 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, the mean annual air temperature is projected to rise by 2.6°F in the near future period compared to the reference period (1984-2003), and by an additional 1.2°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 3.0°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, 4.0°F, reaching 102°F. These projected temperatures represent potentially hazardous outdoor working conditions at the hatchery.

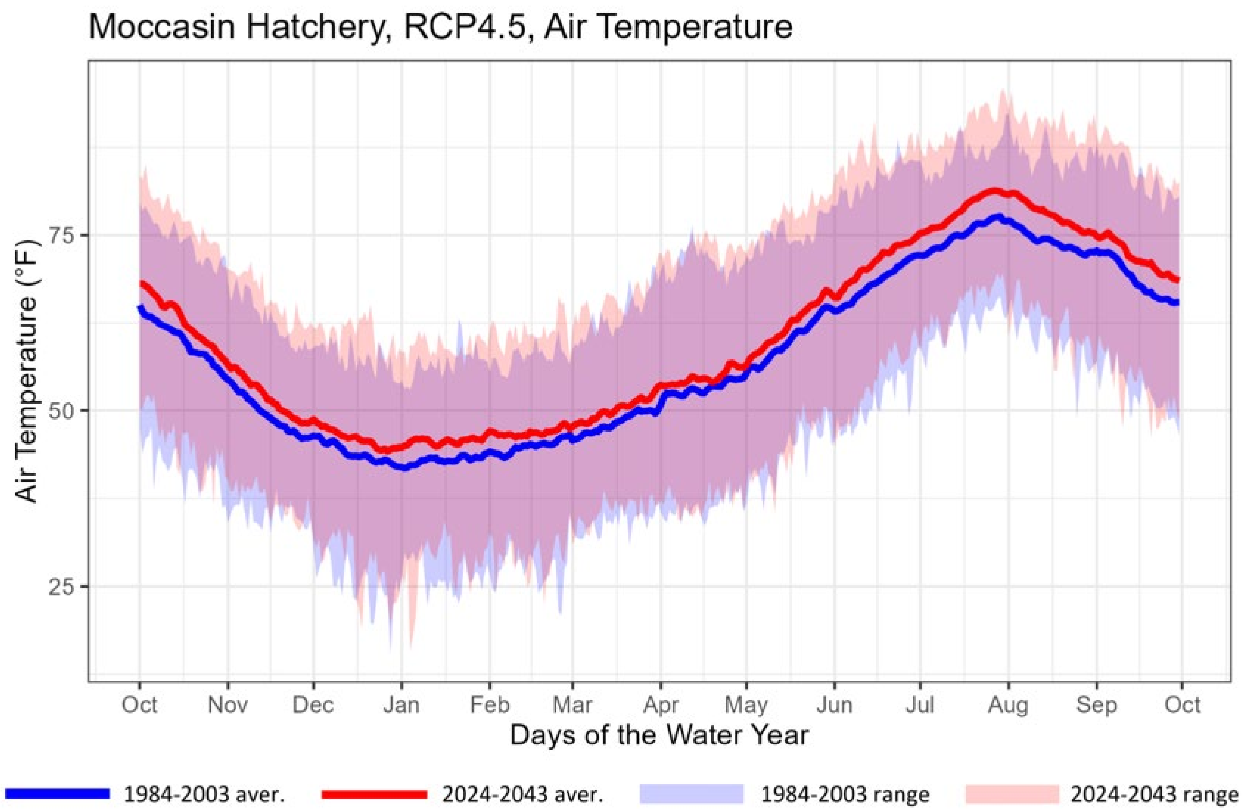

Figure 3-3. Mean Daily Air Temperature and Range for Each Day of the Year.

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

GCM	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Ensemble mean	60.5°F (+2.6°F)	46.7°F (+2.3°F)	56.5°F (+1.9°F)	76.3°F (+3.4°F)	62.4°F (+2.8°F)
Lowest	59.7°F (+1.8°F)	45.9°F (+1.5°F)	55.6°F (+1.0°F)	75.0°F (+2.1°F)	60.8°F (+1.2°F)
Highest	61.1°F (+3.2°F)	47.6°F (+3.2°F)	57.6°F (+3.0°F)	77.3°F (+4.4°F)	63.4°F (+3.8°F)

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

GCM	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Ensemble mean	61.7°F (+3.8°F)	47.8°F (+3.4°F)	57.8°F (+3.2°F)	77.6°F (+4.7°F)	63.4°F (+3.8°F)
Lowest	60.9°F (+3.0°F)	47.2°F (+2.8°F)	55.9°F (+2.3°F)	76.2°F (+3.3°F)	61.7°F (+2.1°F)
Highest	62.2°F (+4.3°F)	48.6°F (+4.2°F)	58.4°F (+3.8°F)	79.0°F (+6.1°F)	64.3°F (+4.7°F)

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

GCM	3rd percentile	25th percentile	50th percentile	75th percentile	97th percentile
Ensemble mean	47.6°F (+2.2°F)	60.2°F (+2.1°F)	73.2°F (+2.3°F)	89.3°F (+3.0°F)	102.0°F (+4.0°F)
Lowest	46.6°F (+1.2°F)	59.4°F (+1.3°F)	72.8°F (+1.9°F)	88.6°F (+2.3°F)	100.2°F (+2.2°F)
Highest	49.4°F (+4.0°F)	60.9°F (+2.8°F)	73.9°F (+3.0°F)	89.9°F (+3.6°F)	103.0°F (+5.0°F)

Table 3-5. Projected GCM 2044-2063 Percentiles of Highest Air Temperature in Each Day (T_{max}).

GCM	3rd percentile	25th percentile	50th percentile	75th percentile	97th percentile
Ensemble mean	48.9°F (+3.5°F)	61.3°F (+3.2°F)	74.4°F (+3.5°F)	90.5°F (+4.2°F)	102.8°F (+4.8°F)
Lowest	48.0°F (+2.6°F)	60.7°F (+2.6°F)	73.7°F (+2.8°F)	89.3°F (+3.0°F)	100.9°F (+2.9°F)
Highest	50.2°F (+4.8°F)	62.1°F (+4.0°F)	75.1°F (+4.2°F)	91.3°F (+5.0°F)	105.1°F (+7.1°F)

3.5.2 Water Temperature

Projections of water temperature from the hatchery's Moccasin Reservoir water source are obtained based on the empirical relationship between daily water temperature and air temperature. Daily water temperature records are available for the calendar years 2015-2022. Daily water temperature is plotted against the air temperature on the same day at the hatchery's location from the Livneh gridded air temperature dataset (upper panel of Figure 3-4). The two variables are weakly correlated because a third variable on which water temperature depends – the storage volume in the reservoir – is not represented, as it is unknown.

On the lower panel of Figure 3-4, color is used to indicate the month, showing that the highest observed water temperatures have occurred in October, followed by August, September, and November. From August through November, a lower air temperature is required to produce a high water temperature. The likely reason is the declining storage volume in the reservoir. The dashed line plotted tentatively represents the response of water temperature to air temperature when reservoir storage levels are low. The line's slope indicates a water temperature response by 1°F to a 3.3°F change in air temperature. Relative to the time period of the data plotted (2015-2022), the projected temperature rise for the fall season in 2024-2043 is 1.5°F, and 2.5°F in 2044-2063, which may lead to a rise in the highest water temperatures by 0.5°F in the next 20 years by 0.8°F in 2044-2063.

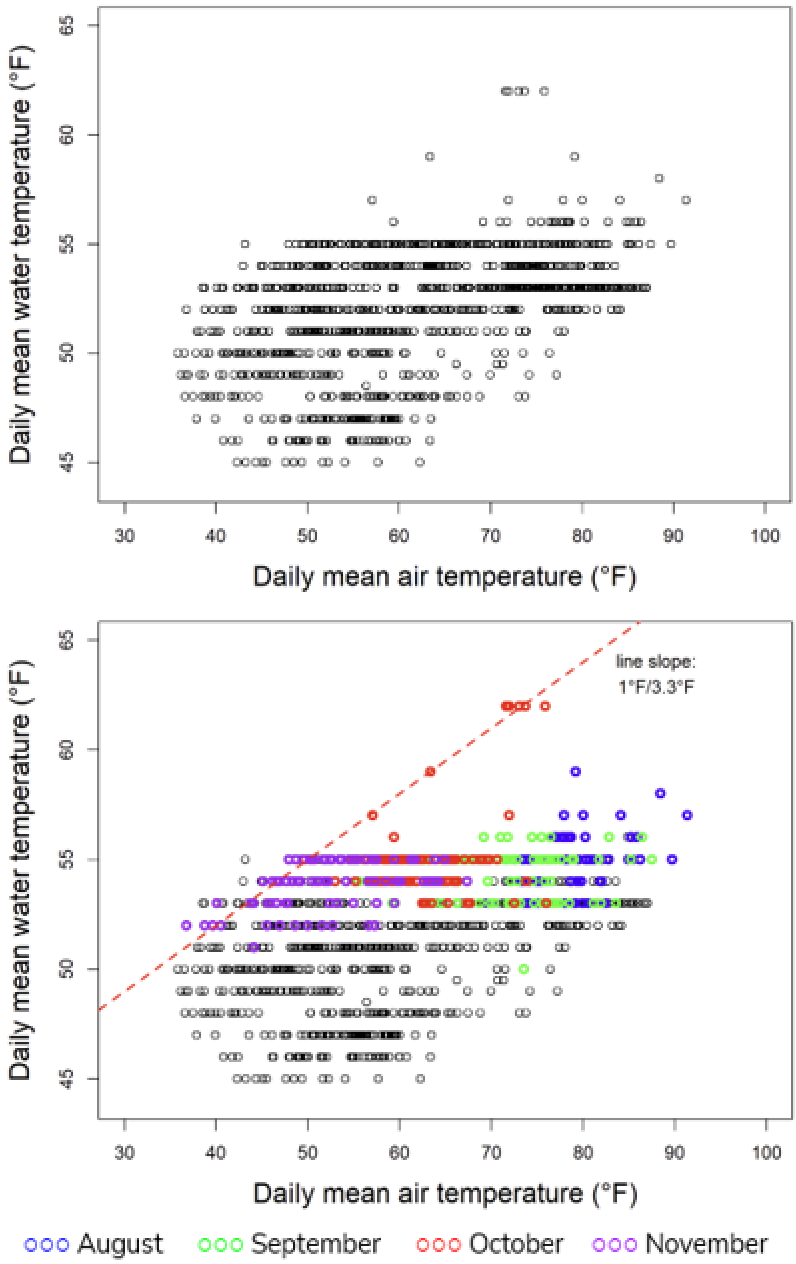

Figure 3-4. Water Temperature's Dependence on Air Temperature.

Top panel: **Daily mean water temperature at the hatchery plotted against the mean air temperature on the same day. *Bottom panel:* Same as the top panel, with the four key months indicated by color. The dashed line tentatively approximates the dependence of water temperature on air temperature when reservoir levels are low, such as they occasionally are in October and November.**

3.5.3 Streamflow Input to the Moccasin Reservoir

The watershed upstream from the Moccasin Reservoir (estimated to cover 26 square miles) receives little snowfall, and the main factor determining seasonal streamflows into the reservoir is rainfall, followed by evapotranspiration. Given the intense variability of precipitation, especially marked in California, from year to year and decade to decade, future seasonal streamflows are subject to great stochastic uncertainty regardless of any long-term trend in their mean values due to anthropogenic climate change. Therefore, the streamflow projections based on 10 global climate models run under RCP4.5 shown in Figure 3-5 and Table 3-6 contain a strong stochastic element and are very uncertain.

Due to stochastic variability, the future climate may differ considerably in magnitude and in the sign of change projected for each season in Table 3-6 and Table 3-7. For example, a seasonal decrease in streamflow may occur where an increase had been projected, and vice-versa. The intense uncertainty is exemplified by the minimum and maximum projected from among the 10 GCMs, which are also given in the table. The projections given by the ensemble of 10 GCMs considered together are for increased runoff in the wettest season, winter (December-February), by +10% in the near-future period and +15% in the mid-century period. The second wettest season is the fall (September-November), and while a streamflow increase of +14% is projected for the near-future period, a decline (-8%) is projected for the mid-century period, a reverse in the direction of change which is likely to be the product of random chance. Despite projected declines in streamflow in spring and summer, the mean annual runoff is projected to increase by +5% in the near-future period and +2% in the mid-century period.

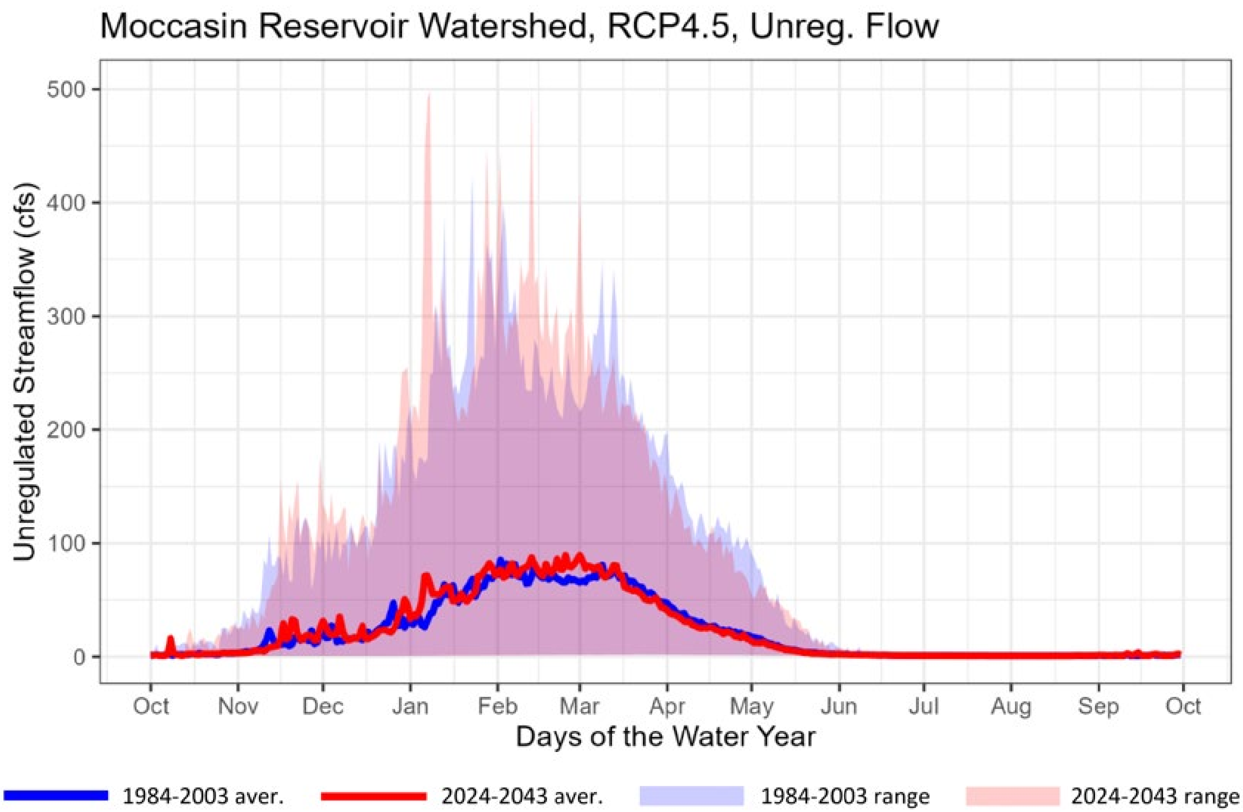

Figure 3-5. Mean Daily Streamflow and Range for Each Day of the Year for the Moccasin Reservoir Watershed.

Table 3-6. Projected GCM 2024-2043 Percent Change in Annual and Seasonal Streamflow for the Moccasin Reservoir Watershed (change relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Ensemble mean	+5%	+10%	-4%	-3%	+14%
Lowest	-37%	-45%	-33%	-10%	-27%
Highest	+72%	+109%	+26%	+14%	+130%

Table 3-7. Projected GCM 2044-2063 Percent Change in Annual and Seasonal Streamflow for the Moccasin Reservoir Watershed (change relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Ensemble mean	+2%	+15%	-14%	-7%	-8%
Lowest	-35%	-41%	-48%	-12%	-38%
Highest	+78%	+138%	+22%	+5%	+98%

3.5.4 Fire Risk

Historical wildfires have been documented within the immediate vicinity of the hatchery and throughout most of the watershed (Figure 3-6). About 20% of the watershed was burned in 2020, but the remaining area has not burned for several decades. Large fires are common in the surrounding basin uplands, including the 2013 Rim Fire, which came within 15 miles of the hatchery. The surrounding land cover varies from shrubland to hardwood forest, corresponding to fuel recovery rates of 5 to 20 years depending on the species and burn severity. Given the lack of large fires in the uplands since 2013, fuels in the surrounding uplands are mature enough to reburn.

Expressing wildfire risk as a percent chance of occurring at least once in a decade, the projected wildfire risk at the hatchery site is between 25 and 30% through mid-century (Figure 3-6).

Fire-related risks to the hatchery consist of surface water impacts from wildfire burn scars as well as infrastructure impacts. Increased runoff along burn scars can increase flooding and turbidity within the first five years of the post-fire landscape. Increased runoff and turbidity and other debris from flooding, debris flows or landslides can impact the Moccasin Reservoir and its associated infrastructure. Additionally, more proximal fires can directly impact hatchery grounds and roadways.

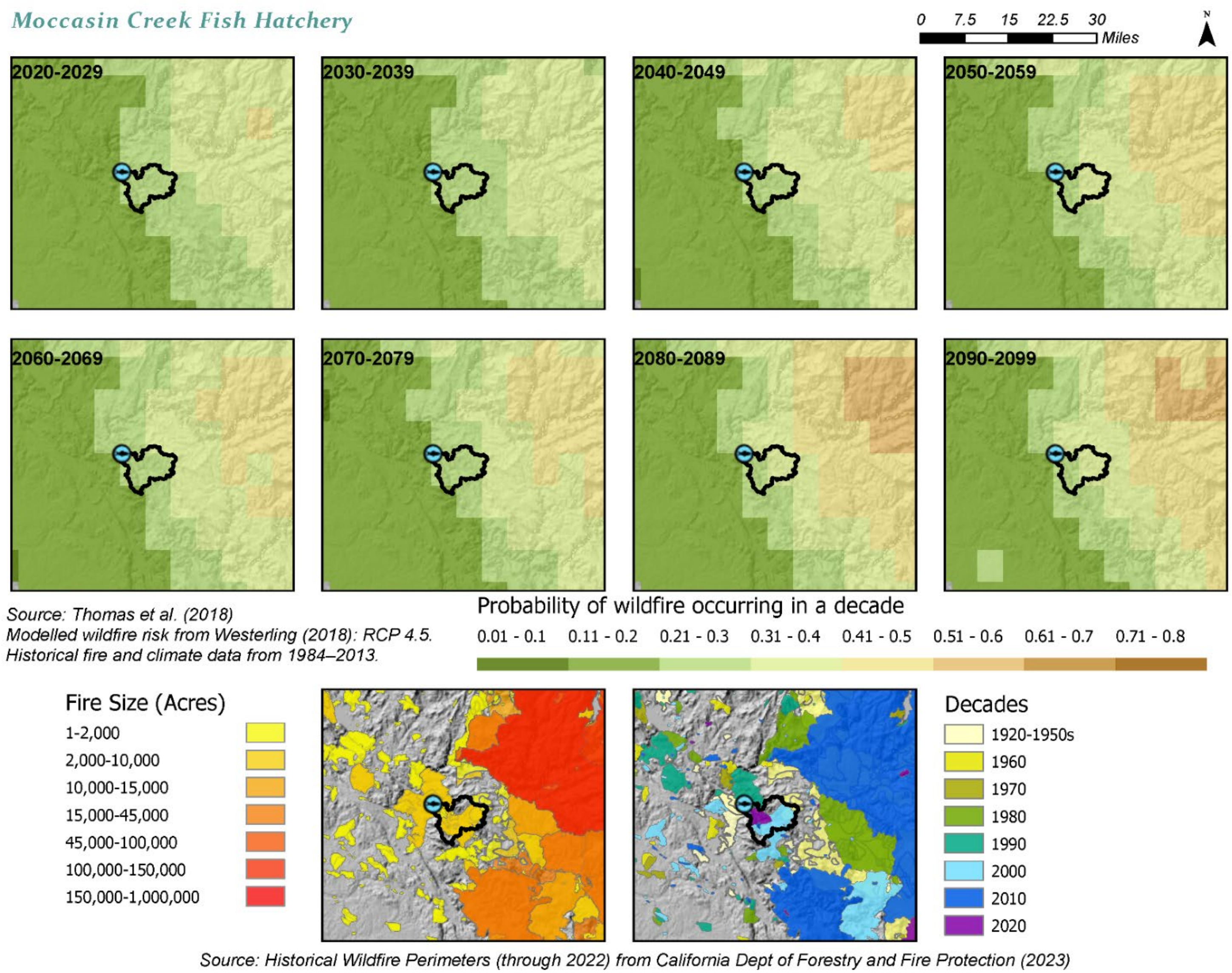

Figure 3-6. Wildfire Risk as Probability of Future Occurrence and Known Historical Fires.

3.6 Conclusions

Significant increases in air temperature and water temperature are expected for the Moccasin Creek Hatchery. Mean annual air temperature is projected to rise by 2.6°F in the next 20 years (2024-2043) and by an additional 1.2°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 75^{th} percentile and 97^{th} percentile of daily temperatures are projected to warm by 3.0°F and 4.0°F, respectively, in the next 20 years, relative to the reference period.

According to gridded air temperatures for the reference period 1984-2003, the 75^{th} and 97^{th} percentiles of peak daytime temperature (i.e., the temperature at the hottest time of day) were 86.3°F and 98°F. For the near-future period (2024-2043), these percentiles are projected to rise by 89.3°F and 102°F, respectively. Such an increase in the peak air daytime temperature requires adaptation measures for the 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 the highest water temperatures at the Moccasin Reservoir intake have occurred in October, followed by August. Water temperature responds to air temperature the most when reservoir storage is lowest, and air temperature can reach high values. Although the analysis presented in this report was limited by the absence of reservoir storage volume data, a tentative approximation was developed based on summer and fall months of the year known to have low storage volumes, which indicates that water temperature changes by 1°F occur in response to air temperature changes of 3.3°F. Accordingly, the highest of summer and fall water temperatures may rise by 0.5°F in the next 20 years and by 0.8°F in the mid-century period, compared to the period of record (2015-2022).

The hatchery is at significant risk of wildfires. There is a history of fires in the watershed, as well as a history of large destructive fires in adjacent basin areas. Given the absence of large fires in the uplands since 2013, there is an increasing risk of fire in the near future. The projected chance of at least one wildfire occurring in a 10-year period at the hatchery site is estimated as 30% through mid-century.

4.0 Existing Infrastructure Deficiencies

While the Moccasin Creek 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 production goals and provide protection against climate change. The main areas of concern for the hatchery included the leaking intake tower, lack of water treatment, exposed HDPE pipe susceptible to thermal expansion/contraction, insufficient water reuse, outdated plumbing, raceway deterioration, and lack of centralized monitoring. Biosecurity deficiencies and potential solutions for addressing these concerns were identified in Sections 3.0 and 3.2 of the Site Visit Report, respectively. These measures include treating all incoming water using filtration, aeration, and UV disinfection, placing footbaths at the entrance of each hatchery building with Virkon™ Aquatic (Lanxess) alternative, and covering the outdoor rearing vessels with solid roof structure and enclosing the sides. Additional considerations include water intake and distribution upgrades, flow meter installation on circular tanks, and backup power upgrades. The details of these deficiencies are further expanded upon in Sections 4.1 and 4.2.

4.1 Water Process Infrastructure

4.1.1 Leaking Intake Water Distribution Structure

Supply water flows by gravity from an intake located at the Moccasin Dam, which then flows beneath the flood wall where it enters the hatchery's intake tower. There is no water treatment or gas management incorporated with the current intake tower setup. The water distribution structure provides constant head pressure for the hatchery. However, the head tank leaks causing water loss before it reaches the production areas.

4.1.2 Lack of Incoming Water Treatment

The hatchery staff have reported several fish health concerns within the hatchery. This has included bacterial gill disease (caused by various bacteria but primarily *Flavobacterium branchiophilum*), bacterial coldwater disease (causative agent *F. psychrophilum*), *Gyrodactylus* spp., *Costia* spp., and *Trichodina* spp. One likely pathway for these pathogens to enter the hatchery is through the water supply. There is no incoming water treatment to disinfect the water before it is used for fish rearing.

4.1.3 Abandoned Moccasin Creek Diversion Structure

There is an emergency pump station on Moccasin Creek, below the dam. Plumbing is designed for the option that this intake can supply the hatchery facility if required. According to CDFW, Moccasin Creek has significant parasitic infection concerns and is not a viable water source for fish rearing. Therefore, this intake system has never been used and will not be used in the future at Moccasin Creek Hatchery.

4.1.4 Exposed HDPE Piping

The temporary raceway reuse system involves an exposed HDPE pipe above ground. This exposed pipe has been reported by CDFW to overheat stored water when not in use. When the recirculation system is not in use, water is still required to be pumped through at all times. This is required to keep the pipe cool to minimize expansion and contraction, which could potentially break the manifolds. A redesign of the raceway recirculation system is underway but will not include burying the exposed HDPE pipe.

4.1.5 Low Oxygen Levels in Raceways

Maintaining adequate oxygen levels is a limiting factor for fish production in the 600-foot-long Moccasin Creek Hatchery raceways. There is currently no mid-pond aeration system to provide gas management in the lower halves of these raceways. The permanent raceway recirculation redesign is not likely to include proper oxygenation and degassing due to funding limitations.

4.1.6 Aged Plumbing and Insufficient Flow Control

CDFW reported that the water conveyance piping and valves throughout the hatchery are functioning but should be replaced due to aging and leakage. Additionally, the site currently does not have control of water flow through the hatchery. To assist with optimizing inflows and outflows, hatchery staff expressed the desire to add flow meters throughout the hatchery.

4.1.7 Truck Fill Station

The existing truck fill station is fed by the head pressure from the intake tower. CDFW staff reported being unhappy with the risks and uncertainty associated with the current setup.

4.2 Rearing Infrastructure

4.2.1 Exposure to Predation Issues in Raceways

The raceways are enclosed in chain-link fencing with bird wire strung across the top. There is also bird netting on the sides of the chain-link fencing. However, fish in the raceways still experience predation. In addition to losses associated with predation, predators also increase the risk of spreading pathogens to the fish. Birds and other animals can carry diseases and cause stress in the fish which can result in fish loss. With only bird wire above, the raceways experience direct sunlight during increased temperature periods in the summers. Prolonged exposure to sunlight and UV rays warms the water, can cause sunburn on the fish, and damages the infrastructure. As noted in Section 3.0, both air and water temperatures at Moccasin Creek Hatchery are projected to rise in the future.

4.2.2 Raceway Deterioration

The concrete raceways are showing signs of deterioration due to age. Concrete spalling consistent with the concrete's age is present in multiple areas throughout the production raceways.

4.2.3 Limited Backup Power Generation

The primary loads are the recirculation pumps and water treatment equipment for the temporary raceway recirculation system. A backup generator is provided on site by the San Francisco Public Utilities Commission (SFPUC) to power the temporary raceway recirculation system during maintenance shutdown periods. No additional backup generators are available to provide backup power to the hatchery.

5.0 Alternative Selected

5.1 Alternative Description

During the site visit, several 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 and potentially expand production, 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, maximize fish production, and respond to the climate change projections described in Section 3.0. The conceptual layout of the alternative described below is shown in Appendix C.

5.1.1 Replace Intake Water Distribution Structure

The replacement of the head tank, valves, and piping directing water through the hatchery is recommended to decrease leakage and increase efficiency. Flow meters and main shutoff valves would be added for better water control. To provide better quality production water, the incorporation of water supply treatment is recommended in the head tank redesign. The attached truck fill station would also be a part of this redesign.

5.1.1.1 Filtration, UV Disinfection, and Aeration of Hatchery Water Supply

There is currently no permanent filtration, UV disinfection, or aeration systems to treat the 30 cfs of incoming water to Moccasin Creek Hatchery. This provides the opportunity for significant pathogens to be introduced to the fish reared at the facility. A filtration, UV disinfection, and aeration system for the water entering the production areas would improve biosecurity by reducing potential pathogen outbreaks for the fish, especially during the early rearing stages at the hatchery when fish are most susceptible to pathogens. The proposed head tank would consist of a concrete vault that sits on a suitable foundation. The head tank building would incorporate drum filters for removing solids, UV treatment for pathogens, counter-current packed columns for removing nitrogen and carbon dioxide, and LHOs to provide oxygen to the water flow.

The drum filters are assumed to have a 40-micron drum screen and integrated backwash system, subject to adjustment based upon future water quality sampling and turbidity measurements. Each drum filter will be connected to a main pipe header within the head tank and receive a portion of the total flow for treatment. The amount of turbidity anticipated will determine the size of filter required, such that the UV reactors downstream can effectively provide the correct UV dose for the system. The system is assumed to have multiple drum filters to treat the total potential flow. This allows one to be offline for maintenance and provides redundancy during high turbidity events. With design progression, sand or other media filters may be looked into as an alternative to drum filters.

The UV disinfection will be through “U” or branch style UV reactors. The UV dose in 126 mJ/cm^2 will be based upon water quality testing and ultimate turbidity allowed through the drum filters. Multiple UV disinfection units will be incorporated into this system’s design. This will allow redundancy such that any of the reactors can be taken offline for maintenance and the system will still process the full flow of 30 cfs. During normal operations, all UV reactors would be in operation to provide redundancy and better dosage to the water supply as needed. The water would then discharge into the packed columns below.

It is assumed that there would be multiple packed columns and the water would discharge into the LHOs below. Based on standard packed column design, an average of 100 gpm flow needs 1 square foot of packed column area for proper aeration/stripping. Outdoor-rated exhaust-type blowers would be mounted to the packed columns to pull air up through the packed column media, improving the gas exchange rate from air to water. The exhaust would be vented to the outside to prevent potential undesirable gases from accumulating within the building.

After flowing down the packed columns, water would fall into Low Head Oxygenators (LHOs) and be injected with oxygen, supplied by on-site oxygen generation. Once water is degassed and oxygenated, it would discharge into the head tank below where it would then be split and conveyed to specific rearing areas throughout the facility.

The water treatment equipment would be enclosed in a pre-engineered metal building (PEMB) that would sit on top of the head tank concrete vault. The PEMB will have insulated metal panels and an insulated roof for protection of the treatment equipment. Proper ventilation will be included to eliminate moisture build-up within the small building. A small HVAC system would be required for the winter months to maintain a minimum temperature inside the building and prevent ice formation. Lights would be provided for maintenance activities.

5.1.1.2 New Float Alarm System

CDFW reported being unsatisfied with the original mercury switch float alarm system in the intake tower. Included in the redesign of the intake tower, a float alarm system would be installed to meet the needs of CDFW operators. The improved float alarm system would be connected to the proposed SCADA system to provide hatchery operators with centralized monitoring and control of the facility (see Section 5.1.7).

5.1.1.3 Redesign Truck Fill Station

The truck fill station is fed directly off the head pressure of the existing intake tower and would be redesigned to meet CDFW's needs. A booster pump system would be installed to provide consistent pressure and decrease the risks associated with the current truck fill station setup.

5.1.2 Bury HDPE Recirculation Pipe

Burying the HDPE pipe is proposed to prevent water from heating up when the recirculation system is not in operation. Stagnant water in the pipe experiences temperature increases caused by sunlight. Pipe burial has the potential to help maintain cooler water temperatures in the recirculation system.

5.1.3 Valving, Piping, and Flow Control

Various valves and pipes across the hatchery are more than 50 years old and experiencing leakage. The preferred alternative is to inspect valves and pipes throughout the hatchery and to replace infrastructure that is leaking, not operable, heavily aged/worn, or likely to fail in the near future. Replacing the valves and pipes would allow for better flow control and would allow for the hatchery to continue operating into the future.

Additionally, the intake plumbing, head tank, raceways, circular tanks, etc. should be considered for flow meter installation. The circular tank system specifically could benefit from the installation of flow meters by providing flow information to staff to align appropriate flows for rearing vessels.

5.1.4 Incorporate Additional Treatment for Reuse Water

5.1.4.1 Incorporate Mid-Pond Aeration to Raceways

If the permanent reuse design does not include proper oxygenation and degassing, mid-pond aerators should be considered. The incorporation of oxygenation into the mid-pond aeration through LHOs, Speece cone, or another design is recommended if head is available, or an airlift system is implemented into the bottom half of the raceways. Mid-pond aeration systems have the potential to increase the overall production capacity of the raceways at Moccasin Creek Hatchery.

5.1.4.2 Incorporate UV Disinfection to Permanent Raceway Recirculation System

A permanent raceway recirculation system is currently being designed. However, UV disinfection is not included in the recirculation system design. Prior to returning reuse water to the heads of the raceways, it is proposed that the water is disinfected to decrease pathogen load within the system. It is important to note that disinfection occurs last with the cleanest water, as UV disinfection works by irradiating DNA in organisms, and its efficiency requires water with low total suspended solids content. It is suggested that prior to UV treatment, water is passed through a 40-micron filter to remove organic and inorganic compounds. The UV dose would be set to inactivate a specific pathogen that the system is intended to prevent based on guidance from CDFW.

5.1.5 Concrete Raceway Improvements

5.1.5.1 Cover Raceways with Permanent Roof Structure

Covering the raceways with solid roof structures and enclosing the sides (e.g., fine mesh chicken wire) to eliminate access to predators, ducks, etc. would improve biosecurity. The solid roof structures would also reduce the warming effects of the hot summer sun as the water passes through the 600-foot-long raceways. The warming effect of the hot summer would be magnified since these raceways are operating on reuse rather than single pass. As mean and maximum ambient air temperatures continue to rise in the future, reducing the solar effects on water temperature in the hatchery will be critical to maintaining temperatures within the range for salmonids. Since vehicles regularly drive between the raceways, the roof structures would be designed with adequate space between structural columns and tall enough for the passage of trucks underneath.

A new photovoltaic system would be included atop the cover structures to help offset the power requirements of the new hatchery infrastructure while also lowering the overall cost of operating the hatchery.

5.1.5.2 Skim Coat Concrete Raceways

The concrete in the raceways is showing signs of aging. The abrasive surface caused by aging can be harmful to fish as well as a surface that promotes algae growth. Adding a coating to the concrete can help alleviate the present issues and reduce the rate at which the concrete surface deteriorates. Raceway coatings are typically epoxy, polyurethane, or mortar based, but they all serve the same general purpose. Prior to coating the raceways, they must be emptied, cleaned, and completely dried. Additionally, any large cracks in the existing concrete will need to be fixed prior to coating. After applying, the coating will need to cure, which can take anywhere from 1-14 days depending on the manufacturer’s instructions and base component of the coat. Depending on factors such as weather and sun exposure, raceway coatings can last anywhere from 5 to 15 years. Applying a coat to the concrete creates a surface which is easier to clean, provides for a smoother rearing environment, improves solids movement to the tail end of the raceways, does not promote algae growth, reduces sun and water exposure to the aging concrete underneath, and protects the tanks from further deterioration.

5.1.6 Increase Backup Power Generation

It is important to ensure that backup power generators are appropriately sized to accommodate the permanent reuse equipment, and any other additional technology designed. New propane-fed backup power generators would be installed to maintain production operations of the recirculation system and walk-in freezer during periods of power outages. The generators will be chosen to meet current air quality standards required for this area and sized to meet the power needs of the hatchery during temporary outages.

5.1.7 Centralized Monitoring

Install a Supervisory Control and Data Acquisition (SCADA) system at Moccasin Creek Hatchery to support centralized monitoring and controls of the facility.

5.2 Pros/Cons of Selected Alternative

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

Table 5-1. Pros/Cons of Selected Alternative – Moccasin Creek Hatchery.

Description	Pros	Cons
Replace intake water distribution structure.	• Eliminates leakage, reducing water loss. • Increases the efficiency of the water distribution system. • Improves biosecurity with increased water treatment. • Provides an improved float alarm system.	• Increases cost due to redesign and installation. • Disrupts hatchery operations during construction.
Bury HDPE recirculation pipe.	• Helps maintain cooler water temperature in the recirculation system. • Extends the life of the supply pipe.	• Increases cost due to burial. • Shuts down the system during construction.

Description	Pros	Cons
Upgrade valving, piping, and flow control.	• Improves operability and control of flow. • Increases hatchery infrastructure lifespan.	• Increases cost due to installation. • Disrupts hatchery operations during construction.
Incorporate additional treatment for water reuse.	• Increases water quality to raceways, reducing their reuse rate. • Increases mid-pond oxygenation, which has the potential to increase the production capacity of raceways.	• Disrupts hatchery operations during rerouting of piping. • Increases cost due to treatment equipment.
Improve concrete raceways with a cover structure.	• Reduces the warming of water during recirculation. • Reduces predation. • Provides a smoother rearing environment, reduces algae growth, and protects concrete from further deterioration.	• Increases cost due to cover structure installation. • Disrupts hatchery operations during raceway resurfacing.
Increase backup power generation.	• Provides power redundancy in case of power outage.	• Increases cost due to system installation. • Has long distribution lead time for large generators.
Install a SCADA system for centralized monitoring.	• Provides flow and water quality information in real time, allowing staff to align appropriate flows for rearing vessels.	• Increases cost due to system installation.

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 Bird Predation Netting Over Raceways

If permanent roof structures are not the selected alternative, the predator exclusion system should include the replacement of the bird netting over the outdoor raceways. Bird wire is currently strung across the top of the raceways, but birds still enter the outdoor rearing space.

According to CDFW, snow load is not a concern at Moccasin Creek Hatchery, but sun exposure has previously caused rapid deterioration of bird netting over the raceways.

5.3.2 Skim Coat Concrete Raceways

Due to the aging and deterioration of the concrete raceways, refurbishment and the application of a skim coating are recommended. See more details regarding coating alternatives and general refurbishment in Section 5.1.5.2.

5.3.3 Repair Intake Water Distribution Structure

Leakage in the intake water distribution structure provides significant water loss and decreased efficiency. If full replacement and treatment incorporation is not economically feasible, the repair of the existing water intake distribution structure is recommended.

5.4 Natural Environment Impacts

The proposed upgrades to the Moccasin Creek Fish Hatchery should have negligible impacts on the natural resources in the surrounding area. All improvements would occur within currently developed areas, avoiding requirements for 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 Moccasin Creek Fish Hatchery will change the existing infrastructure and increase the number of rigid structures on site. However, they will not have a significant impact on fire risk at the facility. The hatchery was under an evacuation order in 2020 because of nearby wildfires, and based on the climate change evaluation, fire risk is projected to increase in the coming decades.

The hatchery was previously damaged in a 2018 flood caused by heavy rainfall overwhelming the Moccasin Reservoir and Moccasin Creek. A flood wall protects the hatchery from rising water levels in Moccasin Creek currently. However, the climate evaluation projects a net increase in runoff associated with the Moccasin Creek Reservoir watershed during the winter season, particularly in January and February. Ultimately, the hatchery's location at the bottom of the Moccasin Dam will leave the entire facility susceptible to flooding if the dam becomes overwhelmed during high rainfall or runoff events. The recommended upgrades do not alter the configuration of any rearing systems; therefore, the alternatives will have a minimal functional impact on the risk of flood damage to hatchery infrastructure or fish production. Replacing the valves and piping as needed will provide the hatchery with better flow control of the facility. The hatchery staff will be able to manage surges in flow and prevent flooding of the rearing vessels.

5.4.2 Effluent Discharge

The proposed upgrades to the hatchery would not include an overall increase in production goals. There should be no changes necessary to the NPDES permit requirements. Incorporating UV disinfection equipment into the raceway recirculation system will improve the water quality of the effluent by reducing pathogen loads relative to the current system. Additionally, installing mid-pond aeration will increase the dissolved oxygen levels of discharged water, further improving the effluent quality. There is potential for a slight increase in the concentration of total suspended solids within the effluent due to reusing the hatchery building effluent in the raceways. Reuse of hatchery effluent would decrease the overall water demand in the raceways while maintaining fish production, causing the increase in solids concentration. Ultimately, the proposed upgrades would likely improve the quality of effluent water discharged into Moccasin Creek because of the increased water quality in the production areas.

5.5 Hatchery Operational Impacts/Husbandry

Hatchery operations and husbandry would have limited impacts from the proposed upgrades. Moccasin Creek Hatchery staff currently have experience using a raceway recirculation system, additional UV disinfection should only increase the welfare of fish. The completion of maintenance on the Moccasin Dam will allow hatchery staff to be more selective of their rearing practices, choosing to use the recirculation system at their discretion to maximize fish welfare and production. Additionally, updating valving and water distribution systems throughout the hatchery will improve the ability for staff to control and manage flow rates. Burying the water reuse pipe would or painting it with a passive cooling paint will also allow for hatchery operations to more safely start up the raceway reuse system without concern for introducing heated water into the raceways.

One exception is reusing the hatchery building effluent; staff should ensure that any instances of disease, chemical, or drug treatments occur in the hatchery building that water is discharged directly to the settling ponds. Incorporating a UV disinfection system for the hatchery effluent should reduce the potential for pathogen transmission, but best practices would isolate any flow that may have a higher-than-normal pathogen abundance. Operation of the reuse systems (completely within the raceways and reuse of the hatchery effluent) should include regular water quality monitoring to ensure optimal rearing conditions.

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. Moccasin Creek Fish Hatchery reported several disease concerns including bacterial coldwater disease (causative agent *Flavobacterium psychrophilum*), Costia (*Ichthyobodo* spp.), mixed bacterial infections, and external parasites including *Gyrodactylus* spp. and *Trichodina* spp. The most likely pathways for pathogens to enter the hatchery and spread throughout are from the incoming water supply or environmental exposure within the hatchery.

5.6.1 Incoming Water Supply

The Moccasin Creek Hatchery is supplied with exceptionally high quality, albeit low mineral content, water because it is conveyed primarily through underground pipe from Hetch Hetchy Reservoir located in the relatively undisturbed Yosemite National Park. Disease concerns are present, but the hatchery rarely experiences substantial losses. The recommended alternatives include filtration and UV disinfection for the hatchery's water supply, further increasing water quality and decreasing pathogen loads for the facility.

5.6.2 Environmental Exposure/Bio Vectors

The existing facility has several areas that are potential pathways for pathogens due to environmental exposure. The existing concrete raceways are enclosed by perimeter fencing with bird wire overtop, but these structures are not completely effective in excluding predators. The current water reuse system for the raceways does not include UV treatment, which can potentially expose fish to water with higher pathogen loads. The recommended alternatives reduce the risk of pathogens entering the raceway rearing areas by including UV disinfection and an upgraded predator exclusion system. Covering the raceways will further reduce the ability of predators to enter the raceways, which can transmit pathogens to the fish and cause significant stress events.

5.7 Water Quality Impacts

The recommended alternatives will improve the water quality within the raceways as well as marginally improve effluent water quality. Providing UV disinfection for the raceway reuse system will ensure that pathogen loads are decreased prior to water being recycled, this also applies to any effluent from the hatchery building being reused in the raceways. Additionally, the mid-pond aeration system would further improve dissolved oxygen levels and the rearing environment in the lower raceway sections.

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 application of appropriate overhead and profit markups have been included in the presented 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.
- Geotech investigation cost assumes seven bore holes (20 feet deep), material testing, piezometer installation, and a written report.
- Topographic survey cost assumption is based on $1,000/acre.

- Building joist/eave height will be 18 feet.
- Site geotechnical properties have not been evaluated but are assumed to be good for construction of the hatchery.
- Topographic survey has not been completed. Site survey will be required to establish elevations of all systems to ensure proper hydraulics can be achieved.
- A facility condition assessment was performed for the Moccasin Creek 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 $3,420,113 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 Moccasin Creek 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.
- 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 demonstrates strong potential for PV installation, especially with the extension of PV covers over raceways and parking lots. However, its location in a steep valley might reduce direct sunlight exposure, affecting PV efficiency. Despite this, the surplus of available area for installation (10,000 square feet) indicates that achieving net zero energy is feasible with strategic planning. Refer to Appendix H for more information.

6.6 Alternative Cost Estimate

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

Table 6-2. Alternative Cost Estimate.

Item	Estimate	
Division 01 – General Requirements	$	5,090,000
Division 02 – Existing Conditions	$	135,000
Division 03 – Concrete	$	2,257,000
Division 05 – Metals	$	100,000
Division 07 – Thermal and Moisture Protection	$	20,000
Division 13 – Special Construction	$	17,139,000
Division 23 – Mechanical & HVAC	$	8,000
Division 26 – Electrical	$	3,440,000
Division 31 – Earthwork	$	221,000
Division 32 – Exterior Improvements	$	63,000
Division 40 – Process Water Systems	$	1,872,000
Division 44 – Pumps	$	198,000
2024 CONSTRUCTION COST	**$**	**30,543,000**
Construction Contingency	$	7,636,000
Overhead	$	1,833,000
Profit	$	2,443,000
Bond Rate	$	306,000
2024 CONSTRUCTION PRICE	**$**	**42,761,000**
Design, Permitting, and Construction Support	$	6,415,000
Geotechnical	$	25,000
Topographic survey ($1000/acre)	$	10,000
PROJECT TOTAL	**$**	**49,211,000**
Accuracy Range +50%	$	73,900,000
Accuracy Range -30%	$	34,500,000
Photovoltaic (Full kW Required)	$	6,326,100
Photovoltaic (Proposed Rooftop Space kW)	$	4,746,600

7.0 Moccasin Creek Hatchery Environmental Permitting

The proposed Project would involve the modification to the existing hatchery or construction of a new hatchery facility and associated infrastructure. It would potentially involve the development of new water supply/intake/pumpstation, requiring instream construction, for the hatchery operations. 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 of California 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
California Division of Water Rights Water Rights	Application or Transfer	N/A	4 months	N/A

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

Table 7-3. Anticipated Tuolumne County Permits and Approvals for Selected Location

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

7.1 National Pollutant Discharge Elimination System (NPDES) Permitting

The Moccasin Creek Hatchery is classified as a cold water Concentrated Aquatic Animal Production (CAAP) facility and is eligible to operate under General Order R5-2019-0079-010 issued by the Regional Water Quality Control Board, Central Valley (Region 5) and NPDES Permit No. CAG135001. This general order supersedes the previous NOA issued January 15, 2015.

The permit identifies formaldehyde as a potential pollutant from the hatchery. The following limitations for formaldehyde are specified:

- 0.65 mg/L (monthly average), 1.3 mg/L (daily maximum)

7.2 Water Rights

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

8.0 Conclusions and Recommendations

The report provides valuable information on the impacts that the Moccasin Creek 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, significant increases in air and water temperature are expected at Moccasin Creek Hatchery. Additionally, there is an increasing risk of wildfire in the near future and as the climate changes.

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

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

- Replacing the intake water distribution structure has the potential to decrease leakage, increase efficiency, and provide better quality water to the rearing vessels.
- Burying the HDPE recirculation pipe has the potential to help maintain cooler water temperatures in the recirculation system.
- Replacing pipes and valves that are near the end of their effective lifespan or are currently inoperable due to age will provide improved flow control.
- Incorporating additional water reuse and treatment will reduce the amount of water that is required to raise fish.
- Covering the raceways with a solid roof will reduce the impacts of increased air temperatures for both the fish and the employees.
- Applying a skim and epoxy coating on the concrete raceways will extend the usable life of the existing rearing infrastructure.
- Adding more backup power generators will ensure that hatchery staff can maintain production operations during periods of power outages.
- Installing centralized monitoring will allow for improved control and oversight of flows throughout the facility.
- Installing solar panels atop new structures will offset some of the power demands associated with new hatchery equipment.

The proposed upgrades to the Moccasin Creek 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 $49,211,000.

9.0 References

Cal-Adapt. 2023. *Wildfire Simulations Derived Products, RCP 4.5, Global Climate Models HadGEM2-ES, CNRM-CM5, CanESM2, MIROC5.* Cal-Adapt website developed by University of California at Berkeley's Geospacial Innovation Facility under contract with the California Energy Commission. Accessed September 1, 2023. http://cal-adapt.org/data/download/.

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

Klontz, G. W. 1991. "Manual for Rainbow Trout on the Family-Owned Farm." *University of Idaho Department of Fish and Wildlife Resources.* Moscow, ID.

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

Livneh, B, E A Rosenberg, C Lin, B Nijssen, V Mishra, K M Andreadis, E P Maurer, and D P Lettenmaier. 2013. "A Long-Term Hydrologically Based Dataset of Land Surface Fluxes and States for the Conterminous United States: Update and Extensions." *Journal of Climate* 26. https://psl.noaa.gov/data/gridded/data.livneh.html (information) and https://downloads.psl.noaa.gov/Datasets/livneh/metvars/ (data access).

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

Thomas, Nancy, Shruti Mukhtyar, Brian Galey, and Maggi Kelly. 2018. *Cal-Adapt: Linking Climate Science with Energy Sector Resilience and Practitioner Need. California's Fourth Climate Change Assessment.* University of California Berkeley, California Energy Commission.

University of Washington Computational Hydrology Group. 2021. *VIC Model Overview.* https://vic.readthedocs.io/en/master/Overview/ModelOverview/.

Vano, J, J Hamman, E Gutmann, A Wood, N Mizukami, M Clark, D W Pierce, et al. 2020. *Comparing Downscaled LOCA and BCSD CMIP5 Climate and Hydrology Projections - Release of Downscaled LOCA CMIP5 Hydrology. 96 p.* https://gdo-dcp-ucllnl.org/downscaled_cmip_projections/dcpInterface.html.

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