Climate Induced Hatchery Upgrades

Merced River Hatchery

Alternatives Analysis Submittal

Final Report
Revision No. 4

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Revision Log

Revision No.	Date	Revision Description
0	4/9/2024	65% Draft Internal Technical Review
1	4/12/2024	65% Draft for CDFW Review
2	9/5/2024	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.

The Merced River Hatchery has an aging infrastructure and deficiencies that need to be addressed in the near future to meet fish production goals, along with the potential future increase in smolt production. Issues identified during the site visit and ensuing discussions include the following:

- The intake experiences periodic clogging from debris that inhibits the quantity and quality of flow.
- The UV disinfection system is currently unable to treat the operating flows of 3 cfs within the raceways.
- The hatchery/incubation building is too small and cannot complete early rearing within the building prior to transferring to the raceways.
- With the small hatchery/incubation building, undersized fry are transferred early to covered outdoor tanks, where they are vulnerable to predation and loss.
- The concrete within the raceways is deteriorating, which results in water exfiltration and loss along with undermining of subgrade soils.
- The site runs off power supplied by PG&E with no backup generators apart from the recirculating aquaculture system (RAS) unit.

The preferred hatchery upgrade alternative includes the following:

- A new hatchery will be constructed to meet early rearing objectives.
- The UV disinfection system will be upgraded to treat the minimum 3 cfs flows.
- Raceways will be replaced with circular tanks that are covered and use partial recirculating aquaculture systems (PRASs), eliminating water loss from damage.
- The site will include the installation of backup power.
- Intake structure upgrades will improve flow and oxygen reliability to the hatchery but will require coordination with the Merced Irrigation District.

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

Project Total	Photovoltaic – Zero Net Energy
$28,544,000	$2,575,800

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

1.4 Project Location Description

The Merced River Hatchery is in the town of Snelling, CA, and approximately 40 miles east of Modesto, CA (Figure 1-1).

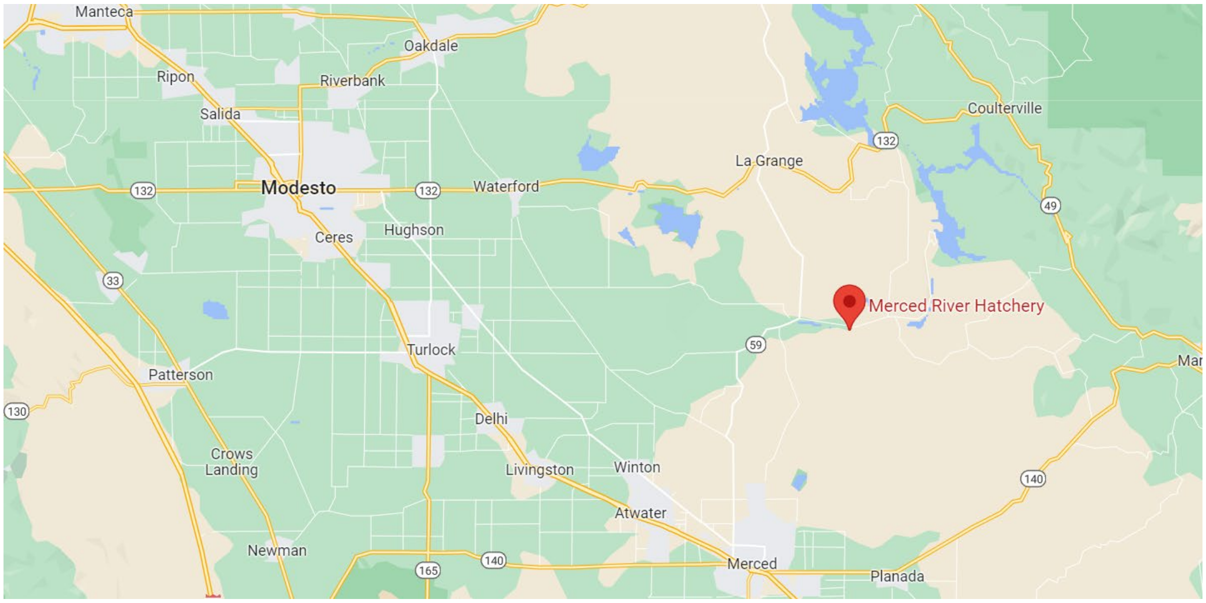

Figure 1-1. Merced River Hatchery Location Map.

The Merced River Hatchery's original construction was completed in 1970 by the Merced Irrigation District and is located just downstream of the Crocker-Huffman Dam. Initially, the hatchery included a Chinook Salmon (*Oncorhynchus tshawytscha*) spawning channel designed to enhance salmon runs. The hatchery was renovated in the 1980s and 1990s to accommodate spawning and rearing to increase production capability.

The hatchery collects, spawns, and rears fall-run Chinook Salmon with a production goal of 1 million smolts weighing approximately 15,000 pounds. The hatchery operates seasonally and exclusively on the surface water source of the Merced River via a gravity fed 26-inch-diameter pipe off the face of the dam. Temperatures typically range between 56-58°F during broodstock trapping, which begins in September, and egg collection efforts that occur from October to mid-December. Fish are reared until their release in May or early June. Rearing temperatures during the winter are typically near 52-53°F, and water temperatures gradually increase in the spring. Fish are released as smolts before water temperatures exceed their upper range of tolerance. The general hatchery facilities are shown in Figure 1-2. See the Site Visit Report (Appendix A) for additional details regarding descriptions and photos of the existing hatchery.

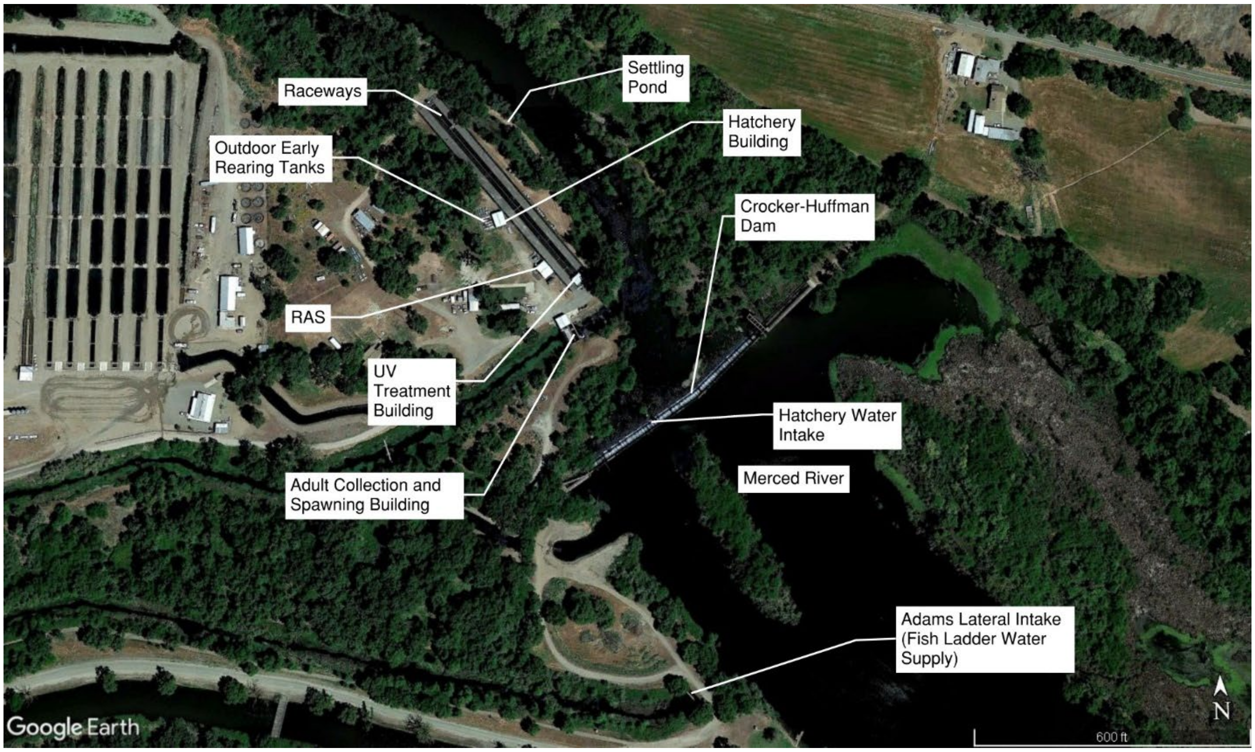

Figure 1-2. Merced River Hatchery Facilities Layout. Google Earth Image.

2.0 Bioprogram

2.1 Production Goals and Existing Capacity

2.1.1 Anadromous Fisheries

The Merced River Hatchery was established as a spawning channel to passively enhance salmon runs in 1970. The facility was expanded by Merced Irrigation District (MID) to include more robust collection, spawning, and rearing facilities in the 1980s and 1990s. This expansion helped MID mitigate the loss of salmon spawning and rearing habitat from construction of the Crocker-Huffman, Merced Falls, and Exchequer dams.

The Merced River Hatchery collects, spawns, and rears fall-run Chinook native to California's Central Valley. 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 Merced River Hatchery is 1 million smolts released at approximately 70 fish per pound (fpp); 3.6 inches long, or 14,285 lbs of fish. The first production goal at the hatchery is 1 million smolts (70 fpp/3.6 inches). The fish rearing capacity determined by the Capacity Bioprogram is shown in Table 2-1.

Table 2-1. Fall-Run Chinook Salmon Capacity of Rearing Units.[a]

Rearing Unit (max. fish size)	Total Capacity (Fish)[b]	Limiting Factor
Combined early rearing (300 fpp/2.2 inches)	284,174 (947.2lbs)	Rearing volume
Raceways (70 fpp/3.6 inches)	981,517 (14,072 lbs)	Water flow

[a] See Appendix A for further discussion regarding the Merced River Hatchery bioprogram.

[b] 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 Merced River Hatchery for several stages of fish production. The capacity of each rearing area (-10% to provide an additional safety factor), limited by water flow or available rearing volume, is shown in Table 2-1. At a high level, the total capacity for the Merced River Hatchery falls short of the production goal of 1 million smolts released at approximately 70 fpp; though, nuances of the timing of fish releases and spawning dates allow for annual production to meet the production goals. The main limiting factor for this facility is low numbers of returning adults, ultimately limiting the number of eggs collected for rearing and release. 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 a 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 Merced River Hatchery can be found in Appendix A. For reference, the established criteria are shown in Table 2-2. To model the production cycle schedule for the Production Bioprogram, survival rate assumptions were made and included in Table 2-3. Survival rates and relevant information to calculate the growth rate, which is 0.4 inches per month, were provided by Merced River Hatchery staff. It is important to note that growth rates are highly variable among different lots of fish from different spawn dates. Growth rates are influenced by culture practices to avoid stocking fish from all egg lots as too large (early spawn dates) or too small (later spawn dates). Other assumptions include the following:

- There will be optimal conditions for egg development and fish growth given the water temperatures experienced at the facility.
- There will be an adult salmon return in sufficient numbers to collect the necessary number of eggs to meet production goals.

Table 2-2. Production Bioprogram Criteria.

Criteria[a]	Value
Density index (DI)	0.3
Flow index (FI)	1.61
Water temperature	Varied 46-70°F

[a] See Appendix A for further discussion regarding bioprogram criteria.

Table 2-3. Survival Rate Assumptions Used for the Production Bioprogram.

Life Stage	Value
Egg-to-fry	90%
Fry-to-juvenile (300 fpp)	80%
Juvenile-to-outplant (70 fpp)	95%

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 and staggering of egg collection days. The model is meant to show an example of how production may occur given the criteria and assumptions outlined in the previous section.

This bioprogram models the capacity of rearing areas for a single group of fish, but it is important to understand that actual operations involve multiple lots of fish that are staggered based on spawn dates. Fish are continuously moved through early rearing and into the raceways on a weekly basis, as opposed to the monthly view captured in this report.

Assuming spawning begins in early October, the first groups of fish are hatched and swimming up in early December (Table 2-4). These fish are expected to reach approximately 300 fpp (2.2 inches) by the end of January and will be ready for transfer to the raceways. The bioprogram models the total capacity for fish at a size of 300 fpp in the early rearing tanks (approximately 284,174 fish). However, spawning occurs twice weekly resulting in multiple groups occupying early rearing tanks, each at a different size and development stage. The spawning groups move through the early rearing space like an assembly line; as one group reaches a size of 300 fpp and transfers to the raceways, another group hatches and occupies the vacant early rearing space. The multiple groups of fish from several spawning days, each at a different size and stage of development, are not captured in this bioprogram. The total number of fish in the early rearing tanks is expected to be greater than the capacity, but the DI and FI criteria are not exceeded because of the constant turnover of fish entering and leaving the early rearing system.

At the end of February, it is assumed that multiple other groups have cycled through the early rearing stage and that there are approximately 550,000 fish in a single raceway. For simplicity, the bioprogram assumes all fish in this group are the same size, approximately 150 fpp (2.9 inches). By the end of March, the rest of the fish have been transferred out of the early rearing tanks, and there are approximately 985,000 fish split between both raceways. The average size of fish at the end of March is 92 fpp (3.3 inches). At the end of April, all groups have reached the target stocking size of 70 fpp (3.6 inches). Hatchery operations require strict feed rationing to prevent fish from earlier spawn dates from growing too large, and for fish from later spawn dates to reach the target stocking size. A total of 981,517 smolts weighing approximately 14,021 pounds are produced in alignment with the capacity of the raceways. This falls slightly short of the 1 million smolt production goal for the facility, but there is flexibility within operations based on the number of lots and their size variation throughout the production cycle to meet the facility's mitigation goals.

Table 2-4. End of Month Production Information, Fall-Run Chinook Salmon Smolt.[a]

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Early Dec	Early rearing	26	1,200	1.4	355,220	296.0	1.0	0.13	0.48
Dec	Early rearing	26	575	1.8	319,697	556.0	1.0	0.18	0.70
Jan	Early rearing	26	300	2.2	284,174	947.2	1.0	0.26[b]	0.98
Feb	Raceways	1	170	2.7	550,000[c]	3,235.3	3.0	0.10	0.89
Mar	Raceways	2	100	3.2	985,000[c]	9,850.0	6.0	0.12	1.15
Apr	Raceways	2	70	3.6	981,517	14,021.7	6.0	0.16	1.45[d]

[a] End of month production information for Fall-Run Chinook Salmon Smolt Bioprogram includes realized DI and FI values.
[b] Early rearing becomes volume-limited as fish reach 300 fpp.
[c] Fish population increases because of more lots cycling out of early rearing and into the raceways.
[d] The raceways are flow limited once fish reach the target stocking size.

This is a high-level view of the production at the Merced Hatchery. The production schedule in Figure 2-1 reflects the use of raceways and early rearing areas for all groups of fish. The figure also estimates the water demand assuming all rearing areas in use would require the maximum flow rate available. Note that the colored blocks in the figure correspond to the months in which different activities take place at the hatchery over a two-year period. Water use is expected to peak in March and April when fish are at their largest and occupy both raceways. In early March, fish may also occupy some early rearing tanks, requiring water flowing to multiple areas.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fall-run Chinook Salmon																								
Eggs Received																								
Egg Incubation																								
Early Rearing Tanks																								
Rearing in Raceways																								
Max. Flow Required (cfs)	1.0	4.0	7.0	6.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.0	1.0	4.0	7.0	6.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.0

Figure 2-1. Two-Year Production Rearing Schedule.

3.0 Climate Evaluation

3.1 Introduction

In this section, projections of air temperature conditions at the hatchery are presented for the next 20 years (2024-2043) and the following 20 years (2044-2063). These time horizons are referred to as the near-future period and the mid-century period, respectively. These projections inform the project team of potential needs for adaptive changes. Air temperature projections inform us of potentially hazardous working conditions.

3.2 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 RCP4.5 scenario of future greenhouse gas emissions, which represents a future with modest reductions in global emissions compared to current levels.

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

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

#	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

#	GCM	Research Institution
6	CNRM-CM5	Centre National de Recherches Météorologiques / Centre Européen de Recherche et Formation Avancées en Calcul Scientifique, France/European Union
7	GFDL-CM3	NOAA Geophysical Fluid Dynamics Laboratory, United States
8	HadGEM2-CC	Met Office Hadley Centre, United Kingdom
9	HadGEM2-ES	Met Office Hadley Centre, United Kingdom
10	MIROC5	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies, Japan

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

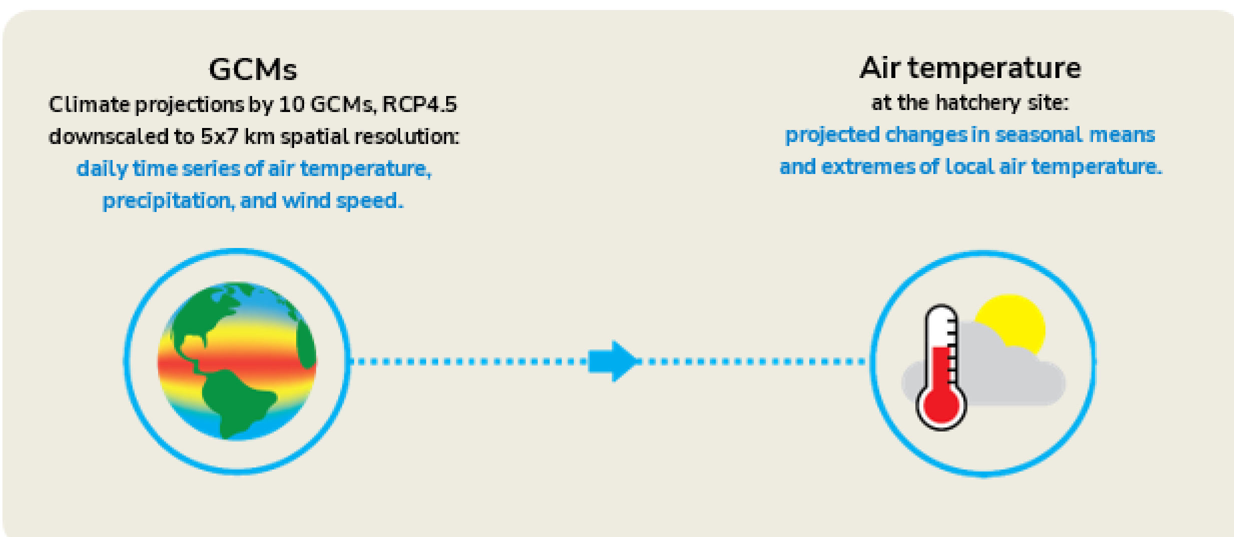

Figure 3-1. Methodology for Obtaining Air Temperature Projections.

3.3 Uncertainty and Limitations

It is important to acknowledge the large and unquantifiable uncertainty associated with these and any climate projections. The projections of air temperature presented here should therefore be considered as plausible representations of the future, given the best current scientific information, and do not represent specific predictions. The actual future realizations of air temperature over this hatchery area will differ from any of the projections considered here, and their differences compared to historical climate may be greater or smaller than the differences in the projections considered.

3.4 Projected Changes in Climate at the Hatchery Site

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

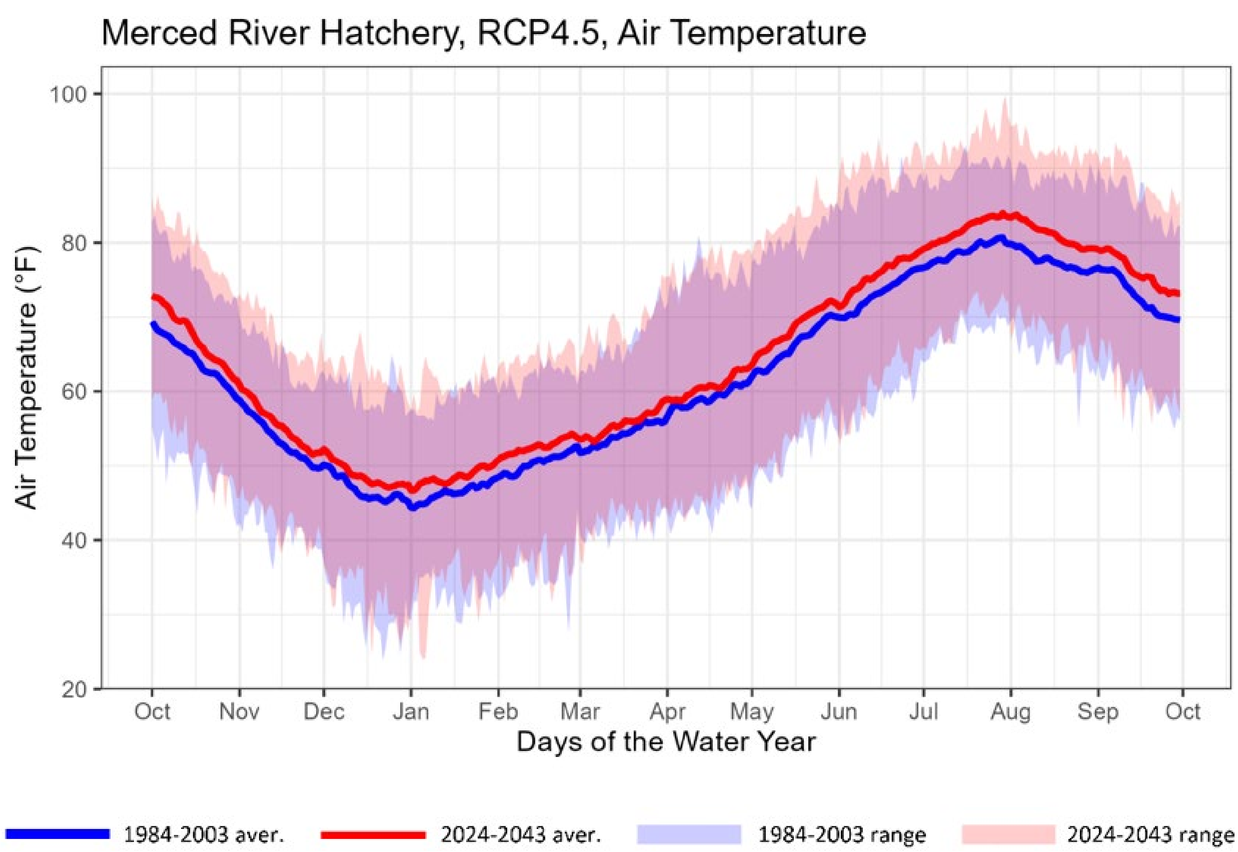

Figure 3-2. Mean Daily Air Temperature and Range for Each Day of the Water Year.

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

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

At the hatchery site, mean annual air temperature is projected to rise by 2.4°F soon compared to the reference period (1984-2003), and by an additional 1.1°F in the mid-century period. The season with the most warming is the summer (Figure 3-2, 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 2.9°F in the next 20 years, relative to the reference period. The 97th percentile of the daytime maximum temperature is projected to rise by even more, 3.3°F, reaching 104.4°F. These projected temperatures represent potentially hazardous outdoor working conditions at the hatchery.

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	64.3°F (+2.4°F)	49.4°F (+2.1°F)	62.3°F (+1.8°F)	79.1°F (+3.0°F)	64.6°F (+2.7°F)
Lowest	63.7°F (+1.8°F)	48.3°F (+1.0°F)	61.6°F (+1.1°F)	78.0°F (+1.9°F)	63.3°F (+1.4°F)
Highest	64.7°F (+2.8°F)	50.0°F (+2.7°F)	63.4°F (+2.9°F)	80.0°F (+3.9°F)	65.3°F (+3.4°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	65.4°F (+3.5°F)	50.6°F (+3.3°F)	63.4°F (+2.9°F)	80.3°F (+4.2°F)	65.5°F (+3.6°F)
Lowest	64.6°F (+2.7°F)	49.4°F (+2.1°F)	62.5°F (+2.0°F)	78.8°F (+2.7°F)	64.0°F (+2.1°F)
Highest	66.0°F (+4.1°F)	51.5°F (+4.2°F)	64.2°F (+3.7°F)	81.5°F (+5.4°F)	66.4°F (+4.5°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	51.3°F (+1.9°F)	63.8°F (+1.8°F)	77.7°F (+2.0°F)	92.3°F (+2.9°F)	104.4°F (+3.3°F)
Lowest	50.3°F (+0.9°F)	62.8°F (+0.8°F)	77.4°F (+1.7°F)	91.6°F (+2.2°F)	102.9°F (+1.8°F)
Highest	52.6°F (+3.2°F)	64.4°F (+2.4°F)	78.4°F (+2.7°F)	92.9°F (+3.5°F)	106.3°F (+5.2°F)

Table 3-5. Projected GCM 2044-2063 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	52.6°F (+3.2°F)	64.8°F (+2.8°F)	78.9°F (+3.2°F)	93.5°F (+4.1°F)	105.5°F (+4.4°F)
Lowest	51.6°F (+2.2°F)	64.0°F (+2.0°F)	78.1°F (+2.4°F)	92.4°F (+3.0°F)	103.6°F (+2.5°F)
Highest	53.7°F (+4.3°F)	65.5°F (+3.5°F)	79.6°F (+3.9°F)	94.5°F (+5.1°F)	107.6°F (+6.5°F)

3.5 Fire Risk

Historical wildfires have been documented both in the immediate vicinity of the hatchery and within the watershed perimeter, as mapped in Figure 3-3. Most of the watershed area has burned within the past century but large amounts of fuel stores are likely present given the overwhelming presence of grasslands and shrub in the watershed, which have an anticipated fuel recovery rate ranging from 2 to 5 years.

Expressing wildfire risk as a percent chance of occurring at least once in a decade (Westerling, 2018), the projected wildfire risk at the hatchery site is 15% through mid-century (Figure 3-3). Across the uplands, the projected fire risk is higher, with local zones increasing to 45% towards the end of this century.

The primary risks to the hatchery operations include infrastructure impacts from local fires, as well as sedimentation and debris impacts from fires in the upper basin. Because the hatchery relies on intake from a heavily regulated river, the hatchery is shielded from most flooding that can impact hatcheries along running rivers, except for catastrophic dam failures. Wildfires can impact intake pipes at dams by increasing runoff and turbidity along burn scars. Clogging of the intake pipe was listed as an existing maintenance concern. Watersheds are most sensitive to flooding and suspended sediment impacts in the first five to ten years after the fire, or the time it takes for new vegetation to mature. The largest risks to the hatchery are therefore increased turbidity following wildfires in the basin, as well as localized fire-related infrastructure hazards to the hatchery itself.

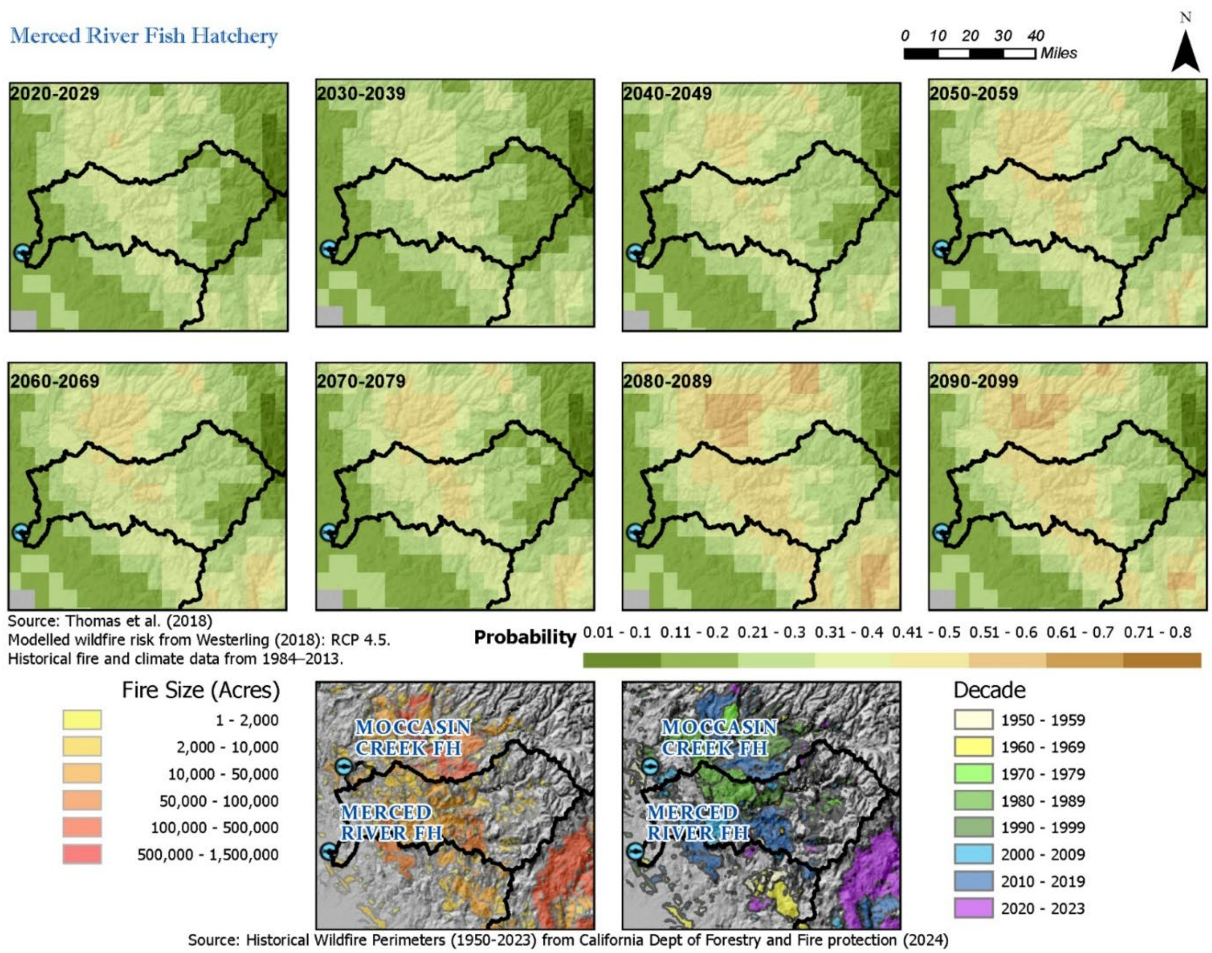

Figure 3-3. Wildfire Risk as Probability of Future Occurrence and Known Historical Fire.

3.6 Conclusions

Significant increases in air temperature and water temperature are expected for the Merced River Hatchery. The projected increases in seasonal means and extremes are among the highest of the California hatcheries studied. Mean annual air temperature is projected to rise by 2.4°F in the next 20 years (2024-2043) and by an additional 1.1°F in the mid-century period (2044-2063), compared to the reference period (1984-2003). The summer will experience the most warming, and the largest temperature increases are projected to occur on the hottest days. Days with temperatures representing the 75th percentile and 97th percentile of daily temperatures are projected to warm by 2.9°F and 3.3°F, respectively, in the next 20 years, relative to the reference period.

According to gridded air temperatures for the reference period 1984-2003, the 75th and 97th percentiles of peak daytime temperature (i.e., the temperature at the hottest time of day) were 89.4°F and 101.1°F. For the near-future period (2024-2043), these percentiles are projected to rise to 92.3°F and 104.4°F, respectively. Increases in the peak air daytime temperature requires adaptation measures to protect hatchery workers against heat stress, heat stroke, and other heat-related injuries. Roads and roofs may need to be replaced using more heat-resistant and reflective materials.

The hatchery is at moderate to high risk of wildfires. The projected chance of at least one wildfire occurring in a 10-year period at the hatchery site is estimated as 15% through mid-century. There is a history of fire both within the immediate vicinity of the hatchery, as well as frequent moderate to large fires in the watershed. Post-fire conditions also pose risks to the hatchery, including scar-induced flooding, turbidity, and debris.

4.0 Existing Infrastructure Deficiencies

While the Merced River Hatchery is an operational facility, multiple deficiencies were identified during the site visit and described in Section 4 of the Site Visit Report (Appendix A). Section 5.4 of the Site Visit Report identified potential technologies and solutions available to address specific deficiencies that would allow the hatchery to meet production goals and provide protection against climate change. Biosecurity deficiencies and potential solutions for addressing these concerns were identified in Section 3.0 and 3.2 of the Site Visit Report, respectively. During the site walk and subsequent discussions with CDFW employees, there were several deficiencies identified throughout the hatchery. Deficiencies included the following:

- Clogging and debris at Crocker-Huffman Dam intake
- Undersized UV disinfection unit
- Outdated site water distribution infrastructure
- Increased water temperatures
- Insufficient space in hatchery building for early rearing
- Outdated hatchery building plumbing
- Inefficient outdoor early rearing
- Raceway deterioration
- Inadequate predator exclusion

The following provides additional details regarding the site infrastructure, hatchery building, raceway, early rearing, predatory, and backup power deficiencies. The details of these deficiencies are further expanded upon in Sections 4.1 and 4.2.

4.1 Water Process Infrastructure

The Merced River Hatchery water source is obtained from the Merced River through a 26-inch steel pipe with the inlet located at the Crocker-Huffman Dam. The hatchery has an allowable 8 cfs they can pull from the inlet. The pipe enters the facility and either runs through a non-functioning UV disinfection unit into the raceways or into the hatchery building. Several issues with the inlet, UV system, overall hatchery water quality and quantity control, and site valving and distribution were identified during the site walk and subsequent discussions.

4.1.1 Diversion

The existing diversion inlet is located at the Crocker-Huffman Dam immediately upgradient of the hatchery. The inlet has a history of clogging with debris during high flow periods, which affects both the quality and quantity of water entering the hatchery. Additionally, flows have been inconsistent during drought years, and the quality of water is impacted by inconsistent seasonal temperature changes. As a result, recent droughts have decreased the overall production at the site. These conditions led to an approximate 20% loss in the years 2002-2006 from impacts to both the quantity and quality of flows (low flow and oxygen levels).

4.1.2 UV Disinfection System

There are currently two UV disinfection units at the head of the raceways to treat the incoming water. These units were installed to treat incoming water for potential pathogens once the fish ladder became functional. Opening the ladder would allow wild fish to bypass the hatchery, creating the opportunity for pathogen spread (transmission), and result in possible impacted water entering the hatchery from above the Crocker-Huffman Dam.

The units were designed to treat 1 cfs of incoming water per raceway. However, the raceways operate at 3 cfs, leaving the units undersized, ineffective, and non-functional. Additionally, the existing units were reported to leak water.

4.1.3 Temperature Control

Water quality temperature controls are not available at the hatchery, which has led to reductions in production numbers as well as accelerated growth relative to other mitigation hatcheries in California’s Central Valley. Staff noted that 15 years ago, stocking in May was common because of the extra time needed to achieve the target stocking size. More recently, stocking is completed in April because of warmer water temperatures. This issue is expected to worsen (see Section 0) which could cause faster growth rates or limit the ability of the hatchery to raise salmonids.

4.1.4 Water Distribution Infrastructure

The water distribution infrastructure, from the 26-inch steel pipe beginning at the intake to valves and gates within the hatchery property, is aging and requires improvement to increase functionality and efficiency of water distribution and control. An existing valve located at the head of the raceways’ controls water distribution to the hatchery. This valve is aging and requires replacement to help maintain proper flows through both the raceways and hatchery building. Additionally, the lack of metering impacts the optimization of flows, which can lead to under- or overuse of available water.

As noted below in Section 4.2.2, the raceways have extensive erosion and undermining occurring beneath. While the leakage can be linked to the raceways observationally, there is potential leakage coming from the raceways' distribution piping and valves, including both inlet and outlet. This aging infrastructure would require replacement in the event the raceways were to be reconstructed and improved.

There are no valves and/or meters located at the inlets to the different areas of the hatchery. The only control to the hatchery building and the raceways is the valve noted above. Additional valving and metering at each location would assist with controlling and optimizing flows through the entire hatchery.

4.2 Rearing Infrastructure

4.2.1 Hatchery Building

The existing hatchery building is fed directly from the intake structure without any filtration or treatment as noted above. The building is used for incubation and early rearing and consists of a deep tank modified to operate as a headbox, Heath stacks, and two deep tanks. The headbox supplies the Heath stacks where the eggs are incubated. Once hatched, the fry are placed within the two deep tanks for early growth. However, because the building is undersized and additional tanks cannot be added, fry are relocated to the outdoor early rearing tanks prior to reaching their target density. The plumbing throughout the building is aging and requires both replacement and modification to meet future goals, such as inclusion of meters to control and optimize flows.

4.2.2 Outdoor Early Rearing Tanks

Once the fry exceed the capacity of the indoor deep tanks, they are moved outside to continue their early rearing. There are ten fiberglass "tomato" tanks, four deep troughs, and three smaller fiberglass tanks where the fry are distributed for early growth. The tanks are covered with screens to protect against predation; however, raccoons, herons, and other predators still access the undersized fry which leads to high loss from predation. Additionally, the tanks are exposed to the sun and experience water loss from evaporation.

The tanks are fed through a series of PVC pipes, fittings, and valves. To maintain flexibility within the piping system the pipe, fittings, and valves have been installed without properly cementing the PVC. This can lead to leakage and possible damage should the system fail.

4.2.3 Raceways

The concrete raceways are deteriorating and cracking which has led to substantial water loss and structural compromise from soil erosion and tunneling. This has resulted in both operational and economic impacts to CDFW from loss of water and possible damage to fish during growth.

The raceways are fenced and have bird netting over the top to provide both avian and mammalian predator protection. However, due to age and deterioration of the lower portions of the fence, small predators and raccoons are still able to gain access. Not only are there losses associated with predation, but 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 additional fish loss. Additionally, the netting does not reduce direct sunlight during high summer temperatures experienced throughout the region. Prolonged exposure to sunlight and UV rays warms the water, potentially sunburns the fish, and damages infrastructure. As noted in Section 3.0 both air and water temperatures are projected to increase in the future, and with the hatchery already experiencing the effects of increased water temperatures, this could further affect salmonid production.

4.2.4 Backup Power Generation

The hatchery is powered by Pacific Gas and Electric (PG&E). There is no backup power for the hatchery building or raceways mainly because the facility does not rely on pumps for its water supply.

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 Intake Upgrade

The intake structure is the front-end water source with the largest potential to impact the hatchery. Debris accumulating at the intake screen has been shown to affect both flows and water quality. By upgrading the intake with a debris boom, traveling screen, or other debris removal/protection, the water quantity and quality would remain consistent and substantially reduce the potential of future loss like that experienced from 2002-2006. This upgrade would likely require coordination with the Merced Irrigation District.

5.1.2 UV Disinfection System

The existing UV disinfection system was constructed to treat the raceways, is both outdated and undersized, leaks, and remains unused. Additionally, there is no pre-treatment for the hatchery building, which leaves the entire facility susceptible to pathogens. Should the fish ladder become active, this would increase the potential for pathogen exposure as wild fish bypass the hatchery and continue upstream.

A new intake UV disinfection system located near the existing control valve will treat both the raceways and hatchery building, improving biosecurity throughout the hatchery in the event the fish ladder becomes operational. UV disinfection will be through an intake water UV disinfection unit designed to address any possible pathogens and microorganisms. The UV dose, measured in millijoules per square centimeter (mJ/cm^2), will be determined by the most UV-resistant pathogen or microorganism potentially encountered. Currently, this is estimated at 126 mJ/cm^2, which is sufficient to target the majority of pathogens of concern, including *Flavobacterium psychrophilum*.

The UV disinfection system will be enclosed in a pre-engineered metal building (PEMB) located near the existing UV disinfection system and raceways. The PEMB will include insulated metal panels and roof to protect equipment against vandalism and local climate conditions. Adequate ventilation will be provided to address potential moisture accumulation. A small HVAC system will be installed to maintain air temperature variances within the building and prevent overheating depending on the season. Lights will be provided to assist with maintenance and operational activities.

5.1.3 Temperature Control

The Merced River Hatchery could opt to chill the full water right of up to 8 cfs, which would provide water temperature control and the ability to maintain upper-temperature thresholds when river quality is impacted. However, space and electrical costs for chilling 8 cfs are relatively high and the chiller size to meet the full water right may be difficult to acquire.

To control costs and alleviate rising temperatures, a smaller unit will be added to the hatchery to help control temperatures during hatching and early growth.

5.1.4 Water Distribution Infrastructure

As noted above, the water distribution infrastructure is aging and requires improvement to the existing gates, piping, and valves. Replacing and upgrading the existing control valve located at the head of the raceways will be required. This work would include upgrades to the UV system, addition of a chiller, and construction of the distribution building. Additionally, meters could be installed to help control the flows to the hatchery and new tanks. Additional valving and metering within the hatchery and tank headworks would assist with controlling and optimizing flows through the entire hatchery.

5.1.5 Hatchery and Early Rearing Building

The existing hatchery building is undersized and does not allow for adequate early growth before the fry are moved outside to the early rearing tanks. Once outside, the undersized fry are exposed to predation and direct sunlight, which leads to high loss. Early rearing space is also limited, requiring staff to transfer fish to the raceways earlier than desired. The selected alternative will be to construct a new hatchery building with space for egg incubation in Heath stacks and early rearing, eliminating both the high predation and ambient temperature extremes. The chilling system will address warming water temperatures that may impact water temperatures during the egg incubation and early rearing period. With UV-treated water entering the building, the effluent could be directed to the raceways, prior to their eventual replacement, for a small amount of reuse, helping to further reduce costs for overall disinfection.

The expansion includes space for up to six full Heath stacks (16 trays each), which provide flexibility to include eggs while deep tanks are occupied by either hatching jars or fry. The early rearing space includes 50 deep tanks (each 16 ft x 3 ft x 2 ft, volume of 96 ft^3), each provided with a flow rate of 20 gpm and a total water demand of approximately 1,000 gpm (2.2 cfs) if all were operating at once. This would provide enough space and flow to hold approximately 900,000 Chinook Salmon at 300 fpp at the same time. The natural timing of salmon returns will allow for more flexibility to start and transfer fish from deep tanks to the final smolt rearing without concern for overcrowding given the current production goals.

5.1.6 Raceway Replacement with PRAS Circular Tanks

There are two 500-foot-long raceways where the concrete is deteriorating and cracking, leading to significant water loss. With the excessive water loss from the cracks and evaporation, the better alternative is to replace the raceways with circular tanks that are using a partial recirculating aquaculture system (PRAS), which meet both staff and production requirements. A permanent roof structure and perimeter netting and fencing will reduce predation while protecting both staff and fish from increasing temperatures and direct sunlight. The new circulars will be partially buried for ease of access and the area will have gravel surfacing. A concrete slab will also be provided for use during tagging.

5.1.6.1 Grow Out Production

To replace the production currently taking place in the raceways, a system of sixteen (16) 20-foot-diameter tanks, each with a water depth of 6 feet and a wall height of 7 feet, for a total rearing volume of approximately 30,160 ft^3 is proposed (1,885 ft^3 per tank). Tanks and equipment would be covered with a solid roof structure and enclosed in fencing and predator exclusion netting. The tanks would be organized into two separate PRAS modules, each with eight tanks.

A recommended HRT of 45 minutes would require a flow rate of 325 gpm per tank, or 5,200 gpm (11.6 cfs) of total process flow for the system. Each module would require 2,600 gpm (5.8 cfs) of process flow. Assuming a recirculation rate of 50%, the fresh make-up water requirement for each module would be 1,300 gpm (2.9 cfs), or 2,600 gpm (5.8 cfs) for the entire system. Once staff are familiar with the recirculation equipment and processes, tanks may operate at a recirculation rate of 75% without a biofilter. A 75% recirculation rate would require 650 gpm (1.5 cfs) of fresh make-up water per module (1,300 gpm, 2.9 cfs, for the entire system). Each PRAS module would have a new microscreen drum filter, CO_2 removal, LHO, and UV disinfection. Appendix E (Alternatives Development TM) provides detailed information on the equipment components required for each PRAS module. At this reuse rate, a biofilter would not be required.

PRASs for the Merced River Hatchery can reduce water demand and improve water quality within the rearing environment. This alternative is meant to show how production could be maintained, assuming that eggs are available regularly throughout the year. Dual-drain circular tanks provide a completely mixed environment as opposed to a raceway that has a gradient of high to low dissolved oxygen (DO) along its length. This characteristic of circular tanks makes the entire volume available to the fish, as opposed to fish crowding at a raceway's head end, and thereby not using the entire raceway volume. Other benefits include self-cleaning of fish waste, concentration of fish waste in a small center drain flow that can be treated continuously, and capacity for providing exercise velocities. Covering the tanks with a solid roof structure with perimeter fencing and netting will also reduce heat gain and improve biosecurity.

5.1.7 Backup Power Generation

The site is dependent on PG&E power with no standby emergency generators with the exception of the small RAS unit. It is important to ensure that backup power generators are appropriately sized to accommodate the permanent reuse equipment, and any other additional technology proposed. New propane-fed backup power generators would be installed to maintain production operations during periods of power outages. The generators 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.

5.2 Pros/Cons of Selected Alternative

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

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

Description	Pros	Cons
Upgrade intake.	• Improves water quality and quantity by reducing potential blockage from debris. • Reduces maintenance. • Reduces potential for future losses from impacted water quality and quantity.	• Requires coordination with the intake's owner Merced Irrigation District, which may affect the schedule for upgrades. • Could be high cost.

Description	Pros	Cons
Upgrade UV disinfection system.	• Reduces cost by treating single source. • Improves biosecurity if/when the fish ladder becomes operational. • Is sized to meet the site-specific treatment needs.	• Increases cost due to procurement and installation. • May have permitting challenges.
Provide water chillers within the PRAS and the water supply treatment system.	• Increases water quality. • May maintain production while reducing water consumption. • Prevents fish evacuations and lost production time by using chilled water. • Helps to maintain water temperatures and lower energy costs by reusing chilled water.	• Increases operating costs. • Increases cost due to chiller(s) procurement and installation. • Disrupts hatchery operations during construction.
Improve water distribution infrastructure.	• Improves operability and control of flow. • Increases hatchery infrastructure lifespan.	• Increases cost due to installation. • Disrupts hatchery operations during construction.
Build a new hatchery and early rearing building with rooftop solar panels.	• Allows for optimal water conditions and flow control. • Increases production flexibility at early life stages. • Reduces loss from predation and direct exposure to sunlight. • Offsets the power requirements of the new hatchery infrastructure while also lowering the overall cost of operating the hatchery. • Allows fish to be vaccinated prior to transfer to larger rearing vessels (if necessary).	• Increases the cost of construction and operation. • May have permitting challenges. • Requires new water demand at the facility.

Description	Pros	Cons
Replace raceways with circular tanks on PRASs.	• Provides a healthier rearing environment for fish. • Increases biosecurity. • May maintain production while decreasing water use. • Reduces water loss through covering tanks. • Decreases footprint. • Reduces the total water required and provides flexibility. • Replaces aging infrastructure. • Reduces labor because it is self-cleaning. • Concentrates waste for effluent treatment for NPDES permit compliance. • Reduces degradation of plumbing and tanks from UV exposure. • Provides space for fish tagging activities using the adjacent concrete pad.	• Increases costs due to construction, including demolition, subgrade preparation, water distribution infrastructure, tanks, roof structure, etc. • Requires operational changes when loading fish out of circular tanks. • Requires additional training for staff. • May have permitting challenges.
Install backup power generation.	• Provides power to all life support systems in the event of a power outage.	• Increases cost due to generator installation and maintenance. • Has long distribution lead-time for large generators.

5.3 Alternatives for Short-Term Improvements

In the event that funding is not available to construct the preferred alternatives, the following short-term upgrades are recommended to aid with improved hatchery operation. The conceptual layout of the short-term improvements is shown in Appendix C.

5.3.1 Cover Early Rearing Tanks

Covering the outdoor early rearing area with a solid roof structure and enclosing the sides (e.g., fine mesh chicken wire) to eliminate access to predators, ducks, etc. would improve biosecurity and reduce losses associated with predation. The solid roof structures would also reduce the warming effects of the hot summer sun as the water passes through the early rearing tanks. 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.

5.3.2 Refurbish Raceways

The existing raceways could be refurbished by pressure grouting the tunneling and sinkholes impacting the structural stability of the raceways. When dry, the raceways can be observed using ground penetrating radar to pre-survey the underlying conditions for potential impact. Once the subgrade is repaired, application of a skim coat is recommended. Adding a coating to the concrete can help reduce aging of the concrete while addressing both fish health and algae growth. Additionally, it will improve the flow of waste through the system, helping to keep the raceways cleaner. 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 be cured, which can take anywhere from 1-14 days depending on the coating selected and the manufacturer's instructions. Depending on factors such as weather and sun exposure, raceway coatings can last anywhere from 5-15 years. Applying a coat to the concrete creates a surface which is easier to clean, does not promote algae growth, and reduces sun and water exposure to the aging concrete underneath.

5.3.3 Upgrade Valves and Piping

The valve at the inlet has aged and requires replacement. When this valve is replaced the piping and valves for the raceways can be addressed to reduce the potential for further leakage and undermining of the raceways.

5.4 Natural Environment Impacts

The proposed upgrades to the Merced River 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 climate change analysis does not include a fire or flood risk assessment due to the heavily manipulated waterways of California's Central Valley. Fire risk is generally expected to increase because of future climate change impacts, but the proposed upgrades to the facility do not significantly contribute to added fire risk. The Crocker-Huffman Dam controls the flow of the Merced River at the hatchery for the purpose of supplying irrigation rights within the Merced Irrigation District (MID). Flood risk is dependent on the MID's operation of the water system; however, flood risk and severity are generally expected to increase due to climate change (CDWR 2024). The proposed upgrades to the facility will aid staff in controlling water entering the hatchery with updated intake screening and water distribution infrastructure. The recommended changes will slightly increase the total impervious surface of the site, but designs will ensure that stormwater runoff is directed to appropriate discharge areas to limit inundation of hatchery infrastructure. Overall, the proposed upgrades will provide added benefits of water control at the hatchery's intake, but flood risk will still increase due to climate change and the hatchery's location directly downstream from the Crocker-Huffman Dam.

5.4.2 Effluent Discharge

The recommended changes to the hatchery do not include an overall increase in production goals. This will ensure limited changes to the NPDES permit requirements. Flows will still be routed to the existing effluent pond prior to discharging back into the Merced River. Incorporating water reuse for egg incubation systems will slightly decrease the flow demand of the facility. The discharge from the egg incubation reuse will contain little to no solids during the egg and fry life stages and therefore should not impact the operation of the settling pond. Additionally, treating the hatchery's water supply should result in a slight increase in water quality of the effluent because of the generally improved water quality supplied to the fish production areas. It is important to note that changes to the existing aquaculture programs (renovations, new construction) may trigger (administratively) the requirement for new and/or updated NPDES permits. Acknowledging that waste load (fish biomass) is not anticipated to change with the proposed alternatives, we assume that the increase in effluent removal efficiencies provided by the PRAS systems will result in net effluent "gains" to the overall aquaculture program.

5.5 Hatchery Operational Impacts/Husbandry

The production schedule will remain the same and is dependent on the Chinook Salmon run timing. The increased early rearing capacity will allow for more flexibility during production, providing hatchery staff the means to grow fish to larger sizes before transferring them to the grow-out vessels. This will allow for staff to monitor fish more closely during their early life stages when they are most susceptible to disease.

The upgrades would also be designed to allow for the ability to use a small fish pump to transfer fish from the deep tanks to the outdoor circular tanks, significantly reducing the handling stress and staff labor required. Once fish have been transferred to the circular tanks, they will be grown to their target release size at which time they will maximize the biomass and DI capacity of the system. Truck loading for fish release will basically continue as the hatchery has previously operated, using fish pumps and dewatering towers with a few minor adjustments unique to circular tanks relative to traditional raceways.

Operation of the PRAS for egg incubation will require some additional training, but CDFW has expertise with these systems at other hatcheries. Care must be taken when treating eggs with any chemicals in a reuse system, and water quality should be closely monitored to ensure it remains acceptable for incubation requirements.

5.5.1 PRAS Circular Tank Operations

The final rearing tanks will operate as PRAS systems reusing up to 75% of their water flow. The hydraulic self-cleaning characteristics of the circular tanks will reduce labor associated with tank cleaning. Additional tank sweeper systems are also available and can further reduce staff labor associated with maintaining tank hygiene. Staff time will be required for monitoring PRAS components including routine water quality checks, flow adjustments, and monitoring LHO and CO_2 systems to ensure a high-quality rearing environment. Staff will make routine flow adjustments as fish grow to maintain a maximum velocity of approximately two body lengths/second. Sein nets, clamshell crowders or other crowder types can be used to concentrate fish for collection and handling.

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

5.5.2 PRAS Equipment

The PRAS provides tremendous benefits in reducing the water flow requirements to produce large numbers/biomass of fish while maximizing water quality. However, these systems are more complex and require additional skillsets to monitor and maintain the equipment to ensure reliable system operations for successful fish production. The PRAS modules will be operated seasonally, providing maintenance windows and opportunities for cleaning and disinfection. All PRASs should be programmed into the facilities maintenance and management system to schedule, perform, and document preventative and corrective maintenance.

5.5.3 Feeding

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

5.6 Biosecurity

The goal of biosecurity measures is to minimize the risk of pathogens entering the facility and spreading between rearing areas at the facility. The Merced River Fish Hatchery previously vaccinated (2014) for enteric redmouth disease (causative agent *Yersinia ruckerii*). However, conversations with hatchery staff did not identify any additional major issues associated with current fish pathogens at the facility.

5.6.1 Incoming Water Supply

The proposed alternatives include UV disinfection of the entire facility's water supply. This also includes filtration and will significantly decrease the total suspended solids and pathogen load in the supply water. Disinfection of the water supply will also provide an additional layer of safety if adult Chinook Salmon repopulate the Merced River upstream of the hatchery.

Filtration of the water supply will also eliminate instances of debris entering the facility and clogging pipes, fouling rearing tanks, and negatively impact fish welfare.

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 recently replaced bird netting overtop. However, the presence of these exclusionary structures is not completely effective and requires continuous maintenance. The recommended alternatives would improve predator exclusion by placing a solid roof structure over the outdoor circular tanks, with fencing and netting along the sides. This would significantly decrease required maintenance and increase the effectiveness of excluding predators versus the existing fencing and netting. The UV disinfection system would also significantly reduce pathogen loads in the rearing areas, lowering the risk of transmission and disease.

5.7 Water Quality Impacts

The recommended alternatives will improve the water quality within the existing rearing vessels, with no significant effect on the effluent water quality. Replacing the existing concrete raceways with dual-drain circular tanks can improve the water quality of the rearing environment. Dual-drain circular tanks provide a completely mixed environment as opposed to a raceway that has a gradient of high to low dissolved oxygen (DO) along its length. This characteristic of circular tanks makes the entire tank volume available to the fish, instead of fish crowding at a raceway's head end, thereby not using the entire raceway volume. The dual-drain system in circular tanks aids in waste removal, allowing for more effective removal of solid waste and uneaten feed. This can contribute to better overall water quality.

The other PRAS equipment will also improve the water quality within the system. The microscreen drum filters will remove the solids in the water. The LHOs will ensure the dissolved oxygen levels enter the tanks at saturation or higher. The carbon dioxide strippers will remove dissolved carbon dioxide as well as other undesirable gases, and the UV unit will reduce the pathogen load of the water that returns to the tanks. Additionally, installing a rigid roof structure with bird netting will reduce heat gain during the summer months and algae growth in the rearing tanks.

Each PRAS module will concentrate the fish waste into smaller flows from the center drain and drum filter backwash. The recommended alternatives include treating this effluent waste with a drum filter and settling pond. This will reduce the solids and improve the water quality of the effluent being discharged.

The proposed filtration and UV disinfection of the water supply will provide cleaner water with less debris and pathogen loads. Additionally, installing a rigid roof structure for the outdoor circular tanks will reduce heat gain as air temperatures increase, with the added benefit of reducing algal growth in the rearing tanks.

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. See Appendix F for detailed cost estimates including assumptions and inflation information.

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 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 Merced River 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 $350,726 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 facility condition assessment may be resolved as part of the proposed upgrades at the Merced River 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

There is substantial space to the west of the site, potentially part of a different hatchery, which may help bridge the gap needed to achieve 100% PV capacity. This land, consisting of barren areas, could be utilized to meet energy goals. Further investigation is necessary to confirm ownership and potential use of this area, with 80% PV capacity currently achieved. To reach net zero energy, an additional 10,000 square feet of green space would need to be covered with PV panels. 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	$ 2,952,000
Division 02 – Existing Conditions	$ 431,000
Division 03 – Concrete	$ 1,139,000
Division 05 – Metals	$ 170,000
Division 08 – Openings	$ 40,000
Division 13 – Special Construction	$ 8,218,000
Division 23 – Mechanical & HVAC	$ 334,000
Division 26 – Electrical	$ 2,000,000
Division 31 – Earthwork	$ 417,000
Division 32 – Exterior Improvements	$ 50,000
Division 40 – Process Water Systems	$ 1,958,000
2024 DIRECT CONSTRUCTION COST	**$ 17,709,000**
Contingency (25%)	$ 4,427,000
Overhead (6%)	$ 1,063,000
Profit (8%)	$ 1,417,000
Bond Rate (1%)	$ 178,000
2024 TOTAL CONSTRUCTION COST	**$ 24,794,000**
Design, Permitting and Construction Support (15%)	$ 3,720,000
Geotechnical	$ 25,000
Topographic Survey	$ 5,000
PROJECT TOTAL	**$ 28,544,000**
Accuracy Range +50%	$ 42,816,000
Accuracy Range -30%	$ 19,981,000
Photovoltaic (Full kW Required)	$ 2,575,800
Photovoltaic (Roof kW Available)	$ 1,314,900

7.0 Merced River 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

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
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
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
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

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
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
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 Merced County Permits and Approvals for Selected Location

Agency and Permit/Approval	Submittal / Document Type	Supporting Documentation	Anticipated Time Frame	Notes
Merced County Building and Safety 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 Merced River Hatchery is classified as a cold water Concentrated Aquatic Animal Production (CAAP) facility and is eligible to operate under General Order R5-2019-0079-011 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 20, 2015.

Wastewater from the 561,000-gallon settling basin is discharged through Discharge Point 001 (Latitude: 37 degrees 30 minutes 55 seconds N; Longitude 120 degrees 22 minutes 20 seconds W). Wastewater from the raceways is discharged through Discharge Point 002 (Latitude: 37 degrees 30 minutes 58 seconds N; Longitude: 120 degrees 22 minutes 23 seconds W).

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

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

7.2 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 Merced 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 climate data performed by NHC provides projections to forecast changes that may be experienced. In general, significant increases in air temperature are expected at the Merced Hatchery. Groundwater supply is not expected to warm appreciably but given current temperatures in the upper range for fish rearing, additional warming may require adaptation.

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. Increased 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:

- Constructing a new hatchery building to accommodate egg incubation, early rearing, and intermediate rearing that currently takes place at the Fillmore Hatchery. Intermediate rearing would use PRASs to achieve production goals.
- Upgrading the existing intake structure and debris boom. This would help to prevent flow and water quality issues associated with debris clogging the current system.
- Adding water treatment equipment including a new UV disinfection system, drum filters, and temperature controls. This would allow the hatchery to maintain their desired water quality parameters and reduce the overall risk of pathogens entering the system.
- Constructing a new incubation and early rearing hatchery building with water chilling capability that would include 50 new deep tanks and 6 new incubation stacks. Moving these systems into a new building would allow better control of water quality, incoming flows, and biosecurity at the early life stages.
- Replacing the existing raceways with 16 new circular tanks housed in an open-sided PEMB. This would eliminate the water losses currently seen due to cracking within the raceways. This would also reduce the risk of predation and the introduction of pathogens to the grow-out life stage.
- Installing solar panels atop new structures to offset some of the power demands associated with new hatchery equipment.

The proposed upgrades to the Merced River Hatchery would have negligible impacts on the natural resources in the surrounding area. All improvements would occur within currently developed areas, which lessen the permit requirements. The total cost estimate of the proposed design modifications is $28,544,000.

9.0 References

California Department of Forestry and Fire Protection. 2023. California Fire Perimeters (1950+).

CDWR, California Department of Water Resources. 2024. Merced River Watershed Flood-MAR Reconnaissance Study. Statewide Infrastructure Investigations Branch. Available from: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Flood-Management/Flood-MAR/230410_Merced-R_FloodMAR-Reconnaissance-Study_Division-Report_v7.pdf

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

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

Terracon Consultants, Inc. 2022. Facility Condition Assessment Report Merced River Fish Hatchery (Property Number 44441). Terracon Project No. FT20P020.

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

Vano, J., J. Hamman, E. Gutmann, A. Wood, N. Mizukami, M. Clark, D.W. Pierce, D.R. Cayan, C. Wobus, K. Nowak, and J. Arnold. 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.