Climate Induced Hatchery Upgrades

Mount Shasta Hatchery

Alternatives Analysis Submittal

Final Report
Revision No. 3

McMillen

February 2025

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Revision Log

Revision No.	Date	Revision Description
0	3/8/2024	65% Draft Submittal
1	8/19/2024	Draft Final Submittal
2	10/31/2024	Final Submittal
3	2/07/2025	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).

Mount Shasta Hatchery has an aging infrastructure and deficiencies that need to be addressed in the near future in order to meet fish production goals. The following current deficiencies have been noted to hinder current production. The effects of which will magnify with climate change.

- The Big Springs water supply lacks screening, and it is not disinfected.
- Flow is delivered via an open channel from an inlet, allowing pathogens to enter the system.
- Hatchery Building E lacks heated water in the incubation area.
- The nursery tanks have poor predator protection.
- Earthen A&B Bank Raceways do not allow for flow control and have poor predator protection.
- Raceways C, D, E, and F do not have a drum filter or UV water treatment.
- Hatchery Building E is undersized, so it does not meet the needs of the McCloud Redband Program and cannot be updated due to historical protection.
- There is general aging of the infrastructure throughout the hatchery (e.g., the concrete, valves, and pipes).

The preferred alternative for hatchery upgrades includes replacing the existing diversion from Big Springs Creek with an inlet that provides debris removal and flow control, piping the canal from the inlet to the hatchery with a 36-inch pipe, removing the existing concrete nursery tanks and replacing with circular culture tanks supplied with partial recirculating aquaculture systems (PRASs) that includes a roof and predation protection, replacing the existing earthen ponds with circular culture tanks that includes a roof and predation protection, providing a roof over Raceways C-F with predation protection, and constructing a new hatchery building to replace Hatchery Building E that includes space for the Photoperiod Program.

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. These 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.

Total Cost Estimate	Photovoltaic for ZNE
$49,586,000	$5,791,500

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 Mount Shasta Hatchery is located approximately 63 miles north of Redding, CA (Figure 1-1).

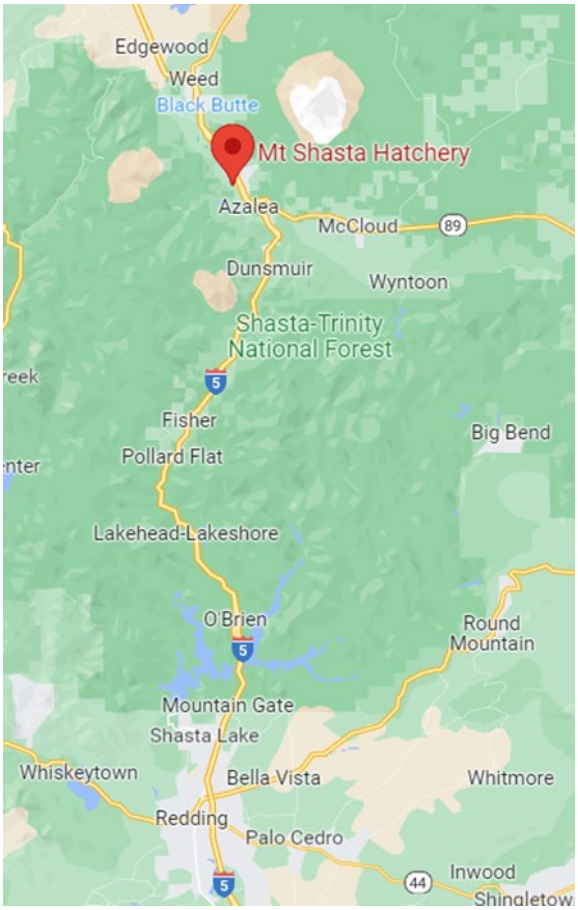


Figure 1-1. Hatchery Vicinity Map.

The Mount Shasta Hatchery raises 3-4 strains of Rainbow Trout (*Oncorhynchus mykiss*) and Brown Trout (*Salmo trutta*) with a production goal of approximately 100,000 pounds. The hatchery is developing a “Photoperiod Program” for their Rainbow Trout broodstock to control spawn timing and has incorporated a “triploid” component into their Rainbow Trout egg production program. Additionally, the hatchery raises the McCloud Redband Rainbow Trout (*O. mykiss stonei*), which is designated as a “Species of Special Concern.” The general hatchery facilities are shown in Figure 1-2. See the Site Visit Report (Appendix A) for more details and photos regarding the existing hatchery facilities.

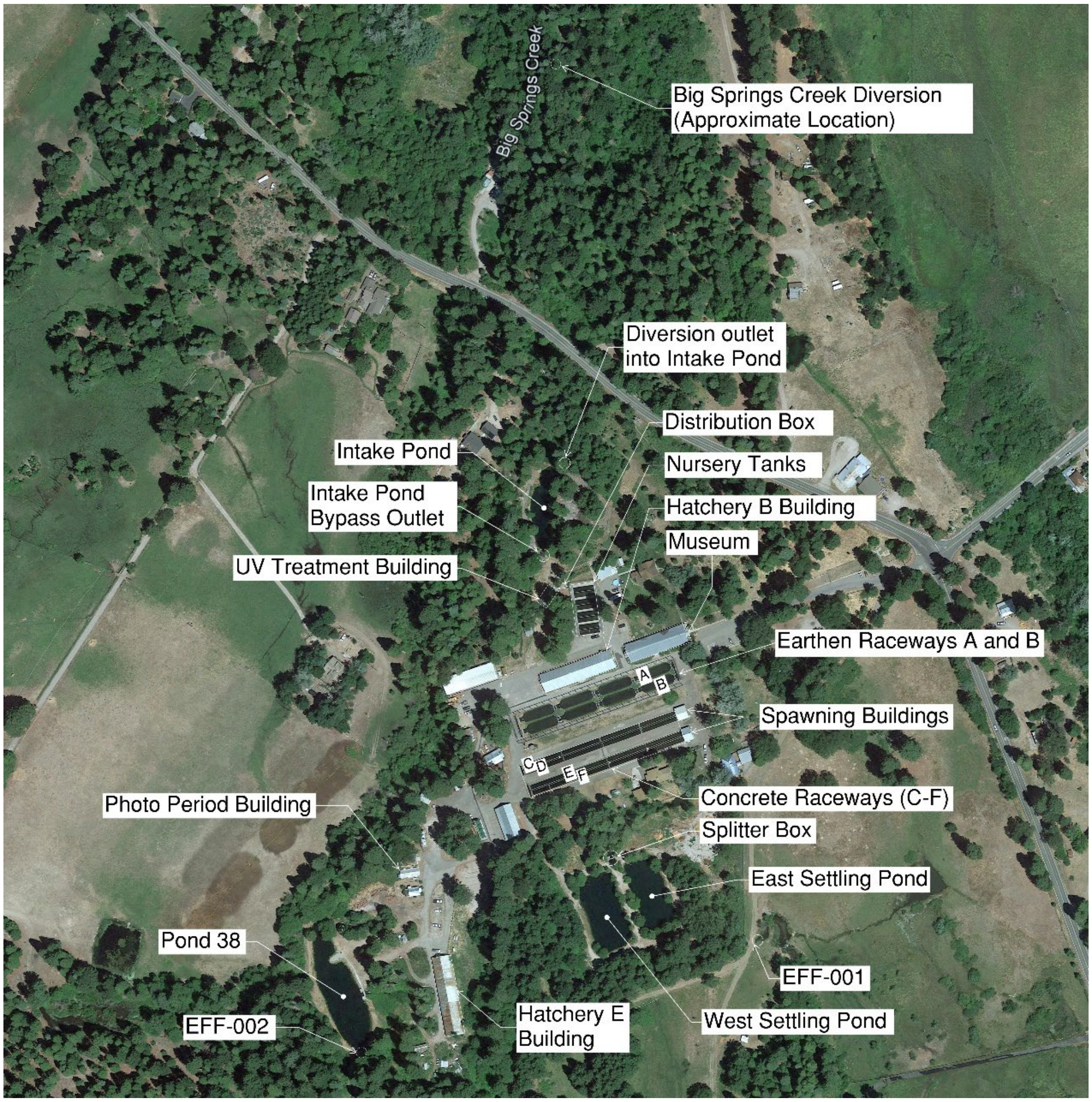


Figure 1-2. Mount Shasta Facilities Layout. Google Earth image date: 6/11/2023.

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 [fpp]) 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 Mount Shasta Hatchery produces several strains (i.e., Eagle Lake Trout-Hatchery (ELT-H), Rainbow Trout Hoffer (RT-CO), Rainbow Trout West Virginia (RT-WVPR), and a small group of Rainbow Trout Shasta (RTS)) of Rainbow Trout and serves primarily as a broodstock facility for Rainbow Trout and Brown Trout. The facility also raises the McCloud Redband Rainbow Trout, recognized by the State of California as a "Species of Special Concern." The Mount Shasta Hatchery serves as a broodstock facility providing eggs to multiple other hatcheries. The broodstock program is inclusive of diploid and triploid egg production as well as providing a level of timing control for egg production through its Photoperiod Program.

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 (Piper, 1982) to ensure oxygen levels appropriately align with production. This information is available in the Site Visit Report. 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 Mount Shasta Hatchery is 200,000 catchable Rainbow Trout weighing 100,000 pounds, as provided by CDFW in the initial questionnaire. The fish production goal, and rearing capacity determined by the Capacity Bioprogram is shown in Table 2-1, Table 2-2, and Table 2-3.

The following are the fish production goals for each fish species:

- Rainbow Trout: 200,000 fish (100,000 lbs), including 100,000 Eagle Lake (Hatchery Origin)
- Brown Trout: 87,000 fish (4,000 broodstock, 3,000 catchable, and 80,000 fingerling at 100 fpp)
- McCloud Red Band Trout: 80,000 fish (2,710 lbs)

Table 2-1. Rainbow Trout Production Capacity of Various Rearing Units at the Mount Shasta Hatchery per the Capacity Bioprogram (Appendix A).

Rearing Unit (fish per pound (fpp)/max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
California Troughs (500 fpp/1.7 inches)	671,373	Rearing Volume
Deep Tanks (500 fpp/1.7 inches)	21,651	Rearing Volume
Concrete Nursery Tanks (15 fpp/5.5 inches)	147,335	Water Flow[b]
A & B Raceways (2 fpp/10.8 inches)	272,160	Rearing Volume
C & D Raceways (0.5 fpp/17.1 inches) Broodstock	84,645	Rearing Volume
E Raceway (0.5 fpp/17.1 inches) Broodstock	48,340	Water Flow

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

[b] Flows provided in the questionnaire (i.e., 159 gpm) do not meet the FI requirements for the concrete nursery tanks and were increased for the bioprogram to generate an FI within the limits as identified by CDFW.

Table 2-2. Brown Trout Production Capacity of Various Rearing Units at the Mount Shasta Hatchery per the Capacity Bioprogram (Appendix A).

Rearing Unit (fish per pound (fpp)/max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
California Troughs (200 fpp/2.3 inches)	361,206	Rearing Volume

Rearing Unit (fish per pound (fpp)/max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
Concrete Nursery Tanks (8 fpp/6.8 inches)	97,152	Water Flow[b]
F Raceway (0.5 fpp/17.1 inches) Broodstock	48,340	Water Flow

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

[b] Flows provided in the questionnaire (i.e., 159 gpm) do not meet the FI requirements for the concrete nursery tanks and were increased for the bioprogram to generate an FI within the limits as identified by CDFW.

Table 2-3. McCloud Redband Trout Production Capacity of Various Rearing Units at the Mount Shasta Hatchery per the Capacity Bioprogram (Appendix A).

Rearing Unit (fish per pound (fpp)/max. fish size)	Total Capacity (Fish)[a]	Limiting Factor
California Troughs (800 fpp/1.5 inches)	910,000	Rearing Volume
6-ft-diameter Round Tanks (40 fpp/4.0 inches)	35,942	Water Flow
10-ft-diameter Round Tanks (15 fpp/5.5 inches)	97,297	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 Mount Shasta 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. At a high level, the total capacity for the Mount Shasta Hatchery aligns with the production goals discussed in the previous section. However, other factors, primarily predation, impact the hatchery's ability to meet production targets annually. Details about the various rearing areas and infrastructure are discussed in the Site Visit Report.

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

2.2.1 Criteria

The methods and reasoning used to determine the criteria associated with biological programming for the Mount Shasta 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, several assumptions are made and included in Table 2-5. Additional assumptions include the following:

- The Mount Shasta Hatchery will continue to serve as a major broodstock facility for the CDFW program and will continue to produce and spawn multiple strains of Rainbow Trout (i.e., Hofer, Eagle Lake [Hatchery Origin], West Virginia, and McCloud Redband) and Brown Trout.
- 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 and recognizing there is significant temperature variability from year to year.

Klontz (1991) provided optimal growth rates for Rainbow Trout at designated water temperatures, and survival rates were provided in the questionnaire completed by Mount Shasta Hatchery staff. The growth rate of the various species varies with temperature based on monthly average water temperatures.

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

Criteria	Value
Density index (DI)	0.5
Flow index (FI)	1.56
Water temperature	Variable 37-52°F

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

Species	Survival
Rainbow Trout	Egg-to-fry: 75% Fry-to-juvenile (500 fpp): 60-70% Juvenile-to-outplant (2 fpp): 40%
Brown Trout	Egg-to-fry: 80% Fry-to-juvenile (200 fpp): 70% Juvenile-to-outplant (2 fpp): 70%
McCloud Redband Rainbow Trout	Egg-to-fry (800 fpp): 39% Fry-to-juvenile (40 fpp): 70% Juvenile-to-outplant (15 fpp): 70%

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 incorporates several existing programs (i.e., Hofer Rainbow Trout, Eagle Lake and West Virginia Rainbow Trout, McCloud Redband Rainbow Trout and the Brown Trout broodstock) and therefore does not include additional production given the logistical timing/rearing space conflicts and limitations of the existing infrastructure. Flow measurements and flow control are lacking at the facility, and the majority of the water is used multiple times as it flows from Hatchery Building B and the concrete nursery tanks to the A & B Raceways and into the broodstock raceways (i.e., raceways C, D, E, and F).

2.2.2.1 Hofer Rainbow Trout

Spawning occurs in the fall for the Hofer strain of Rainbow Trout. Assuming that eggs are available in early November, it takes approximately 82 days from fertilization (i.e., green eggs) to first feeding using the hatchery's monthly average water temperatures (i.e., 43-46°F) for this time of year. The first feeding would be initiated around February 1 when fish are approximately 4,218 fpp (0.84 inches). These fish are reared in the California troughs and should reach approximately 431 fpp (1.8 inches) in mid-April (Table 2-6). At this time, fish may be transferred to the outside concrete nursery tanks, where these fish will remain until they approach their target size of 15 fpp around the end of September. It may be necessary to transfer these fish into the A & B raceways earlier than projected, depending on the availability of the concrete nursery tanks and the timing of the other Rainbow Trout and/or Brown Trout.

Density indices approach the maximum in the concrete nursery tanks; flows were increased 2- and 3-fold in these tanks for this exercise to remain within the FI established for the hatchery. In this scenario, it is assumed that approximately 889,000 eggs are incubated, 666,000 fry are hatched from those eggs, and 400,000 juvenile fish are transferred to the concrete nursery tanks from the California troughs based on survival rates provided by Mount Shasta Hatchery staff for these different life stages. Based on survival estimates, approximately 240,000 juveniles are transferred from the concrete nursery tanks into the A & B raceways, where they will be reared until they achieve the catchable size (i.e., 2 fpp) in August and an approximate ending inventory of 96,000 fish.

Table 2-6. End of Month Production Information for the Rainbow Trout (CO-Hofer) 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 Rearing Feb/Mar/Apr 15	California Trough	120	431.0	1.80	400,000	928.1	1.3	0.35	0.86
Apr/May	Nursery Tank	2	139.0	2.60	346,667	2,494.0	1.6[a]	0.40	1.37
Jun/Jul	Nursery Tank	4	37.0	4.10	293,334	7,927.9	3.1[a]	0.40	1.38
Aug/Sep	Nursery Tank	5	15.0	5.50	240,000	16,000.0	5.0[a]	0.48	1.29
Oct	A&B Bank Raceways	4	11.5	6.00	226,910	19,731.3	35.9	0.23	0.20
Nov/Dec	A&B Bank Raceways	4	6.8	7.10	200,728	29,518.8	35.9	0.30	0.26
Jan/Feb	A&B Bank Raceways	4	5.4	7.70	174,546	32,323.3	35.9	0.30	0.26
Mar/Apr	A&B Bank Raceways	4	3.9	8.60	148,364	38,042.1	35.9	0.32	0.27
May/Jun	A&B Bank Raceways	4	2.6	9.90	122,182	46,993.1	35.9	0.34	0.29
Jul/Aug	A&B Bank Raceways	4	1.7	11.40	96,000	56,470.6	35.9	0.35	0.31

[a] Flows provided in the questionnaire (i.e., 159 gpm, 0.3 cfs per tank) do not meet the FI requirements for the concrete nursery tanks. It is assumed that an increased flow rate (2, 3-fold) is available to generate an FI within the limits as identified by CDFW.

2.2.2.2 Eagle Lake (Hatchery Origin) and West Virginia Rainbow Trout

The Eagle Lake and West Virginia strains of Rainbow Trout spawn in January. It takes approximately 90 days from fertilization (i.e., green eggs) to first feeding using the hatchery's monthly average water temperatures (i.e., 43-44°F) for this time of year. The first feeding would be initiated around May 1 when fish are approximately 4,218 fpp (0.84 inches). These fish are reared in the California troughs and should reach approximately 500 fpp (1.7 inches) in mid-June (Table 2-7Table 2-7). At this time, fish may be transferred to the outside concrete nursery tanks, and these fish will remain in these tanks until they reach their target size of 15 fpp around the end of November. It may be necessary to transfer these fish into the A & B raceways earlier than projected, depending on the availability of the concrete nursery tanks and the timing of the other Rainbow Trout and/or Brown Trout. Density indices reach the maximum criteria in the concrete nursery tanks; flows were increased 2- and 3-fold for this exercise to remain within the FI established for the hatchery. In this scenario, it is assumed that approximately 685,000 eggs are incubated, 514,000 fry are hatched from those eggs, and 360,000 juvenile fish are transferred to the concrete nursery tanks based on survival rates provided by Mount Shasta Hatchery staff for these different life stages. Based on survival estimates, an estimated 250,000 juveniles are transferred from the concrete nursery tanks into the A & B raceways, where they will be reared until they achieve the catchable size (i.e., 2 fpp) in September with an estimated ending inventory of 100,000 fish.

Table 2-7. End of Month Production Information for the Eagle Lake (Hatchery Origin) and West Virginia Rainbow Trout strains Bioprogram(s) 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 Rearing May/Jun 15	California Troughs	120	500.0	1.71	360,000	720.0	1.3	0.29	0.71
Jun 16/July	Nursery Tanks	4	109.0	2.83	332,500	3,050.5	1.7[a]	0.23	1.40
Aug/Sep	Nursery Tanks	4	31.0	4.30	305,000	9,838.7	3.6[a]	0.48	1.43
Oct/Nov	Nursery Tanks	5	15.9	5.40	277,500	17,452.8	5.0[a]	0.54	1.44
Dec/Jan	A&B Bank Raceways	3	10.4	6.20	250,000	24,038.5	26.9	0.37	0.32
Feb/Mar	A&B Bank Raceways	3	7.2	7.00	212,500	29,513.9	26.9	0.40	0.35

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Apr/May	A&B Bank Raceways	4	4.8	8.00	175,000	36,458.3	35.9	0.33	0.28
Jun/Jul	A&B Bank Raceways	4	3.0	9.40	137,500	45,833.3	35.9	0.35	0.30
Aug/Sep	A&B Bank Raceways	4	2.0	10.80	100,000	50,000.0	35.9	0.33	0.29

[a] Flows provided in the questionnaire (i.e., 159 gpm, 0.3 cfs per tank) do not meet the FI requirements for the concrete nursery tanks. It is assumed that an increased flow rate (2, 3-fold) is available to generate an FI within the limits as identified by CDFW.

2.2.2.3 McCloud Redband Rainbow Trout

The McCloud Redband Rainbow Trout, California State "Species of Special Concern," are spawned in the spring. Assuming that spawning occurs in April, it takes approximately 73 days from fertilization (i.e., green eggs) to first feeding using the hatchery's monthly average water temperatures (i.e., 44-47°F) for this time of year. The first feeding would be initiated around May 1, when fish are approximately 4,218 fpp (0.84 inches). These fish are reared in the California troughs and should reach approximately 892 fpp (1.4 inches) around the end of May (Table 2-8). The young McCloud Redbands are transferred into 6-foot- and 10-foot-diameter circular tanks located in Hatchery Building E, where these fish will remain until they achieve their final target size of 15 fpp around December. Density indices and flow indices remain below the hatchery's limits throughout the rearing cycle, and the 6-foot circular tanks were not included in the calculations providing an addition conservative safety factor for rearing this "species of special concern". In this scenario, it is assumed that approximately 421,000 eggs are incubated, 165,000 fry are hatched from those eggs, and 115,000 juvenile fish are transferred from the California troughs into the circular tanks based on survival rates provided by Mount Shasta Hatchery staff for these different life stages.

Table 2-8. End of Month Production Information for the McCloud Redband Rainbow 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 Rearing May	California Troughs	42	892.0	1.40	115,000	128.9	0.5	0.18	0.44
Jun	Circular	14	312.0	2.00	110,000	352.6	1.9	0.05	0.21
Jul	Circular	14	114.0	2.80	105,000	921.1	1.9	0.10	0.39

Production Stage/Month	Tank Type	Tanks Occupied	fpp	Length (in)	Total Fish (#)	Biomass (lbs)	Max. Flow (cfs)	DI	FI
Aug	Circular	14	53.0	3.60	100,000	1,886.8	1.9	0.16	0.62
Sep	Circular	14	31.0	4.30	95,000	3,064.5	1.9	0.22	0.85
Oct	Circular	14	22.0	4.80	90,000	4,090.9	1.9	0.26	1.01
Nov	Circular	14	16.0	5.40	85,000	5,312.5	1.9	0.30	1.17
Dec	Circular	14	13.0	5.80	80,000	6,153.8	1.9	0.32	1.26

2.2.2.4 Brown Trout

Brown Trout are produced at the hatchery to continue to maintain broodstock for CDFW and not for the purposes of stocking. Therefore, production numbers are low to meet the numbers required for the broodstock program. Assuming that eggs are available in November, it takes approximately 105 days from fertilization (i.e., green eggs) to first feeding using the hatchery's monthly average water temperatures (i.e., 43-46°F) for this time of year. The first feeding would be initiated around February 10 when fish are approximately 4,218 fpp (0.84 inches). These fish are reared in the California troughs and should reach approximately 890 fpp (1.4 inches) around the end of March and achieve 200 fpp (2.3 inches) around the middle of June (Table 2-9Table 2-9). At this time fish may be transferred to the outside concrete nursery tanks. These fish will remain in these tanks until they reach their target size of 8 fpp the following spring in May. Once the fish achieve this size, they are transferred into raceway F, where they will be grown and utilized as broodstock.

The bioprogram only shows growth through approximately one year until they reach 2 fpp; actual operations involve holding and spawning fish for multiple years. During rearing the DI approaches the maximum in the California troughs at the time of transfer in accordance with the number of troughs used for these calculations (Table 2-9Table 2-9). For this production modeling, the flows were increased 1.6-fold to keep the FI within the limits set for the hatchery while the Brown Trout were reared in the concrete nursery tanks. In this scenario, it is assumed that approximately 48,000 eggs are incubated, 38,000 fry are hatched from those eggs, and 27,000 juvenile fish are transferred to the concrete nursery tanks based on survival rates provided by Mount Shasta Hatchery staff for these different life stages. It is standard practice for the hatchery to stock out any surplus fish that are not necessary to maintain the Brown Trout broodstock population.

Table 2-9. 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 Rearing Feb/Mar	California Trough	5	890.0	1.40	32,786	36.8	0.1	0.43	1.05
Apr/May/ Jun 15	California Trough	10	200.0	2.30	27,000	135.0	0.1	0.48	1.17
Jun/Jul	Nursery Tank	1	83.0	3.10	25,650	309.0	0.4	0.08	0.63
Aug/Sep	Nursery Tank	1	34.0	4.20	24,300	714.7	0.4	0.14	1.07
Oct/Nov	Nursery Tank	1	20.0	5.00	22,950	1,147.5	0.4	0.19	1.44
Dec/Jan	Nursery Tank	1	14.0	5.60	21,600	1,542.9	0.4	0.23[a]	1.38
Feb/Mar	Nursery Tank	1	11.0	6.10	20,250	1,840.9	0.6	0.25[a]	1.21
Apr/May	Nursery Tank	1	8.0	6.80	18,900	2,362.5	0.6	0.29[a]	1.39
June	Raceway F Brood	1	6.4	7.30	18,270	2,854.7	9.0	0.03	0.10
July-March	Raceway F Brood	1	2.0	10.80	13,230	6,615.0	9.0	0.04	0.15

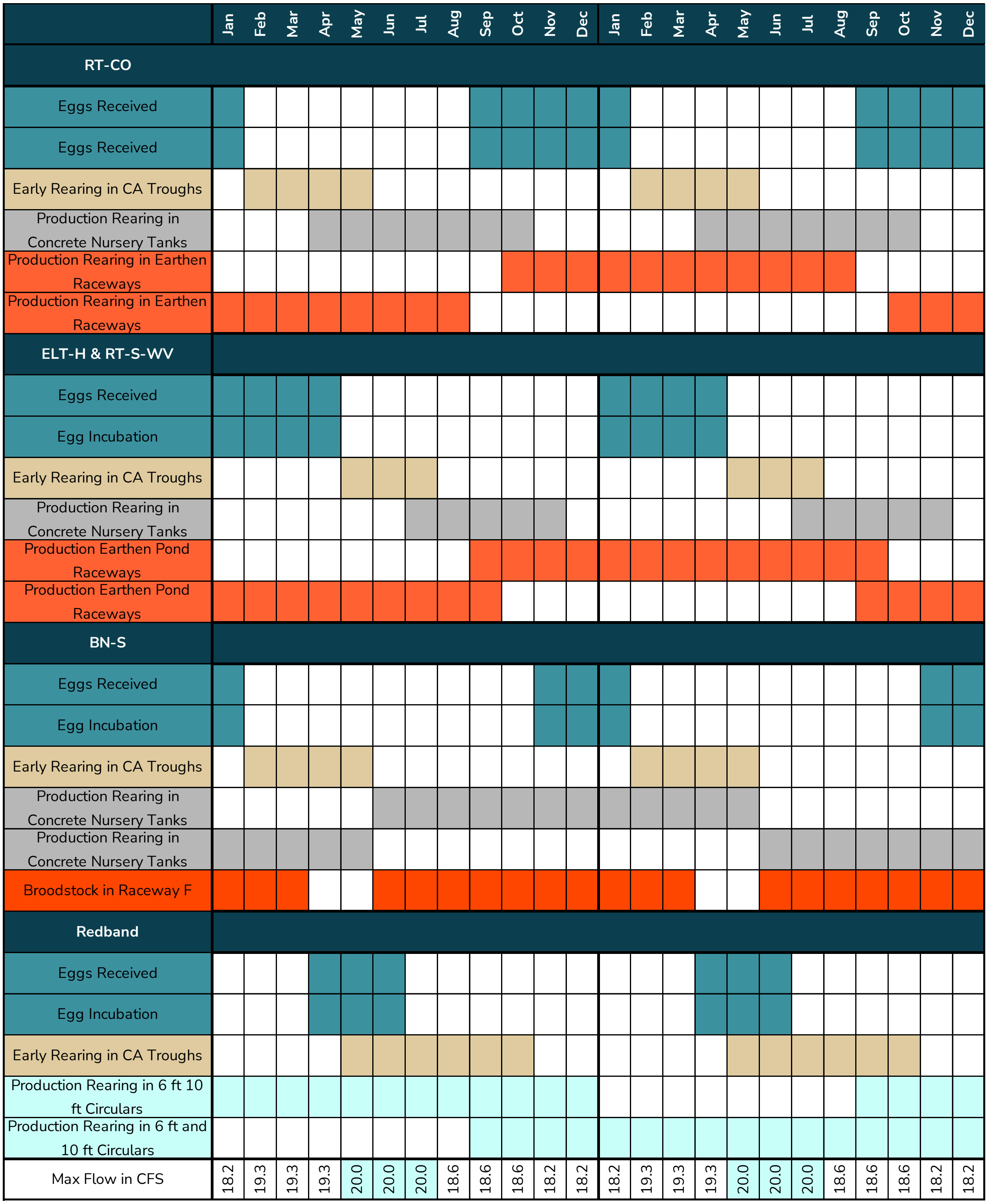
[a] Flows provided in the questionnaire (i.e., 159 gpm, 0.3 cfs per tank) do not meet the FI requirements for the concrete nursery tanks. It is assumed that an increased flow rate (1.6-fold) is available to generate an FI within the limits as identified by CDFW.

2.2.2.5 Summary

It should be noted that the FIs and DIs at the end of each month for each cohort of fish are within the criteria specified in Table 2-4, with the caveat that flow rates were adjusted 1.6 to 3-fold above the 159-gpm reported in the questionnaire. The flows were adjusted to generate calculations specifically for the concrete nursery tanks to operate within the FI selected for the hatchery with the assumption that an increased flow rate is available. This provided realistic production output numbers for this modeling exercise rather than limiting the production potential in a situation when flow is not limiting. It should also be noted that the FI selected for the hatchery is conservative as it is based on a water temperature of 51°F at and an elevation of 3,000 feet; the maximum water temperature the hatchery may experience in any given year. The 51°F water temperature is well within the projected water temperatures in the future relative to climate change as described in Section 0.

Utilizing the existing programs as scheduled, this production allows for several opportunities to depopulate and clean rearing areas, perform routine maintenance, etc., while producing approximately 196,000 catchable size Rainbow Trout (i.e., Hofer, Eagle Lake, and West Virgina strains) weighing approximately 106,470 pounds based on the target stocking size of 2 fpp. Additionally, the hatchery will produce approximately 80,000 McCloud Redband Rainbow Trout sub-catchable fish weighing 6,150 pounds and produce approximately 13,000 future Brown Trout broodstock weighing 6,600 pounds. Total combined annual production for the hatchery is approximately 289,000 fish weighing 119,220 pounds. The modeled production aligns with the hatchery's goal without making any infrastructure changes based on the assumptions for the bioprogram (Table 2-5) and the recommended DI and FI criteria for the water temperatures at the facility. Once fish reach the target stocking size, they should be stocked out relatively soon to open rearing space for the next cohort of fish and because the FI criteria will be exceeded if fish continue to grow (Table 2-6, Table 2-7, Table 2-8, and Table 2-9).

Water demand is projected to be the highest in May, June, and July each year, as shown in Figure 2-1. The water flow specified in Figure 2-1 is meant to show the flow requirement, assuming all rearing areas are supplied with the maximum water flow. In practice, once fish have been transferred from the hatchery building to the raceways, they will likely not require the maximum water flow until they reach a larger size. Due to the lack of operational valves, flow is continuous in the A & B raceways, regardless of the water requirement for the size, number, and biomass of the fish being reared in the raceways. Note that the different colored blocks in the following figure correspond to the months for when each species is in either the deep or round tanks or in the raceways, along with noting when eggs are received and incubated.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RT-CO																								
Eggs Received	🟦								🟦	🟦	🟦	🟦	🟦								🟦	🟦	🟦	🟦
Eggs Received	🟦								🟦	🟦	🟦	🟦	🟦								🟦	🟦	🟦	🟦
Early Rearing in CA Troughs		🟨	🟨	🟨	🟨									🟨	🟨	🟨	🟨							
Production Rearing in Concrete Nursery Tanks				▨	▨	▨	▨	▨	▨	▨						▨	▨	▨	▨	▨	▨	▨		
Production Rearing in Earthen Raceways										🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧				
Production Rearing in Earthen Raceways	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧														🟧	🟧	🟧
ELT-H & RT-S-WV																								
Eggs Received	🟦	🟦	🟦	🟦									🟦	🟦	🟦	🟦								
Egg Incubation	🟦	🟦	🟦	🟦									🟦	🟦	🟦	🟦								
Early Rearing in CA Troughs					🟨	🟨	🟨										🟨	🟨	🟨					
Production Rearing in Concrete Nursery Tanks							▨	▨	▨	▨	▨								▨	▨	▨	▨	▨	
Production Earthen Pond Raceways									🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧			
Production Earthen Pond Raceways	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧												🟧	🟧	🟧	🟧
BN-S																								
Eggs Received	🟦										🟦	🟦	🟦										🟦	🟦
Egg Incubation	🟦										🟦	🟦	🟦										🟦	🟦
Early Rearing in CA Troughs		🟨	🟨	🟨	🟨									🟨	🟨	🟨	🟨							
Production Rearing in Concrete Nursery Tanks						▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨							
Production Rearing in Concrete Nursery Tanks	▨	▨	▨	▨	▨													▨	▨	▨	▨	▨	▨	▨
Broodstock in Raceway F	🟥	🟥	🟥			🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥			🟥	🟥	🟥	🟥	🟥	🟥	🟥
Redband																								
Eggs Received				🟦	🟦	🟦										🟦	🟦	🟦						
Egg Incubation				🟦	🟦	🟦										🟦	🟦	🟦						
Early Rearing in CA Troughs					🟨	🟨	🟨	🟨	🟨	🟨							🟨	🟨	🟨	🟨	🟨	🟨		
Production Rearing in 6 ft 10 ft Circulars	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩									🟩	🟩	🟩	🟩
Production Rearing in 6 ft and 10 ft Circulars									🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Max Flow in CFS	18.2	19.3	19.3	19.3	20.0	20.0	20.0	18.6	18.6	18.6	18.2	18.2	18.2	19.3	19.3	19.3	20.0	20.0	20.0	18.6	18.6	18.6	18.2	18.2

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

3.0 Climate Evaluation

3.1 Introduction

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

3.2 Water Sources

The hatchery's water source is a natural spring which upwells in the City Park about 1 mile away from the facility, and which discharges into Big Springs Creek. Spring flow varies seasonally, with lower flows in the summer months, during which there is significant spring water withdrawal by ranchers. Water temperatures are favorable for fish rearing, varying seasonally between 37°F and 52°F.

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 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
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 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.

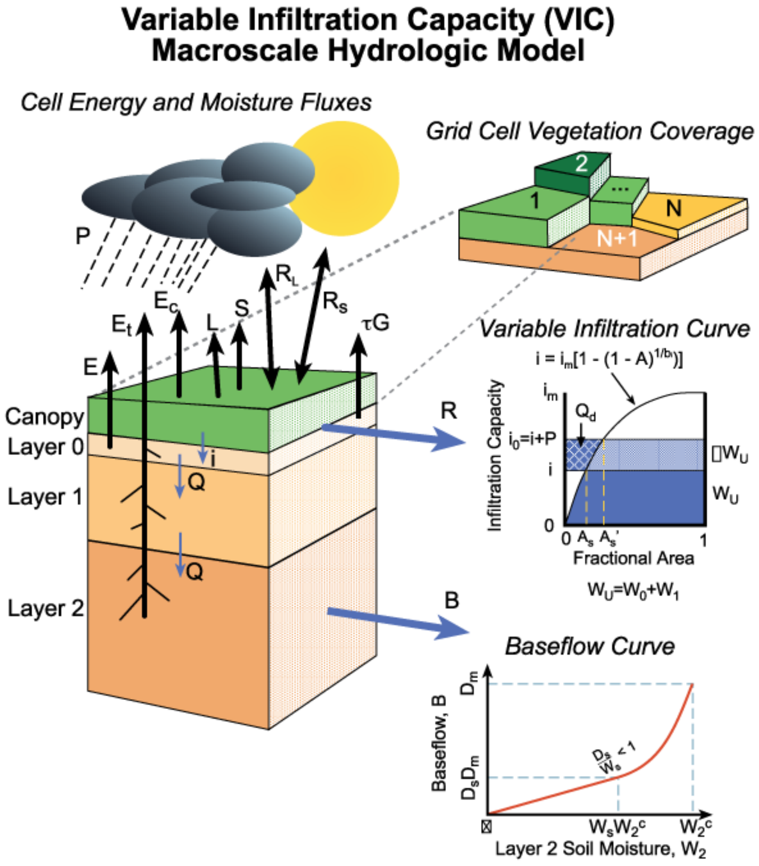


Figure 3-1. The VIC Hydrologic Model. Figure source: University of Washington, 2021.

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, precipitation and evapotranspiration) 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 (b) 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 water temperature** of the natural spring water that is source to the hatchery were obtained using empirical relationships developed in this project between daily observations of air temperature and water temperature. The observed temperature data for the spring water were provided by the hatchery, while the air temperature corresponded to the Mount Shasta meteorological station record, combined with the publicly available Livneh gridded data set (Livneh et al., 2013) for the grid cell containing the hatchery. The Livneh data allowed extending the record back to the reference period 1984-2003 and obtaining estimates of maximum daily temperatures (T_{max}). Methods for developing such relationships between air and water temperature were previously applied successfully in climate vulnerability assessments conducted for Washington state hatcheries (McMillen, Inc, 2023; USFWS, 2021). The empirical relationship specific to this hatchery site was used to obtain projected water temperatures from the projected air temperatures increases determined from item (a) above.
3. **Projections of wildfire risk** at each hatchery site were evaluated at a high level based on the projections by Westerling (2018), which are available through the California government Cal-Adapt.org website (Cal-Adapt, 2023). In addition to the risk that fire poses to the facility, it has the effect of reducing soil permeability, increasing peaks of runoff and stream flows that impact flooding and water quality, and potentially decreasing groundwater recharge.

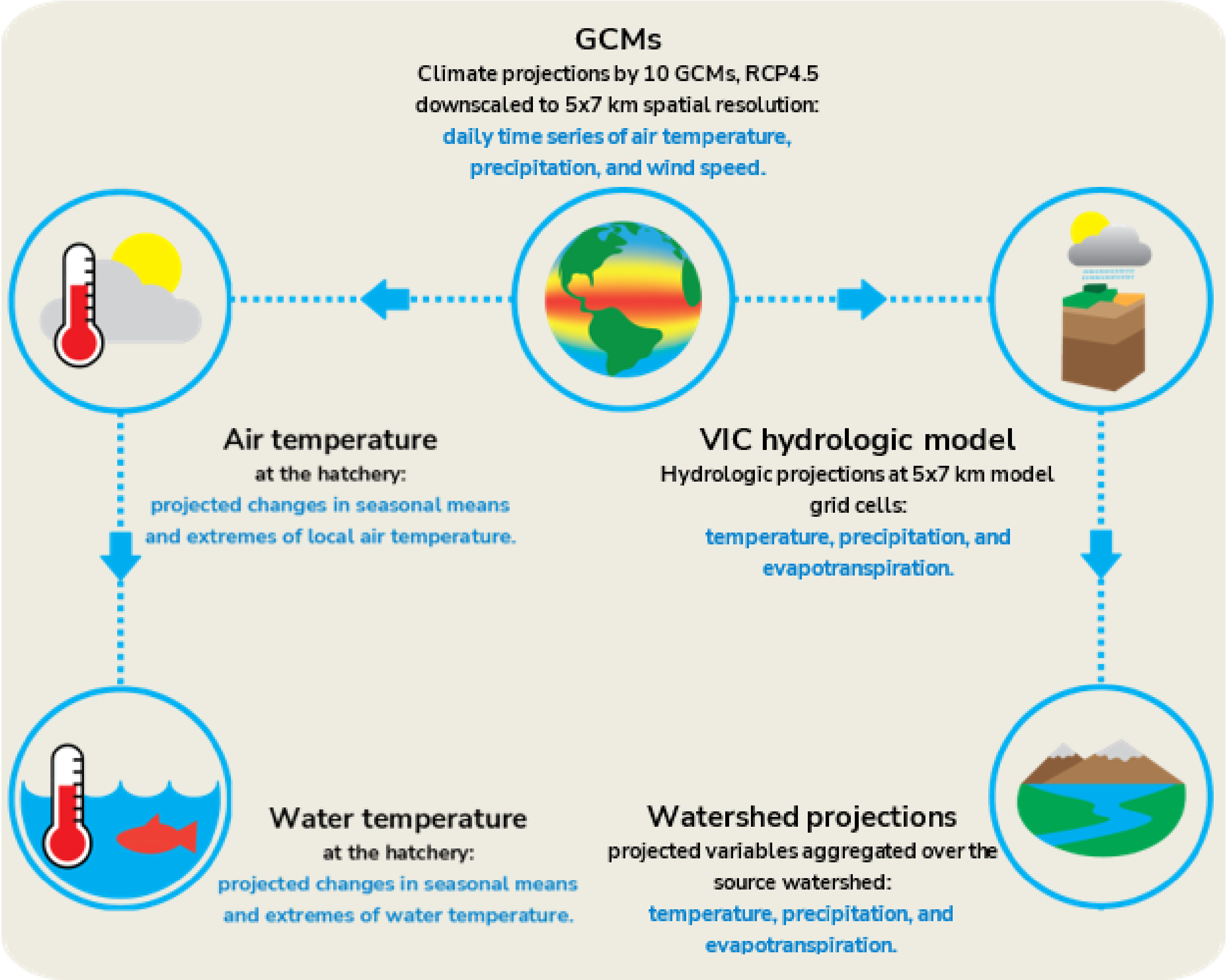


Figure 3-2. Methodology for Obtaining Projections.

3.4 Uncertainty and Limitations

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

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

3.5 Projected Changes in Climate at the Hatchery Site

3.5.1 Air Temperature

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

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

At the hatchery site, mean annual air temperature is projected to rise by 2.5°F in the near future period compared to the reference period (1984-2003), and by an additional 1.3°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 3.1°F in the next 20 years, relative to the reference period. The 97th percentile of the daytime maximum temperature is also projected to rise by 3.1°F, reaching 94.3°F. These projected temperatures represent potentially hazardous outdoor working conditions at the hatchery.

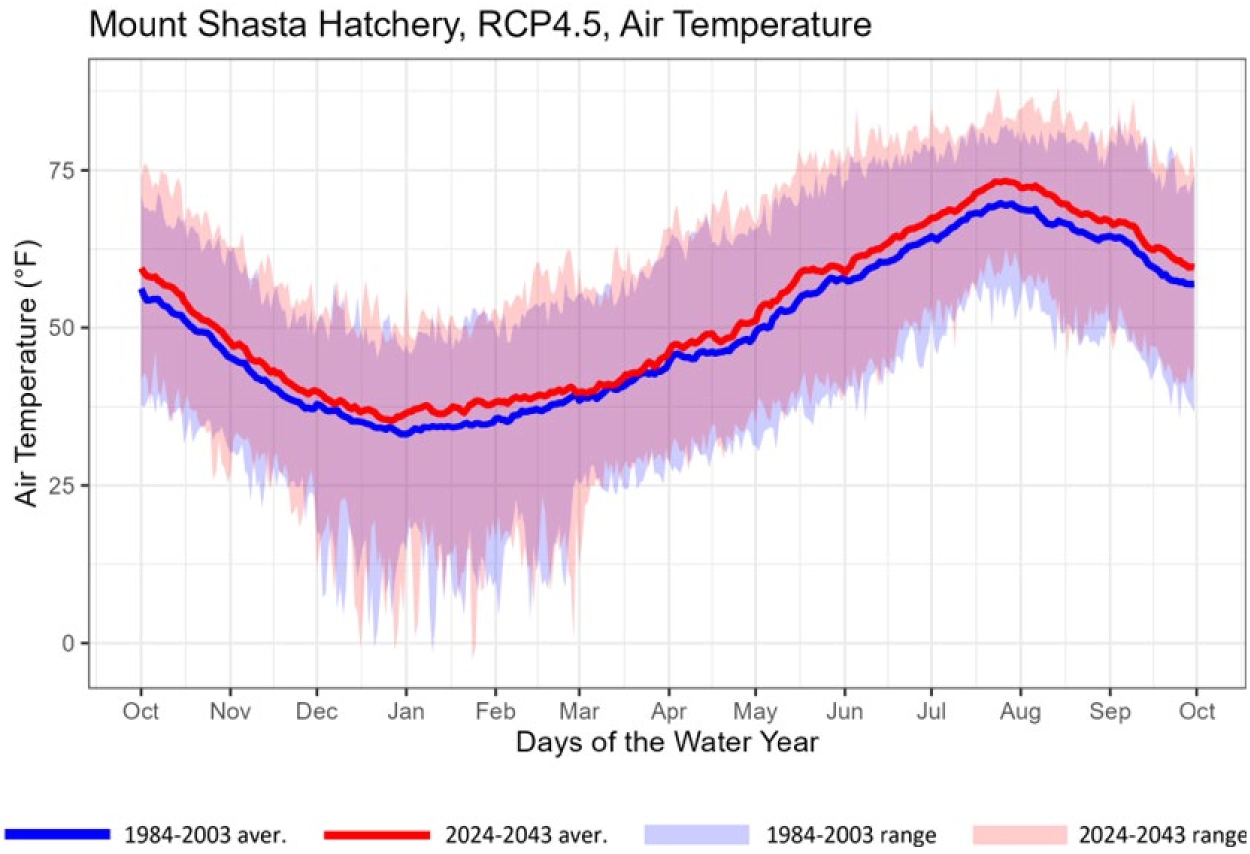


Figure 3-3. Mean Daily Air Temperature and Range for Each Day of the Year.

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	52.1°F (+2.5°F)	38.2°F (+2.4°F)	49.8°F (+2.1°F)	67.7°F (+3.1°F)	53.1°F (+2.8°F)
Lowest	51.7°F (+2.1°F)	37.1°F (+1.3°F)	47.9°F (+1.2°F)	66.4°F (+1.8°F)	51.7°F (+1.4°F)
Highest	52.8°F (+3.2°F)	38.9°F (+3.1°F)	50.9°F (+3.2°F)	68.7°F (+4.1°F)	54.1°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	53.4°F (+3.8°F)	39.4°F (+3.6°F)	51.2°F (+3.5°F)	68.9°F (+4.3°F)	54.1°F (+3.8°F)
Lowest	52.5°F (+2.9°F)	38.1°F (+2.3°F)	50.1°F (+2.4°F)	67.6°F (+3.0°F)	52.8°F (+2.5°F)
Highest	54.5°F (+4.9°F)	40.1°F (+4.3°F)	52.1°F (+4.4°F)	70.8°F (+6.2°F)	55.4°F (+5.1°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	38.6°F (+2.4°F)	51.0°F (+2.2°F)	65.5°F (+2.4°F)	81.5°F (+3.1°F)	94.3°F (+3.1°F)
Lowest	37.7°F (+1.5°F)	50.2°F (+1.4°F)	64.8°F (+1.7°F)	81.0°F (+2.6°F)	93.7°F (+2.5°F)
Highest	40.0°F (+3.8°F)	51.9°F (+3.1°F)	66.2°F (+3.1°F)	82.2°F (+3.8°F)	95.3°F (+4.1°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	40.1°F (+3.9°F)	51.9°F (+3.1°F)	66.8°F (+3.7°F)	82.7°F (+4.3°F)	95.2°F (+4.0°F)
Lowest	38.4°F (+2.2°F)	50.9°F (+2.1°F)	66.2°F (+3.1°F)	81.3°F (+2.9°F)	93.9°F (+2.7°F)
Highest	41.1°F (+4.9°F)	52.4°F (+3.6°F)	67.6°F (+4.5°F)	84.1°F (+5.7°F)	96.6°F (+5.4°F)

3.5.2 Water Temperature

Once-weekly water temperature observations were provided by the hatchery for the period from 2017 through 2022, with year 2020 missing (except for one data point in late December). These data are plotted against time as points in Figure 3-4, with concurrent air temperature at Mount Shasta MTA meteorological station plotted as lines. In Figure 3-5, the same water temperature and air temperature observations are plotted against each other, exhibiting a linear relationship despite considerable scatter. The blue dashed line on Figure 3-5 was fitted to these data by linear regression of water temperature on air temperature. Its slope is 1°F/8.5°F, indicating that mean daily water temperature within this range of observations rises or falls by 1°F for an 8.5°F rise or fall in mean daily air temperature. For this reason, mean annual water temperature is expected to increase by 0.3°F, reaching 46.1°F, as a response to the projected 2.5°F rise in mean annual air temperature. In summer, mean water temperature is projected to increase by 0.4°F, reaching 48.3°F. The range for the different global climate models was 48.1°F to 48.4°F. The 97th percentile of daily water temperature is estimated from the observations to be 50°F, and is projected to increase to 50.4°F. The range of the ten global climate models was 50.2°F to 50.5°F.

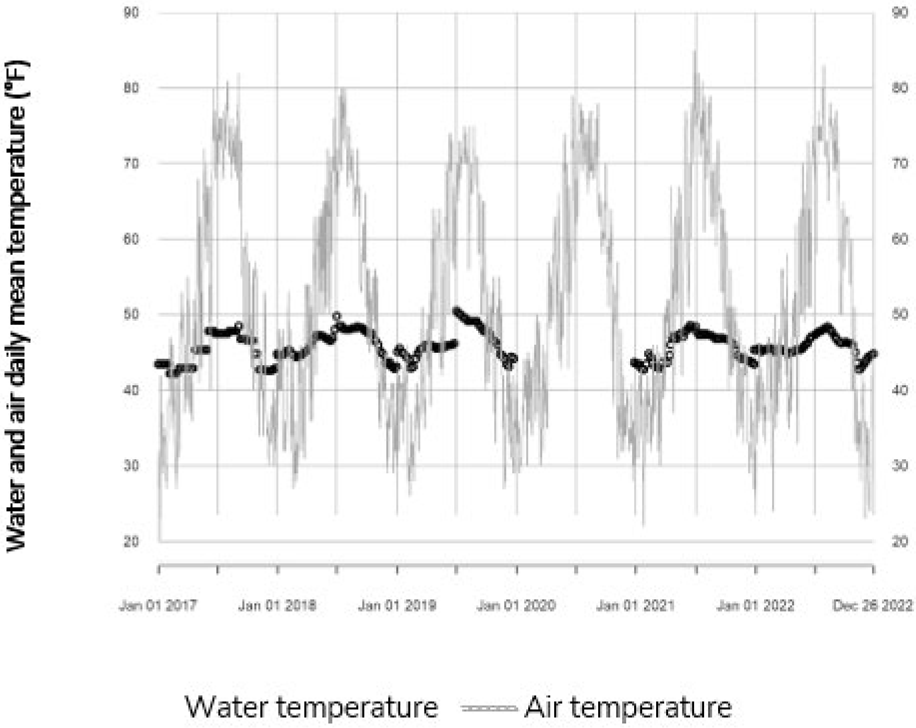


Figure 3-4. Water Temperature and Air Temperature Once-Weekly Observations.

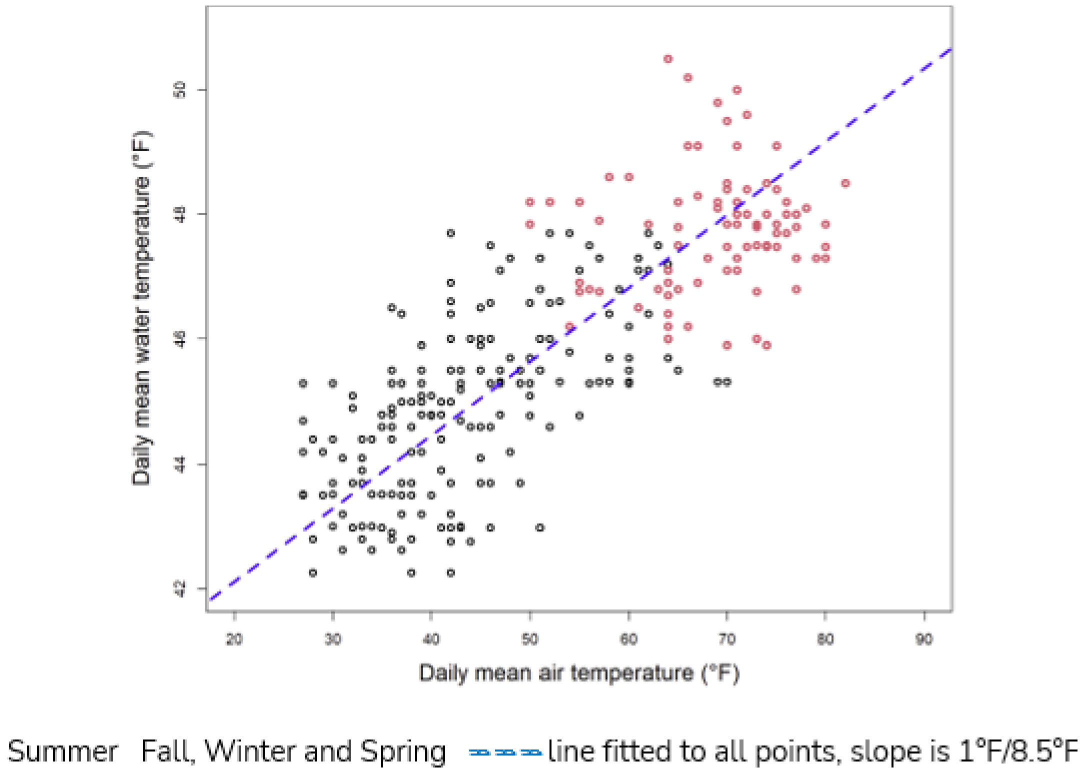


Figure 3-5. Water Temperature's Dependence on Air Temperature.

3.5.3 Precipitation Minus Evapotranspiration

The projected water balance at the land surface, given by total precipitation (P) minus evapotranspiration (ET) is projected to change little on a total annual basis in the next 20 years in the vicinity of the hatchery. However, P-ET has projected large declines in the spring season, averaging -19% over the ensemble of ten GCMs (Figure 3-6, Table 3-6, and Table 3-7). This is due to a significant projected increase in evapotranspiration.

In the mid-century period, the decline in spring P-ET is aggravated, reaching -78% compared to the reference period, and all seasons except for winter have projected declines in P-ET. In winter, P-ET is projected to increase in the mid-century period as a result of a projected increase in precipitation (Table 3-6 and Table 3-7).

The surface water balance, P-ET, is an indicator of future direction of change in groundwater recharge rates but has large associated uncertainty given that precipitation in California is subject to great natural variability, experiencing large departures from the mean in any given year or multi-year period. Mimicking this natural variability, precipitation projections for the next 20 years vary widely between different GCM runs and are subject to great uncertainty.

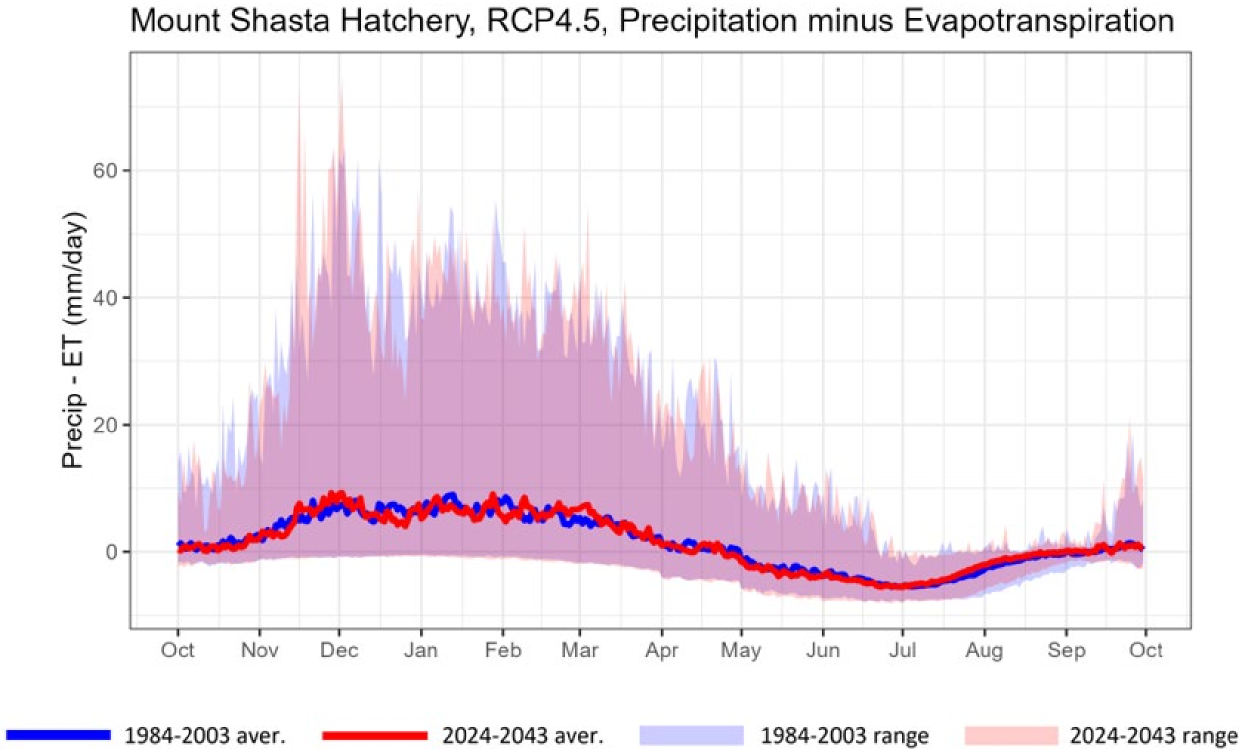


Figure 3-6 Mean Daily Precipitation Minus Evapotranspiration and Range for Each Day of the Year in the Hatchery Site Vicinity.

Table 3-6. Projected 2024-2043 Change in the Seasonal Total Precipitation Minus Evapotranspiration (Change Relative to 1984-2003).

GCM	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Precipitation mean	+1%	≈0	+4%	-5%	≈0
Evapotranspiration (ET) mean	+2%	+37%	+9%	-6%	+1%
Precipitation-ET mean	-1%	-2%	-19%	-6%	≈0

Table 3-7. Projected 2044-2063 Change in the Seasonal Total Precipitation Minus Evapotranspiration (Change Relative to 1984-2003).

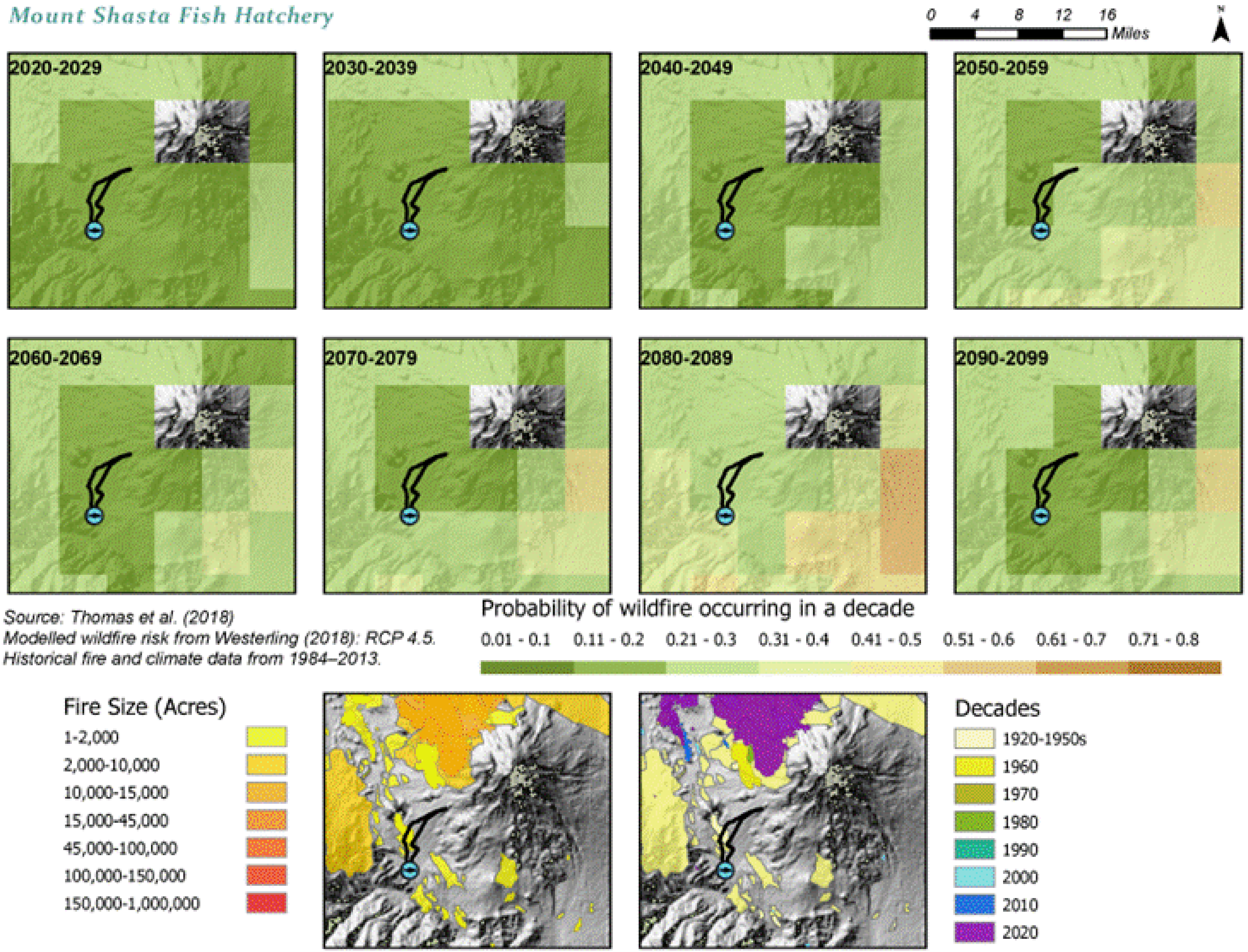
GCM	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
Precipitation mean	+5%	+14%	-4%	-3%	-8%
Evapotranspiration (ET) mean	+3%	+52%	+15%	-10%	+4%
Precipitation-ET mean	+6%	+12%	-78%	-11%	-12%

3.5.4 Fire Risk

Historical wildfires have not been documented at the hatchery location or in adjacent basins for at least 70 years (Figure 3-7). While cyclical fires are common on the northern slopes of Mt Shasta, wildfires are less common along its southern slopes. The surrounding landcover varies from mixed land use to coniferous cover in the uplands. Wildfire fuels in the form of mature coniferous trees are therefore in high supply in the surrounding area given the lack of observed fire in recent decades.

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 13 and 25% through mid-century (Figure 3-7). The risk increases to 30% chance toward the end of this century.

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 with the first five years of a post-fire landscape. This is expected to have the highest impact during high intensity rain events and after spring snowmelt. Stream water temperatures can warm in the summers following fire as well due to reduced canopy cover. Additionally, more proximal fires can directly impact hatchery grounds and surrounding infrastructure.



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

Source: Historical Wildfire Perimeters (through 2022) from California Dept of Forestry and Fire Protection (2023)

Figure 3-7. Wildfire Risk as Probability of Future Occurrence and Known Historical Fires.

3.6 Conclusions

Significant increases in air temperature are expected for the Mount Shasta Hatchery location. Mean annual air temperature is projected to rise by 2.5°F in the next 20 years (2024-2043) and by an additional 1.3°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 both projected to warm by 3.1°F in the next 20 years, relative to the reference period.

According to gridded air temperatures for the reference period 1984-2003, the 75th and 97th percentiles of peak daytime temperature (i.e., the temperature at the hottest time of day) were 78.4°F and 91.2°F. For the near future period (2024-2043), these percentiles are projected to rise to 81.5°F and 94.3°F, respectively. Such an increase in the peak air daytime temperature requires adaptation measures for protection of hatchery workers against heat stroke and other health effects of heat exposure. Roads and roofs may also need to be replaced using more heat-resistant and reflective materials.

Observations show that the mean daily water temperature of the spring that supplies the hatchery changes by 1°F for every 8.5°F of air temperature change. Therefore, the projected 2.5°F atmospheric warming in the next 20 years is expected to elevate water temperature by 0.3 degrees. In summer, mean water temperature is projected to increase by 0.4°F, reaching 48.3°F. The 97th percentile of daily water temperature is estimated from the observations to be 50°F, and is projected to increase to 50.4°F. The range of the ten global climate models was 50.2°F to 50.5°F.

The hatchery is at moderate risk of wildfires. While wildfires have not been documented in the immediate surrounding area within recent decades, there is a history of large fires along the northern slopes of Mount Shasta. Given the recent absence of fire on the southern slopes and recovery of fuels, there is 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 13-25% through mid-century. Post-fire conditions also pose risks to the hatchery, including scar-induced flooding, turbidity, debris, and warmer waters due to loss of riparian tree shade.

4.0 Existing Infrastructure Deficiencies

Multiple hatchery deficiencies were identified throughout the infrastructure descriptions in the Site Visit Report (Appendix A). Section 5.4 of the Site Visit Report identified potential technologies and solutions needed to address specific deficiencies that would allow the hatchery to meet production goals and provide protection against climate change. These technologies and solutions include screening and disinfection of the Big Springs Creek water supply, piping of the Big Springs Creek water supply from the intake to the hatchery, incorporating the ability to heat water for Hatchery Building E for the incubation area, providing roofing/shade cloth (temporary) for the concrete nursery tanks, replacement of the A&B Bank Raceways with circular tanks under a roofed structure with netted sides, skim coating and epoxy painting the concrete nursery tanks and raceways, adding a drum screen and UV treatment for the C, D, E and F Raceways, insulating and heating Hatchery Building B, adding a new building to replace Hatchery Building E to meet the needs of the McCloud Redband Program, and upgrading old plumbing throughout the hatchery to include water control valves for all hatchery production areas. 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 repairing the existing filtration and UV disinfection system for Hatchery Building E (identified in both Sections 3.2 and 5.4 in the Site Visit Report), covering outdoor rearing vessels with solid roof structures and enclosed sides, installing a physical barrier to isolate the McCloud Redband Rainbow Trout from the incubation area in Hatchery Building E, and placing of footbaths at the entrance of each hatchery building with Virkon or an alternative disinfectant. The details of these deficiencies are further expanded upon in Section 4.1 and 4.2.

4.1 Water Process Infrastructure

4.1.1 Uncontrolled and Untreated Intake Flow

The hatchery receives its entire water flow from Big Springs Creek, which is fed from an underground spring located in a public park. At the point of diversion, downstream from the park, water is diverted into a concrete inlet box before continuing in the earthen canal towards the hatchery. The only way to control the amount of flow entering the earthen canal is to manually adjust the wooden stop logs adjacent to the concrete intake box. During storm events, the hatchery experiences significantly higher flows which the staff must manage with numerous valves throughout the facility.

Water travels through an earthen canal for several hundred feet before it enters the hatchery. A public trail and the property lines of several homes are located adjacent to the canal. Water in the canal is open to the environment, which creates a pathway for pathogens and debris from local wildlife, residents, dogs, etc. to enter the water. After traveling through the canal, water enters an intake settling pond and travels through a metal screen (the metal screen is cleaned with a waterwheel-powered cleaning brush). The settling pond is not large enough to treat the higher flows during storms and debris still enters the facility during these events. The water then continues to the main concrete distribution box, where it is directed to different locations throughout the hatchery. Only water traveling to Hatchery Building E is filtered and disinfected using UV prior to use, all other water is unfiltered and untreated.

4.1.2 Low Water Temperature in Hatchery Building E

The Big Springs Creek water supply typically runs cooler than desired for egg incubation, which slows the production schedule and increases the amount of time required to hatch eggs. This increases the time the staff must wait for total temperature units for the triploid program before they pressurize the eggs. Additional incubation time for egg development and hatching also delays starting young fish on feed and increases the overall time it takes for each group of fish to achieve target sizes. This results in increased staff time (e.g., feeding fish, cleaning tanks, etc.) and associated costs. If fungus is present and eggs are treated with formalin routinely to control fungus, there are additional costs associated with chemicals to control fungus depending on the temperature. The lack of temperature control reduces the staff's ability to adjust timing for the various egg groups to maximize production and avoid bottlenecks.

4.1.3 Untreated Water in the C, D, E, and F Raceways

The hatchery water passes through hatchery Building B and the Earthen ponds before entering C, D, E, and F Raceways used for broodstock. This water is untreated. Typically, adult fish are more resilient to pathogens, however, there are many pathways for pathogens to enter the water before it is used for broodstock. Additionally, the hatchery has experienced issues with fungus in the adult fish reared in C, D, E, and F raceways. The Earth Ponds are open to the environment and cannot be cleaned like a typical raceway or tank due to the rock lining. This allows algae to grow, and birds and other predators are frequently in the Earth Ponds. The Earth Ponds have a high exposure to pathogens, and this water flows directly to the broodstock raceways without treatment.

4.1.4 Aging Valves and Piping throughout the Hatchery

The Mount Shasta Hatchery was acquired by the State of California in 1888, and while it has been renovated and upgraded over time, much of the infrastructure is still over 40 years old. Valves and pipes throughout the hatchery have reached the end of their functional life expectancy. The aging valves limit the hatchery staff's ability to control flow to the different rearing units. Additionally, it creates reliability issues. If a pipeline to one or more of the rearing areas was to break, the hatchery would experience a fish loss.

4.1.5 Inoperable Filter and UV Treatment for Hatchery Building E

The hatchery has a microscreen drum filter and a UV unit to treat the incoming water for Hatchery Building E. However, during the initial site visit the drum filter was not working. The hatchery staff reported they have not been able to consistently use it for water treatment. CDFW initiated a process to restore function of the filter and UV system for Hatchery Building E. The repair included increasing the screen size on the microscreen drum filter to 40 microns. However, after this repair the hatchery experienced a storm event that caused the drum filter to break down again. CDFW is working with the manufacturer to find a solution and therefore, this item will not be included in the proposed alternatives for this project.

4.2 Rearing Infrastructure

4.2.1 Biosecurity Concerns and Rearing Limitations in A&B Bank Raceways

The existing A&B Raceways consist of four earthen ponds (80 ft x 25 ft) operating in series. These ponds are lined with rock along the bottoms and sides and separated by metal grates. The raceways have no flow control measures. The rock lining of the earthen ponds provides ample surface area for algae growth while making cleaning difficult. Additionally, the rock lining makes moving or collecting fish difficult as the rocks provide areas for fish to hide in.

The ponds are located in a chain-link fenced area with bird wire strung across, but predation is still high. Birds easily fly through wide gaps between the overhead wire. Additionally, the gates to the chain-link fences are often left open, which allows full access for predators or to members of the public. Mount Shasta allows self-guided tours, so members of the public can walk directly to the banks of the A&B raceways to view or to feed fish. The accessibility of these ponds poses a large biosecurity concern. The survival rate of fish in the A&B Raceways is approximately 15%.

4.2.2 Aging Concrete Nursery Tanks and C, D, E, and F Raceways

Concrete in the nursery tanks and Raceways C-F is showing signs of aging. The underlying aggregate in the floor and walls of the raceways is exposed due to wear which creates an abrasive surface that can be harmful to fish as well as a surface that promotes algae growth. The rough aggregate is difficult for hatchery staff to clean efficiently. The concrete in the nursery tanks and Raceways C-E has no solid covering and is consequently exposed to all weather conditions which can accelerate deterioration.

4.2.3 Failing Water Supply Line and Cold Ambient Temperatures in Hatchery Building B

The main water line runs the length of the Hatchery Building B and is considered a high risk for failure in the near future. This water supply line and components are in need of replacement prior to failure and loss of fish. Additionally, Hatchery Building B is unheated and uninsulated, which results in a cold/damp working environment in the winter.

4.2.4 Limited Capacity and Historical Status of Hatchery Building E

Hatchery Building E is only used for incubation and the McCloud Redband Trout. The building is very limited in space, and while the hatchery has made some changes to accommodate their needs, they are still limited. Additionally, Hatchery Building E was one of the original buildings and, as a result, has historical status. The historical status means that any changes or renovation to the building must undergo a lengthy permitting process, and construction must be completed using approved materials. The hatchery has experienced difficulty meeting the requirements and has been unable to fix the roof, eaves, and siding damage. Inside the building is a single heater for the entire space. In the winter months, condensation has led to the accumulation of mold in the interior of the building because of this limited heating. Besides the damage to the structure of the building, the hatchery is also limited in the treatment and rearing equipment they can utilize in the building because of these historical limitations. Overall, Hatchery Building E is likely reaching the end of its lifespan and will either require extensive renovation or the hatchery will require additional early rearing space.

4.2.5 No Solid Roofing or Enclosure on Concrete Nursery Tanks or C-F Raceways

The concrete nursery tanks are enclosed in high chain-link fencing and bird wire. The existing C-F Raceways have no covering or siding. The hatchery staff has reported bird predation in the concrete nursery tanks and Raceways C, D, E, and F. There was also a bear report at the facility. Predation from birds and other animals can introduce pathogens to the rearing environment and cause stress in the fish, both of which can result in fish loss. In addition, fish raised in the nursery tanks and raceways are fully exposed to all weather conditions, from direct sunlight to rain and snowfall. As mean and maximum ambient air temperatures continue to rise, reducing the solar effects on water temperature in the hatchery will be critical to maintaining temperatures within the range for salmonids. Prolonged exposure to sunlight and UV rays warms the water, can cause sunburn on the fish, and damages the infrastructure.

4.2.6 No Separation Between McCloud Redband from Incubation Space in Hatchery Building E

Hatchery Building E houses the incubation for all eggs at the hatchery, including triploid egg production, and rearing the McCloud Redband Trout, a “Species of Special Concern.” There is no physical barrier between the incubation area and the McCloud Redband Program. The McCloud Redband Trout program brings in wild fish in an effort to rescue and reestablish the fish in native streams. The fish brought in may carry pathogens that may spread to the incubation and early rearing area. Water splashing, equipment, or staff moving between the areas could be a potential vector for the spread of disease. Additionally, many of the McCloud Redband Trout are older fish that are more resilient to pathogens but can still carry them. However, the risk of pathogens could travel in both directions, from egg to fish and fish to egg.

5.0 Alternative Selected

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 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 concept drawing of the selected alternatives is presented in Appendix C.

5.1 Alternative Description

5.1.1 Big Springs Diversion and Piping

Water from Big Springs Creek is diverted through a barred inlet and concrete box before traveling through the earthen canal toward the hatchery. The flow entering the hatchery is currently uncontrolled and, other than the barred inlet, is unscreened until reaching the intake settling pond and intake pond debris screen. When storms occur, the hatchery experiences surges in flow and debris load, the latter having blown out the drum filter in the past.

The preferred alternative is rebuilding the concrete inlet to include flow control and a debris screen. Adding a flow control valve would allow the hatchery to maintain a desired flow limit, and the added debris screening would alleviate the debris load in the water. Adding a debris screen would require routine checks and cleaning to be performed by hatchery staff. While including flow and debris control at the intake from the creek would improve water management and quality at the hatchery, the existing intake structure is approximately 0.25 miles from the hatchery. Providing power and security at the intake structure will require additional complexity.

The hatchery's existing water supply enters the facility through an open, earthen canal and intake pond. Both are exposed to the environment and create biosecurity and water loss issues. It is the preferred alternative to install a 36-inch-diameter HDPE pipe that connects Big Springs Diversion directly to the distribution box located near the concrete nursery tanks. The proposed pipe would follow the path of the existing earthen canal, which would be filled in, and backfilled.

Piping the water directly from the point of diversion would allow the elevation head to be maintained, which would provide increased pressure/flow capabilities. The hatchery would no longer have to maintain the existing earthen canal, which has been prone to failure, the intake settling pond, or the intake pond debris cleaning screen. Eliminating the exposure the water currently undergoes when traveling in the earthen canal would reduce the opportunity for contamination from outside sources, as it is known that wildlife, dogs, and locals frequently enter or drink the water in the canal. Piping and filling the earthen canal would have an unknown effect on the local wildlife, reduce the opportunity for sediment to settle out, and could potentially receive criticism from local citizens.

Table 5-1 provides a water budget comparison between the water requirements for the existing facility relative to the proposed preferred alternatives including replacement of the concrete nursery tanks with intermediate rearing circular tanks with PRAS and final rearing of Rainbow Trout using PRAS to replace the A and B earthen ponds along with valving and piping upgrades. All flows were included in the table, but due to the hatchery design and current operations, the water is reused as it moves through the hatchery; therefore, some flows for the existing facility were not included in the totals in Table 5-1. Water requirements for incubation and early rearing will remain the same utilizing Heath incubation stacks, 164 troughs and two deep tanks for a total of 905 gpm. The new intermediate rearing PRAS circular tanks would replace the existing concrete nursery tanks reducing the flow requirements from 1,272 to 480 gpm for a water flow savings of 792 gpm. Larger PRAS circular tanks would replace the A and B earthen ponds which currently do not have functional water flow control valves. The earthen ponds flows based on the questionnaire are around 8,054 gpm. The proposed PRAS circular tanks would require 1,320 gpm of make-up water, a reduction of 6,734 gpm. The broodstock raceways (i.e., C-F) reuse water from the earthen ponds and operate at 4,027 gpm each for a total of 16,108 gpm. The required flow for these four raceways for broodstock holding is approximately 800 gpm rather than 4,000 gpm per raceway. The valving and piping upgrades will allow the hatchery to adjust and regulate flows reducing water usage at the hatchery. The Redband Trout and photoperiod programs will continue to use the same flow rates. If these programs are expanded requiring additional tanks, flow requirements will increase accordingly. Data for the water budget in Table 5-1 was generated from the information provided by CDFW in the questionnaire relative to maximum flow rates for the various rearing facility components. Overall, a decrease in the water flow requirements of approximately 10,000 gpm is achievable with the implementation of the preferred alternatives.

Table 5-1. Water Requirements for the Existing and Proposed Facility Components

Requirements	Existing Facility Components	Proposed Facility Components
Incubation	65	65
Early Rearing Hatchery B	620[a]	620
Early Rearing Hatchery E	220	220[b]
Concrete Nursery Tanks/Intermediate Rearing PRAS	1,272[a]	480
A&B Earthen Pond/PRAS Circulars	8,054[a]	1,320
C-F Raceways (Brood Ponds)	16,108	3,200
Redband Trout	840	840[b]
Photoperiod	120	120[b]
Miscellaneous Water Use	300	300
Total GPM	**17,653**	**7,165**

[a] The water routed through Hatchery B, the concrete nursery tanks, and the A and B earthen ponds is reused through the C-F broodstock raceways; therefore, these individual flows were not included in the total.

[b] The new proposed Hatchery E will include these programs and the associated water usage (1,180 gpm).

5.1.2 Distribution Box

The distribution box collects water from the intake and diverts it to several locations around the hatchery. Each pipe out of the distribution box is valve-controlled; however, these valves have not been exercised for some time.

The preferred alternative is rebuilding the distribution box to accommodate the changes proposed above and to maintain the pressure captured at the point of diversion from Big Springs Creek. Additionally, each valve should be exercised and replaced as needed.

5.1.3 Install Incoming Water Treatment

The Big Springs Creek water source comes from a spring that is located approximately a quarter mile upstream of the intake. The water from the spring is open to the environment and flows through a public park. This open area creates biosecurity concerns as it is open to the environment. People and animals have access to the spring and during rain events runoff flows into this area. It is recommended that microscreen drum filters (40 micron) and UV disinfection be used to treat all incoming water in a single location as it enters the facility. The drum filter and UV disinfection systems will include one additional unit to serve as a backup and to allow for maintenance providing continuous protection for the facility. The proposed UV will provide a minimum dosage of 126 mJ/cm^2. This will ensure *Flavobacterium* spp. does not enter the facility and will treat most other common aquaculture pathogens. Additionally, UV disinfection will be required at a higher dosage (170 mJ/cm^2) for the new Hatchery Building E (replacing the existing hatchery E building) for egg incubation to control *Saprolegnia*; therefore, a separate UV system will be included for these purposes. This system will include two UV units; one in operation and the second to serve as a backup and facilitate maintenance while still providing UV protection without interruption. The existing water treatment building will be renovated/expanded to house the proposed treatment equipment.

5.1.4 Replace A & B Earthen Ponds with PRAS Circular Tanks

Due to the shape, size, and rocky pond bed, the A & B Earthen Ponds are difficult to clean and to move fish through. Fish in these ponds are extremely susceptible to predation, experiencing survival rates of as low as 15%. The preferred alternative is to replace the earthen ponds with PRAS utilizing circular tanks. These tanks will be covered with a solid roof structure with enclosed sides. The current earthen ponds consist of a total of 8 rearing units that are 80 feet in length, 25 feet wide, with an average depth of 1.75 feet. This provides 3,500 ft^3 of rearing volume per pond and a total of 28,000 ft^3.

A standard size for dual-drain circular tank is a 20-foot diameter with an operating depth of 4 feet. Each 20-foot tank provides 1,256 ft^3 of rearing volume. A total of 24 tanks are being recommended to replace the earthen ponds, which will provide a total of 30,144 ft^3. This exceeds the rearing volume of the earthen ponds by approximately 7%. If the hatchery needed additional rearing volume to meet production goals, the operating depth could be increased; however, the wall height of the tanks should also be increased accordingly. The tank should be installed subsurface, providing easy access for staff to perform fish culture duties and meet the 42-inch minimum wall height from the working surface. There will be a total of four PRAS modules, each supporting six tanks (Table 5-2). The system would provide rearing for 200,000 Rainbow Trout to a size of 2 fpp.

Table 5-2. Proposed Circular Tanks for Replacement of the A & B Earthen Ponds.

Characteristic	A & B Earthen Pond	Circulars
Dimensions (ft)	80 ft long; 25 ft wide	20-ft diameter
Operating Depth (ft)	1.75	4.0
Volume Per Rearing Vessel (ft3)	3,500	1,256

Characteristic	A & B Earthen Pond	Circulars
Number of Rearing Vessels	8	24
Total Volume (ft3)	**28,000**	**30,144**

The total flow for each tank is based on hydraulic retention times (HRT). Typical HRT for circular tanks is between 30 to 45 minutes to maintain water quality and ensure efficient solids flushing from the tank. For 20-foot-diameter tanks, if each tank has a flow of 220 gpm, the resulting HRT would be 43 minutes. The entire flow for a six-tank PRAS module would be 1,320 gpm. If the system is operated at a 75% reuse rate, the total make-up flow per module would be 330 gpm. All four modules would require 1,320 gpm of make-up water. The existing earthen ponds do not have functioning valves to control flow and therefore a total of 8,054 gpm flows through these ponds. The difference between the earthen pond water flows and the 24 circular tanks operating as four PRAS modules is a water savings of 6,734 gpm. If water is available, the facility may choose to operate the PRAS system at a lower reuse rate (e.g., 50%).

Each PRAS module would require microscreen drum filters (40 micron), CO_2 removal, LHO, and UV disinfection at 126 mJ/cm^2 to provide protection to the facility. Appendix F provides details for each treatment equipment item. Additionally, the tanks and equipment should be covered with an open-sided roof structure with predator netting surrounding the open sides (at minimum).

Installing circular tanks on PRAS in place of the earthen ponds can reduce the overall water usage and improve water quality within 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 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.

The addition of a PRAS system will make operations more complex but would significantly reduce the water needed to rear fish. These tanks will provide better flow control, more ease in moving fish, improved tank hygiene, and reduced labor associated with cleaning tanks. The solid roof structure will protect the fish and infrastructure from predation issues, sunlight, and winter conditions.

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

5.1.5 Replace Concrete Nursery Tanks with PRAS Circular Tanks

The concrete nursery tanks serve as an intermediate rearing area for Rainbow Trout and the primary rearing area for Brown Trout. The tanks have aged and require maintenance and water flow currently limits fish production in these tanks. The preferred alternative is to replace these concrete tanks with PRAS utilizing circular tanks. The concrete nursery tanks provide a total of 9,600 ft^3 of rearing volume.

A standard size for a dual-drain circular tank is 10 feet in diameter with a 3.3-foot operating depth. Each 10-foot tank provides 259.2 ft^3 of rearing volume. A total of 24 tanks would provide 6,220 ft^3 of rearing volume and operate on three PRAS modules with eight tanks/module (Table 5-3). It should be noted this would not completely replace the total rearing volume of the concrete nursery tanks but fish production in these tanks would increase as the flow limitations would be eliminated. The system would provide rearing for 250,000 Rainbow Trout to a size of 40 fpp. The preferred alternative to replace the earthen ponds with circular tanks (5.1.3) must be implemented prior to this alternative to ensure the high level of predation associated with the earthen ponds is addressed since these fish will be entering the new PRAS circulars at a smaller size (i.e., 40 fpp rather than 15 fpp) and will be more susceptible to predation.

Table 5-3. Proposed Circular Tanks for Replacement of the Concrete Nursery Tanks.

Characteristics	Concrete Nursery Tanks	Circulars
Dimensions (ft)	50 ft long; 12 ft wide	10-ft diameter
Operating Depth (ft)	2.0	3.3
Volume Per Rearing Vessel (ft3)	1,200	259.2
Number of Rearing Vessels	8	24
Total Volume (ft3)	**9,600**	**6,220**

The total flow for each tank is based on hydraulic retention times (HRT). Typical HRT for 10-foot diameter circular tanks is less than 30 minutes to maintain water quality and ensure efficient solids flushing from the tank. For 10-foot diameter tanks, if each tank has a flow of 80 gpm, then the resulting HRT would be 24 minutes. The entire flow for an eight tank PRAS module would be 640 gpm. If the system is operated at a 75% reuse rate, the total make-up flow per module would be 160 gpm. All three modules would require a total of 480 gpm of make-up water. The recommended PRAS will require 792 gpm less water than the minimum flows provided to the concrete nursery tanks.

Each PRAS module would require microscreen drum filters (40 micron), CO_2 removal, LHO, and UV disinfection (126 mJ/cm^2). Appendix F covers the details for each treatment equipment. Additionally, the tanks and equipment should be covered under a solid roof structure, and the sides of the building enclosed to eliminate predation from larger mammals (i.e., raccoons and bears).

Installing circular tanks on PRAS to replace the concrete nursery tanks can reduce the overall water usage and improve water quality within the rearing environment. As discussed in Section 5.1.4, the circular tanks create a completely mixed environment. These characteristics would allow the hatchery to raise a similar number of fish in less total rearing volume.

Initial early rearing will still occur in the hatchery buildings California troughs on single pass water until the fish reach approximately 500 fpp or larger and will then be transferred into the PRAS module(s). Initially, these modules can be operated on single pass water until the fish have reached a larger size (e.g., 250 fpp) when they have transitioned from the “crumb” feed to pelleted feed to avoid tank fouling. The new system will allow fish to be reared to 40 fpp while following the industry standards for fish culture. Therefore, any bath style treatments to administer vaccinations or therapeutic treatments for disease or parasites may be conducted before the fish are transferred into larger rearing vessels (e.g., raceways or larger PRAS circulars).

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

5.1.6 Raceways C, D, E, and F

Raceways C, D, E, and F primarily serve as broodstock holding and are directly tied into two spawning buildings. The raceways and systems work logistically well with a center channel, which allows staff to crowd fish from the raceways into the center channel to move them to the spawning building. The preferred alternative is to skim coat/paint the raceways and enclose the raceways with a solid roof structure and sides. This coating will protect the concrete from further deterioration and extend the functional life of the raceways. It will also improve tank hygiene as solids will more easily move toward the tail ends of the raceways due to the smoother surface and reduce abrasion potential to the fish. A few locations within the raceways will need concrete repair prior to the application of skim coat/paint. Each raceway will require 800 gpm flow to operate within the FI of 1.56 including a 10% safety buffer for a total of 3,200 gpm. The roof will protect the infrastructure from the sun and winter conditions and extend the life of the raceways. The roof and enclosed sides will provide protection from predation, but added measures may be necessary (e.g., electric fence) to deter bears, which have been a common form of predation at the facility. CDFW would like to incorporate the Photoperiod Program into the broodstock raceways. This may be accomplished by adding a movable curtain system to exclude all natural lighting for different sections of the raceway. This system will likely be incorporated into the roof infrastructure.

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

5.1.7 Valving and Piping

The Mount Shasta Hatchery dates back to 1888. Various valves and pipes across the hatchery site are very old. Multiple valves are inoperable, and in some cases, the hatchery staff cannot control the flow to the rearing units (e.g., A&B Earthen Ponds) or has concerns about failure due to the age of the piping (i.e., Hatchery Building B Main Water Line). This inhibits the staff's ability to provide appropriate flows to rearing units, and the risk of failure of the piping and valving is high. The hatchery has a relatively new water distribution box that provides a common point to direct water flows to the various rearing areas; however, most of the remaining water delivery infrastructure is old, not adjustable due to its condition and is a high priority for the facility.

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 ensure the hatchery can continue to operate into the future.

5.1.8 Hatchery Building B

Hatchery Building B is the primary early rearing area for the facility, housing 120 of the hatchery's 164 California Troughs. The infrastructure in the building is outdated and in need of repair. The main water supply line running the length of the building has been identified as a high priority concern by CDFW due to its age and condition. Failure of this line would be catastrophic for the facility and fish production. Additionally, the building is unheated and uninsulated, which results in a damp/cold working environment in the winter.

The preferred alternative for Hatchery Building B is to insulate the building, update the heating system and replace the incoming water supply line. The water supply to Hatchery Building B can be isolated for line replacement at the distribution box, and this work can be timed when the early rearing troughs are empty. Replacing this line would ensure water to the building is not lost through preventative maintenance. This would minimize the likelihood of a fish loss resulting from pipeline failure and increase reliability. During the replacement, the hatchery could also replace water control valves in each rearing tank, resulting in better flow control. In addition, insulating the building and updating the heating system would improve working conditions for the hatchery staff and extend the life of the building structure by reducing the likelihood of mold forming on the interior.

5.1.9 Hatchery Building E

Hatchery Building E houses all the facility's incubation, including the pressurization components to create triploid eggs and egg enumeration. It also includes the McCloud Redband Rainbow Trout, a State of California Species of Special Concern. The building is classified as a “historic building.” Therefore, modifications to this building are subject to approval by a historical group striving to maintain the building as a historical landmark. Because of this status, the hatchery has had difficulties completing structural renovations.

The preferred alternative is a complete replacement of Hatchery Building E. The existing building would remain in place but would no longer be used. This would eliminate all historical building restrictions and allow the hatchery to develop a new building to meet the needs of the multiple broodstock programs, the McCloud Redband Rainbow Trout program, and the Photoperiod Program. The Photoperiod Program would also be moved to the new building for a more centralized facility and allow the hatchery space to expand the program as needed. The new hatchery building would include incubation facilities with the ability to heat water to control the timing and development of eggs for production. This would increase the efficiency of the triploid program, provide additional control for the Photoperiod Program, and meet the complete spawning/egg incubation needs for each group of broodstock at the hatchery.

The new building would compartmentalize areas to accommodate and isolate the McCloud Redband and Photoperiod programs. This would improve the hatchery’s biosecurity measures and reduce the risk of pathogens spreading throughout the building. The proposed location would be parallel (west side) to the existing Hatchery Building E, and existing troughs, tanks, and infrastructure could be moved from Hatchery Building E into the new building. Additional coordination is necessary to incorporate the components of the Photoperiod Program and move the other programs to optimize production and increase biosecurity. However, a new building would remove all the risks and limitations due to the aging condition of the current Hatchery Building E.

5.1.10 Photoperiod

The Photoperiod Program is being developed and primarily conducted in a separate building. If Hatchery Building E is replaced with a new building, the preferred alternative would be to include the Photoperiod Program within the building. The existing tanks and access platforms could be utilized in the new building. The benefits of including the Photoperiod Program within this building allows staff to work within the same area for this program as is currently done with the McCloud Redband group rather than transferring fish between buildings. This would reduce the number of buildings to have in operation allowing both the McCloud Redband group and the Photoperiod Program fish to be more centrally located. Biosecurity measures would include physical barriers separating the building for the McCloud Redband and Photoperiod Program groups to ensure isolation. Additionally, biosecurity protocols, such as footbaths and equipment disinfection, would be included to maximize biosecurity for all projects within the building.

5.1.11 Backup Power Generator(s)

An electrical assessment will be conducted for the facility to include the existing electrical requirements along with additional components encompassing the suite of alternatives selected to determine the electrical requirements for the facility to appropriately size backup generators.

5.2 Pros/Cons of Selected Alternative

Table 5-4 provides a high-level summary of the pros and cons for Mount Shasta Hatchery's selected alternative.

Table 5-4. Pros/Cons of Selected Alternative – Mount Shasta.

Description	Pros	Cons
Rebuild Big Springs diversion and pipe canal.	• Removes large debris prior to entering hatchery. • Removes large debris/solids and allows the drum filter/UV to function as intended. • Improves flow control. • Increases head pressure for hatchery. • Eliminates canal maintenance. • Eliminates the intake settling pond. • Decreases the risk of contamination/pathogens from people and animals.	• Requires staff to routinely attend to the grating to remove debris, which increases for higher flow events. • Needs primary and backup power. • Presents difficulties for securing the location as it is separate from the hatchery. • Adds O&M tasks. • Decreases the opportunity for sediment to settle. • Increases cost due to pipe purchasing and installation. • Increases public concern as the Big Springs water supply is open to the public and visitors routinely collect water from this pristine water source which is located outside of the hatchery footprint.
Rebuild the distribution box.	• Improves head pressure to hatchery rearing areas in conjunction with canal piping.	• Increases cost. • Impacts hatchery operations to make the changes.
Hatchery UV and filtration.	• Provides filtration for all fish production. • Provides better water quality and addresses basic disease and parasite issues for the entire facility. • Provides control of *Saprolegnia* during egg incubation in Hatchery Building E with increased UV dosage.	• The proposed water treatment at the Big Spring Intake will eliminate large debris and allow filtration systems to function reliably per design. • Increases cost due to installation and operation/maintenance (UV bulb replacement, drum filter panels, etc.).

Description	Pros	Cons
Replace existing A&B earthen ponds with circular tanks, PRAS, and a solid roof.	• Reduces total water required. • Provides a healthier rearing environment for fish. • Reduces labor as the PRAS is self-cleaning. • Concentrates waste for effluent treatment for NPDES permit compliance. • Replaces aging infrastructure. • Provides flow control to each tank. • Protects fish from direct sunlight and avian predation. • Improves biosecurity and predation losses due to the roof and enclosed sides.	• Increases cost due to installation and operation/maintenance (UV bulb replacement, drum filter panels, etc.). • Requires additional components (e.g., drum screen, UV, LHO, CO_2 removal). • Increases complexity. • Requires additional training for staff. • Increases pumping on site. • Increases power requirements (commercial and backup power). • Disrupts hatchery operations during construction.
Replace existing concrete nursery tanks with circular tanks, PRAS, and a solid roof.	• Reduces total water required. • Improves water quality within rearing vessels. • Improves flow control. • Reduces labor as the PRAS is self-cleaning. • Concentrates waste for effluent treatment for NPDES permit compliance. • Replaces aging infrastructure. • Provides flow control to each tank. • Protects fish from direct sunlight and avian predation. • Improves biosecurity and predation losses due to roof and enclosed sides.	• Increases cost of installation and operation/maintenance (UV bulb replacement, drum filter panels, etc.). • Requires additional components (e.g., drum screen, UV, LHO, CO_2 removal). • Increases complexity. • Requires additional staff training. • Increases pumping on site. • Increases power requirements (commercial and backup power). • Disrupts hatchery operations during construction.

Description	Pros	Cons
Rehabilitate Raceways C, D, E, and F.	• Protects and extends the life of the existing infrastructure due to the skim coating. • Improves tank hygiene as solids move toward the tail end of raceways and algae does not grow well on smooth surfaces. • Protects fish from direct sunlight and predation due to the roof and enclosed sides. • Improves biosecurity.	• The work will cause a disruption in the hatchery operations since the broodstock are held in these raceways year-round and therefore, a natural maintenance window does not exist. • Cost to perform this preventative maintenance.
Replace valves and pipe throughout hatchery.	• Improves operability and control of flow. • Increases hatchery infrastructure lifespan.	• Increases cost. • Disrupts operations during replacement.
Upgrade Hatchery Building B.	• Increases reliability due to replacement of the main line in the building. • Increases reliability as preventative maintenance can be scheduled rather than an emergency failure where fish are lost. • Improves the working environment/safety for staff during winter months with insulating and heating the building. • Reduces potential for mold and bacteria growth.	• Increases cost. • Disrupts hatchery operations.

Description	Pros	Cons
Replace Hatchery Building E with a new building.	• Provides flexibility to make changes and operate without historical society limitations. • Provides the space for all programs. • Improves biosecurity due to the walls separating programs and additional life stage measures (e.g., protocols, footbaths, etc.). • Adds heating capability for incubation stacks. • Provides timing control for egg incubation, accelerates the incubation process, and reduces staff time during the "Triploidy" process.	• Increases cost. • Has a larger footprint. • May have permitting challenges.
Include the Photoperiod Program in the new Hatchery Building E.	• Reduces the total number of buildings to manage and operate. • Provides logistic advantages to have different programs in a single building, separated by isolation walls.	• Requires the new building to be larger. • Increases cost due to the new Hatchery Building B to be larger to accommodate the components for the Photoperiod Program. • May have permitting challenges.
Add backup power generator(s).	• Provides power to all life support systems in the event of a power outage. • Enables the hatchery to use modern technology to produce healthier fish.	• Increases cost. • Increases complexity. • Increases maintenance.

5.3 Alternatives for Short-Term Improvements

5.3.1 A & B Earthen Ponds

The recommendation for a short-term improvement to the A & B earthen ponds is to implement circular tanks and a roof structure as specified in Section 5.1.3 and to operate the tanks on a flow-through system. Not implementing a PRAS system, as is the preferred alternative stated in Section 5.1.3, would greatly simplify the complexity of the preferred alternative and would reduce installation costs of improvements made to the A & B Earthen ponds. The circular tanks will provide better flow control, more ease in moving fish, improved tank hygiene, and reduced labor associated with cleaning tanks. However, the number of tanks that could be implemented may be limited by flow availability. More hydraulic head may be necessary to operate the circular tanks as needed depending on the final elevations of the tank bottoms and operating depths. The solid roof structure will protect the fish and infrastructure from predation issues, sunlight, and winter conditions.

5.3.2 Concrete Nursery Tanks

The concrete is aging and deteriorated. To extend the functional life of these concrete structures, skim coating/painting will protect the concrete from further deterioration and provide several additional benefits. This maintenance will provide for improved tank hygiene as solids will more easily move to the tail end of the tanks on the smooth finish, algae will likely be reduced due to the smoother surface as well. The smooth finish will reduce abrasion potential for the fish being reared in the tanks. If a solid roof structure with enclosed sides were included in this project, the potential for algae would be further reduced and predation would be eliminated.

5.3.3 Raceways C, D, E, and F

The concrete is aging and to protect it from further deterioration, skim coating/painting would extend the functional life of these raceways, improve tank hygiene by allowing solids to move to the tail end of the raceways more easily, and reduce abrasion potential to the fish.

5.3.4 Hatchery Building B

The primary concern in Hatchery Building B is the age and condition of the main water supply line and valving to control flow to the tanks. The main line is at risk of failure and puts the fish at higher risk if this line fails when the hatchery building is in operation. The water supply from the distribution box to Hatchery Building B can be isolated to allow for construction while other hatchery rearing areas remain in operation. Replacement of this main line and valving needs to occur proactively with a preventative maintenance approach to protect the fish and restore full function and reliability for hatchery operations in this building. Additionally, the building is unheated and uninsulated resulting in a cold working environment for equipment and staff. Minimal heating in this building will protect the infrastructure and improve the working conditions for staff.

5.3.5 Hatchery Building E

The Hatchery Building E could be renovated to add the capability to heat incubation water within the existing footprint of the building providing the ability to better control incubation time frames and accelerate the process for the triploid program. As part of this renovation, a wall separating the McCloud Redband tank rearing area could be installed along with appropriate procedures to isolate this program to enhance biosecurity measures. Any modifications to this building would need to be reviewed and approved by the appropriate historical group.

5.4 Natural Environment Impacts

The proposed upgrades to the Mount Shasta Fish Hatchery should have negligible impacts on the natural resources in the surrounding area. All improvements would occur within currently developed areas within the hatchery property with the exception of water intake which is located on the Elsa Rupp property. This potentially avoids the need 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 Mount Shasta Fish Hatchery will change the existing infrastructure and the number of rigid structures on site. However, they will not increase or decrease the fire risk. Based on the climate change evaluation, the projected fire risk at the hatchery site is between 13 and 25% through mid-century and increases to 30% through 2099.

Flood potential increases with the increased incidence of fire, therefore, as fire risk increases, the risk of flooding also increases. The hatchery is susceptible to flooding associated with the Big Springs Creek water supply in certain areas at the facility and deals with minor flooding on a regular basis. The recommended changes to the Mount Shasta Fish Hatchery will slightly increase the total impervious surface of the site but decrease the impact of flooding on the facility. The concrete nursery tanks are moderately susceptible to flooding and the existing earthen ponds are located at ground level where runoff from rain/snow and flooding may enter the ponds. Fiberglass circular tanks will replace the concrete nursery tanks and the earthen ponds and provide additional flood protection as they will be installed with the tank tops at heights 30 to 36 inches above ground. The tank height will provide protection from overland flow entering the fish rearing vessels, and the ground will be graded to carry water away from the tanks to the extent feasible.

Additionally, upgrading the Big Springs Creek intake including a debris screen and enclosing the canal in a pipe routed to the hatchery along with replacing the valves and piping within the hatchery will provide better flow control. The hatchery staff will be able to manage surges in flow and prevent flooding of the rearing vessels.

5.4.2 Effluent Discharge

The recommended changes to the hatchery do not include an overall increase in production goals at the Mount Shasta Fish Hatchery. This will ensure there will be no change to the NPDES permit requirements. However, the recommended alternatives will likely improve the water quality of the effluent discharge. The hatchery meets current NPDES permit requirements. Installing dual-drain circular tanks and effluent treatment will improve the water quality of the discharge. The three existing settling ponds (i.e., Pond 38, east and west settling ponds) were designed for full flow single pass fish culture practices. The new PRAS systems will reduce the volume of effluent transported to the existing settling ponds.

It is important to note that changes to existing aquaculture programs (renovations, new construction) may trigger (administratively) the requirement for new and/or updated NPDES permits. Acknowledging that waste load (fish biomass) is not anticipated to change with the proposed alternatives, we assume that the increase in effluent removal efficiencies provided by the PRAS systems will result in net effluent “gains” to the overall aquaculture program.

5.5 Hatchery Operational Impacts/Husbandry

The hatchery will continue its role as a broodstock facility serving multiple CDFW hatchery programs around the state. The production of Brown Trout for broodstock replacement along with multiple groups of Rainbow Trout will be produced throughout the year to maximize production capability at the hatchery. Early rearing fish culture practices will continue as the hatchery has operated previously with single pass flow-through in the troughs in Hatchery B. As the fish outgrow the troughs, they will be transferred into the intermediate rearing PRAS circular tanks. A small fish pump (e.g., 2.5-inch-diameter hose) would minimize handling and stress on the fish as they are transferred. If enumeration of the fish is desired, a fish counter may be utilized in conjunction with the fish pump. Pumping the fish from troughs may be challenging depending upon how much water flow can be provided to the trough to ensure the fish pump does not “out pump” the incoming water supply to the trough during pumping.

The intermediate PRAS circular tanks allow the hatchery to rear fish to approximately 40 fpp (4 inches) before the fish are transferred into final rearing tanks. As the fish approach their target rearing size in the intermediate rearing tanks, they are pumped directly into the final rearing tanks, or they may be pumped into a fish transfer tank equipped with oxygen and offloaded via gravity into the final rearing PRAS tanks. Linear distances from origin to destination rearing tanks may limit how staff desire to transfer the fish at the hatchery. The intermediate rearing tanks range from a minimum 150 feet to 550 feet from the nearest and furthest final rearing PRAS tanks, respectively. Pumping fish these distances would require approximately 600 feet of hose and space to store the hose, but these distances are reasonable and this method of transferring the fish minimizes stress on the fish. Hatchery staff will need to determine the method of choice to be used in transferring the fish from the intermediate tanks into the final rearing tanks.

Once the fish are in the final rearing PRAS circular tanks, the fish will be grown to their target release size at which time they will maximize the biomass and DI capacity of the system. Truck loading for fish release will basically continue as the hatchery has operated in the past utilizing fish pumps and dewatering towers with a few minor adjustments unique to circular tanks relative to traditional raceways.

One of the benefits of this proposed design is to provide the means for staff to maintain fish health and welfare. The intermediate rearing tanks allow for administering chemical treatments as needed (e.g., coldwater disease, parasites) and selection of captive broodstock prior to the fish entering the final rearing tanks, if desired.

5.5.1 PRAS Circular Tank Operations

The intermediate and 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 (or as required for fisheries management objectives). Seine nets, clamshell crowders or other crowder types can be used to concentrate fish for collection and handling.

Transfer of fish between tanks and for truck loading will utilize fish pumps and hosing to minimize handling and stress on the fish and decrease physical labor for staff transferring fish between tanks or loading trucks. For transferring fish into other rearing tanks requiring enumeration, a fish counter can be included at the receiving tank to obtain an accurate inventory of the fish. For fish being loaded onto a transport tanker for stocking, a dewatering tower will allow for the removal of the water through a screen prior to the fish entering the fish transport tanker. This is consistent with current 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. Given the staggered production cycle including Brown Trout and using multiple groups of Rainbow Trout, the PRAS modules will not all be occupied at the same time, 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 troughs can continue using the hatchery's standard feeding practices. 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 it 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, while reducing wasted feed and maximizing water quality. Automated systems require an initial cost for the purchase and installation of the system. The automated feeding systems provide feed intermittently throughout the day including staff non-duty times to maximize growth, reduce 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. Mount Shasta Fish Hatchery reported several pathogens of concern at the facility. This included Gyros (*Gyrodactylus* spp.), bacterial coldwater disease (causative agent *Flavobacterium psychrophilum*), Columnaris (*Flavobacterium columnare*) and fungus (*Saprolegnia* spp.). The most likely pathways for pathogens to enter the Mount Shasta Fish Hatchery and spread through the facility is through the incoming water supply or environmental exposure within the hatchery.

5.6.1 Incoming Water Supply

The Mount Shasta Fish Hatchery currently has limited measures to prevent pathogens from entering the facility. The facility previously installed a drum screen and UV disinfection unit (UV Treatment Building) to treat water for Hatchery Building E, but this system has failed on multiple occasions and is currently inoperable. The recommended alternatives improve biosecurity by removing debris, collecting and containing the Big Springs Creek water supply further upstream in an HDPE pipe reducing many of the environmental risks by eliminating potential human and animal contamination before the spring water enters the facility. Replacing outdated valves and piping will improve the hatchery's ability to control the flow to operate the new systems correctly and maximize the protection of the hatchery from pathogens.

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 earthen ponds, concrete nursery tanks and raceways are enclosed by perimeter fencing with bird wires overtop, but these structures are minimally effective in excluding otters, raccoons, bears and avian predators from accessing the fish. The water enters at the top of the hatchery and in general, the water is reused in each rearing area as it works its way down the hatchery (e.g., nursery tanks to earthen ponds to broodstock raceways). The continual reuse of the water potentially exposes fish located downstream to pathogens from fish reared upstream. The recommended alternatives reduce the risk of pathogens entering the rearing areas by reducing environmental exposure and providing isolation between groups of fish by rearing them in multiple biosecure PRAS modules. Implementing PRAS in covered structures will limit potential pathogen vectors from the incoming water supply and other organisms such as birds, otters, etc., from entering the rearing vessels. The existing broodstock raceways will be covered with a solid roof structure eliminating the overhead threat of avian predation and provide protection from direct sunlight on the broodstock. Predators can be a significant source of stress, and they can transmit pathogens into the facility. Additionally, installing PRAS will ensure high-quality, treated water for all rearing vessels.

5.7 Water Quality Impacts

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

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

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

The recommended alternatives also include improving the incoming water quality. The improved intake structures, filtration and UV disinfection will reduce the debris entering the facility and provide protection from pathogens. This will improve the water quality in the hatchery building, production areas, and broodstock rearing.

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 the Preliminary Concept Planning – Opinion of Probable Construction Cost (OPCC) estimate for this Project. Additionally, McMillen has solicited pricing or utilized recently received material quotes for similar materials and equipment or components. The appropriate overhead and profit markups have been included in the project pricing. The detailed cost estimates, including assumptions and inflation information are presented in Appendix F.

6.2 Estimate Classification

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

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

Criteria	Details
Description	Class 5 estimates are generally prepared based on very limited information and subsequently have wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systemic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with little effort expended—sometimes requiring less than an hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation.
Level of Project Definition Required	0% to 2% of full project definition.
End Usage	Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.

Criteria	Details
Estimating Methods Used	Class 5 estimates virtually always use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques.
Expected Accuracy Range	Typical accuracy ranges for Class 5 estimates are -20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.
Effort to Prepare (for US$20MM project)	As little as 1 hour or less to perhaps more than 200 hours, depending on the project and the estimating methodology used.
ANSI Standard Reference Z94.2-1989 Name	Order of magnitude estimate (typically -30% to +50%).
Alternate Estimate Names, Expressions, Synonyms:	Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of-thumb.

6.3 Cost Evaluation Assumptions

The following assumptions were made while developing the 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 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.
- Topographic survey has not been completed. Site survey will be required to establish elevations of all systems to ensure proper hydraulics can be achieved.
- Additional division specific cost evaluation assumption may be found in Appendix F.

6.4 LEED/Zero Net Energy Assessment

RIM Architects (RIM) and STŌK have reviewed and assessed the 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 the minimum square footage requirements. There is insufficient scope to pursue LEED certification. Refer to Appendix H for more information.

RIM and STŌK also prepared a zero net energy (ZNE) assessment of the facility. This assessment summarizes the power zero net energy (ZNE) assessment of the facility. This assessment summarized the anticipated power needs at the facility and estimated the size of the photovoltaic (PV) system that would be required to offset the power use. Refer to Appendix H for more information.

6.5 Alternative Cost Estimate

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

Table 6-2. Alternative Cost Estimate.

Item	Estimate
Division 01 – General Requirements	$ 5,125,000
Division 02 – Existing Conditions	$ 280,000
Division 03 – Concrete	$ 2,234,000
Division 05 – Metals	$ 250,000
Division 07 – Thermal and Moisture Protection	$ 20,000
Division 08 – Openings	$ 180,000
Division 13 – Special Construction (Buildings and Tanks)	$ 16,202,000
Division 23 – Mechanical & HVAC	$ 836,000
Division 26 – Electrical	$ 2,425,000
Division 31 – Earthwork	$ 947,000

Item	Estimate
Division 32 – Exterior Improvements	$ 592,000
Division 33 – Utilities	$ 535,000
Division 35 – Waterways and Marine Construction	$ 203,000
Division 40 – Process Water System	$ 923,000
DIRECT CONSTRUCTION COST	**$ 30,752,000**
Construction Contingency	$ 7,688,000
Overhead	$ 1,845,000
Profit	$ 2,460,000
Bond Rate	$ 308,000
TOTAL CONSTRUCTION PRICE	**$ 43,053,000**
Design, Permitting and Construction Support	$ 6,533,000
TOTAL COST ESTIMATE	**$ 49,586,000**
Accuracy Range +50%	$ 74,379,000
Accuracy Range -30%	$ 34,711,000
Photovoltaic	$ 5,791,500

7.0 Mount Shasta Fish Hatchery Environmental Permitting

7.1 Anticipated Permits and Supporting Documentation

The proposed Project would involve the modification to the existing hatchery or construction of a new hatchery facility and associated infrastructure. It would potentially involve the modification of the water supply intake, 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 U.S. 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 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 U.S. 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 Siskiyou County Permits and Approvals for Selected Location

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

7.2 National Pollutant Discharge Elimination System (NPDES) Permitting

The Mount Shasta Fish Hatchery is classified as a cold water Concentrated Aquatic Animal Production (CAAP) facility and is eligible to operate under General Order R5-2019-0079-008 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 June 20, 2016.

Wastewater is discharged through three outfalls:

- Outfall 001: Latitude: 40° 18' 22.82" N; and Longitude: 121° 19' 44.70" W
- Outfall 002: Latitude: 40° 18' 20.04" N; and Longitude: 121° 19' 54.01" W
- Outfall 003: Latitude: 41° 18' 29.06" N; and Longitude: 121° 19' 51.18" W

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

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

7.3 Water Rights

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

8.0 Conclusions and Recommendations

This report provides a summary of the state of the Mount Shasta Fish Hatchery, identifies and quantifies the main impacts the hatchery could experience as a result of climate change, and provides proposed facility design modifications to increase the resiliency of the hatchery, along with the associated costs and potential impacts.

The in-depth analysis of the available hydrologic and climatologic data performed by NHC provides projections to forecast changes that may be experienced at the hatchery. In general, air and water temperatures will rise in the future, but water temperatures will remain well within the range of tolerance for trout at Mount Shasta. Additionally, there will be an increasing risk of wildfire as the climate changes by up to 30% by the end of the century.

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:

- Improving the treatment of the incoming water will provide improved flow control and protection against pathogens.
- Replacing pipes and valves that are near the end of their effective lifespan or are currently inoperable due to age.
- Replacing flow-through style raceways with circular dual-drain tanks utilizing partial recirculating aquaculture systems (PRASs) to reduce the amount of water that is required to raise fish and to provide for improved effluent handling and treatment.
- Covering all rearing vessels with solid roofs and predator exclusion sidewalls will reduce the impacts of increased temperatures for both the fish and the employees and address the hatchery's fish losses associated with predation.
- Repairing the concrete, skim coating and painting the concrete broodstock raceways/spawning building areas will extend the life of these critical assets into the future.
- Replacing Hatchery Building E, consolidating the Photoperiod Program and Redband Rainbow Trout program into this building, and adding the ability to heat water for egg incubation and the Triploidy Program will provide essential upgrades to the overall program to maximize efficiency and success of these programs into the future.

The proposed upgrades to the Mount Shasta Hatchery would have negligible impacts on the natural resources in the surrounding area. Most improvements would occur within currently developed areas, which lessen the permit requirements. The total cost estimate of the proposed design modifications is $49,586,000.

9.0 References

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