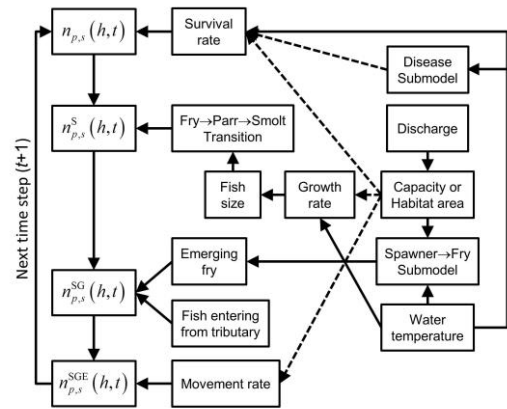
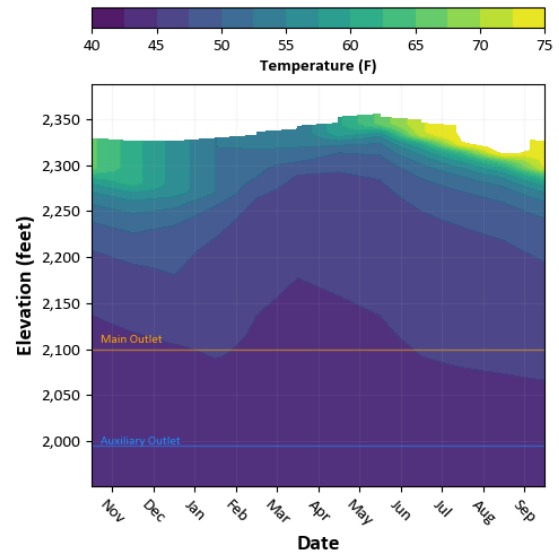


MODELING REPORT

Hydrologic, Water Operations, Reservoir Temperature, River Temperature, Sediment Transport, Habitat, and Fish Population Modeling for the Trinity River Water Management Plan



Top Left: Trinity Lake (Photo from United States Bureau of Reclamation <https://commons.wikimedia.org/wiki/File:TrinityDam2.jpg>)

Top Right: HEC-5Q Model output of Trinity Lake Water Temperatures

Bottom Left: Chinook Salmon (Photo from California Department of Fish and Wildlife <https://wildlife.ca.gov/Fishing/Hatcheries/Trinity-River/Species-Raised>)

Bottom Right: Model Structure of the Stream Salmonid Simulator (Image from Open-File Report 2018-1056. <https://pubs.er.usgs.gov/publication/ofr20181056>)

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Prepared by:	Stantec Consulting Services Inc.
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Project Number:	Trinity River Contract Water Management Plan Project no. 251008

Executive Summary

Humboldt County is developing a Water Management Plan that will describe a range of proposed annual releases from Trinity Reservoir consistent with the 1959 water delivery contract between Humboldt County and the U.S. Bureau of Reclamation (Reclamation). The 1959 contract states that Reclamation shall release not less than an annual quantity of 50,000 acre-feet into the Trinity River for the beneficial use of Humboldt County and other downstream users (Contract Water).

The Water Management Plan will outline how Contract Water should be released for the benefit of fisheries in the Trinity River and lower Klamath River, with the primary goal of expanding a harvestable surplus of Tribal, recreational, and commercial fisheries. A set of annual Contract Water release scenarios were developed during five workshops conducted in 2022 and 2023 with interested parties including Humboldt County, state and federal resource agencies, tribal representatives, Reclamation, and the U.S. Department of the Interior Solicitor's office. A suite of modeling and technical tools was used to analyze annual conditions with and without Contract Water releases.

This Modeling Report describes the modeling tools used to assess Contract Water release scenarios, including CalSim II, HEC-5Q, RBM10, sediment transport models, Chinook Salmon habitat models, and the Stream Salmonid Simulator. Results from all models are summarized to provide a comparative overview of modeled release scenarios to modeled baseline conditions.

Mean annual Contract Water release scenarios ranged from 50,000 acre-feet to 170,000 acre-feet, and varied in timing, magnitude, and duration, though all releases were made between October and April. As shown in Table ES-1, a key finding of this modeling report is Contract Water releases that had the greatest modeled increase in Chinook Salmon abundance relative to baseline conditions included those that released 50,000 acre-feet in the fall period from October through December as pulse flows or baseflows, and those that released 170,000 acre-feet from October through April as a combination of pulse flows and baseflows. Modeled beneficial effects on populations were primarily due to either (1) increases in habitat area during the spawning life stage in October through December, which decreased redd superimposition (e.g., the process of a later arriving spawner building a redd on top of an existing redd) and improved egg survival, or (2) increases in flow during the fry emergence and juvenile rearing life stage in March through April, which increased the fry and parr carrying capacity (e.g., the upper limit for the number of fry or parr that a habitat unit can support) of individual habitat units.

Another key finding of this report is all Contract Water scenarios that released at least 50,000 acre-feet annually from Trinity Reservoir had similar effects on Trinity Reservoir storage, Central Valley Project (CVP) storage, CVP contract water deliveries, and Sacramento River water temperatures. Whether these scenarios were released annually as a fall baseflow, fall pulse flow, spring pulse flow, or spring baseflow, they all resulted in similar storage patterns in Trinity Reservoir – an annual reduction in storage relative to the baseline that was relatively small in wetter years and larger in drier years. As a result of lower Trinity Storage levels, Trinity River Division (TRD) exports to the CVP were reduced. Because the timing of exports is similar each year, reaching a peak in July through September, the reduction to exports occurred at the same time each year, independent of Contract Water release timing, resulting in similar storage, CVP delivery, and water temperature effects in the Sacramento River basin portion of the CVP. The water temperature effects on the Sacramento River were limited to the months of July and August, relatively minor, and were primarily attributed to changes in storage, release magnitude, and release temperature from Lake Shasta, and not due explicitly to inflows from the TRD.

Table ES-1. Mean Annual Percent Changes Between the Scenario Metric and the Baseline Metric for the Seven Modeled Contract Water Release Scenarios in the Restoration Reach of the Trinity River.

	Modeling Tool	CalSim II		Sediment Transport		Habitat Model			Stream Salmonid Simulator (S3)				
	Primary Analysis Metric	Mean annual Lewiston releases	Mean annual CVP Contract deliveries	Total sediment mobilized	Stream bed mobilization	Redd habitat area	Fry capacity	Parr capacity	Egg survival	Juvenile survival	Abundance	Biomass	Fish mass
Scenario #	Scenario Description	Thousand acre-feet	Thousand acre-feet	Tons/year	% bed mobilized	Mean ha (Oct-Dec)	Mean n per m ² (Mar-May)	Mean n per m ² (Mar-May)	Mean annual %	Mean annual %	Mean annual n of fish	Mean annual metric tons	Mean annual grams/n
1	Building baseflow (50 TAF)	5%	-0.2%	-0.3%	0.0%	0.5%	-1.6%	2.3%	-0.4%	0.5%	0.2%	-4.0%	-1.6%
2	Fall pulses (50 TAF)	5%	-0.2%	-1.6%	-0.1%	0.4%	-0.8%	0.0%	1.3%	-0.9%	0.4%	0.9%	3.1%
3	Geomorphic pulse or spring pulses (50 TAF)	5%	-0.2%	7.5%	6.4%	0.0%	0.0%	2.3%	-0.3%	-0.5%	-0.7%	-2.4%	2.3%
4	Combine scenarios 1-3 (170 TAF)	22%	-4.6%	15.0%	7.0%	0.2%	3.2%	10.5%	0.9%	1.4%	2.6%	-2.8%	-1.6%
5	Fall pulses with storage-based delay (50 TAF)	5%	-0.2%	-1.4%	-0.1%	0.2%	-0.7%	-1.0%	1.2%	-0.9%	0.3%	0.8%	0.6%
6	Fall baseflow (50 TAF)	5%	-0.7%	-1.5%	0.0%	5.1%	-0.7%	-1.0%	2.6%	0.2%	2.9%	2.8%	-0.1%
7	Carryover (50 TAF)	5%	-1.2%	7.9%	0.3%	0.0%	4.6%	4.0%	0%	-0.1%	-0.1%	0.3%	0.4%

Notes:

The first row lists the modeling tool used, the second row lists the primary evaluation metric, and the third row lists the units below each primary evaluation metric.

Metrics with greater than a positive 2% change relative to the baseline are presented in bold and highlighted gray.

Metrics with less than a negative 2% change relative to the baseline are presented in bold and highlighted orange.

Key: TAF = thousand acre-feet, ha = hectares, % = percent, m = meters, n = number of fish

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Department of Public Works

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California Department of Fish & Wildlife
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United States Fish and Wildlife Service
National Oceanic and Atmospheric Administration
Hoopa Valley Tribe
Yurok Tribe
United States Bureau of Reclamation

Non-Governmental Organizations

CalTrout
Pacific Coast Federation of Fishermen's Associations

Consultant Team

Suits and Signs Consulting
Stantec Consulting Services Inc.
Thomas Gast & Associates

Individuals

Tom Stokely and Joe Polos

Data Availability Statement

The data that support the findings of this study are available from Hank Seemann, Deputy Director - Environmental Services, Humboldt County Public Works Department, upon reasonable request.

Non-endorsement disclaimer

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government

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Acronyms / Abbreviations

°C	degrees Celsius
°F	degrees Fahrenheit
1-D	one-dimensional
2-D	two-dimensional
Ag	agricultural
AN	above normal
BN	below normal
BO	biological opinion
CCWD	Contra Costa Water District
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
cm	centimeter
CMIP3	Coupled Model Intercomparison Project Phase 3
COA	Coordinated Operating Agreement
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DFG	California Department of Fish and Game
DOI	U.S. Department of the Interior
DSS	decision support system
DWR	California Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
FC&WCD	Flood Control and Water Conservation District
FERC	Federal Energy Regulatory Commission
FRSA	Feather River Service Area
g	grams
GCM	global climate model
GVC	Grass Valley Creek
ID	irrigation district
ITP	incidental take permit
JPOD	joint point of diversion
KCWA	Kern County Water Agency
LTO	Coordinated Long-Term Operation of the Central Valley Project and State Water Project
LTP	Long-Term Plan for Protecting Late-Summer Adult Salmon in the Lower Klamath River
LYRA	Lower Yuba River Accord
m	meters
M&I	municipal and industrial
MAF	million acre-feet
MHU	meso-habitat unit
MWD	Metropolitan Water District
n	number of fish
NBA	North Bay Aqueduct
NCRWQCB	North Coast Regional Water Quality Control Board
NDOI	net Delta outflow index
NMFS	National Marine Fisheries Service

NOD	North-of-Delta
NPS	National Park Service
OMR	Old and Middle River
PCWA	Placer County Water Agency
PP	pumping plant
RBM10	River Basin Model 10
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
ROC on LTO	Re-initiation of Consultation on the Coordinated Long-Term Modified Operations of the Central Valley Project and State Water Project
ROD	Record of Decision
RPA	Reasonable and Prudent Alternative
S3	Stream Salmonid Simulator
SBA	South Bay Aqueduct
SMSCG	Suisun March Salinity Control Gates
SOD	South-of-Delta
SJRRP	San Joaquin River Restoration Program
SRH-2D	Sedimentation and River Hydraulics model
SRP	Stepped Release Plan
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	thousand acre-feet
TRAL	Trinity River at Lewiston
TRD	Trinity River Division
TRDC	Trinity River at Douglas City
TRFES	Trinity River Flow Evaluation Study
TRGVC	Trinity River at Grass Valley Creek
TRLG	Trinity River at Limekiln Gulch
TRRP	Trinity River Restoration Program
U.S.	United States
USBR	U.S. Bureau of Reclamation
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WR	water right
yr	year

1 INTRODUCTION

Humboldt County has a contractual right to annual water releases of not less than 50,000 acre-feet from the Trinity Reservoir for the beneficial use of Humboldt County and other downstream users (Contract Water). This contractual right was authorized by Congress in 1955 through the Trinity River Division Act and confirmed in a 1959 water contract signed by Humboldt County and the U.S. Bureau of Reclamation (Reclamation). However, despite numerous attempts to call on Contract Water over the past several decades, Contract Water has never been released for the beneficial use of Humboldt County or other downstream users.

Congress authorized the Trinity River Division (TRD) as an integrated component of the Central Valley Project (CVP) to increase water supplies for irrigation and other beneficial uses in the Central Valley. Section 1 of the 1955 Act provided for the construction, operation, and maintenance of the TRD. Section 2 of the 1955 Act included two provisos that limit the integration of the TRD into the CVP. Proviso 1 directed the Secretary of the Interior to adopt appropriate measures to ensure the preservation and propagation of fish and wildlife, including certain minimum flows then deemed necessary in the Trinity River for the fishery. Proviso 2 specified that “not less than 50,000 acre-feet shall be released annually from the Trinity Reservoir and made available to Humboldt County and downstream water users”. A contractual right for Proviso 2 was established in a water delivery contract executed between the United States Department of the Interior (DOI), Reclamation, and Humboldt County on June 19, 1959 (1959 Water Contract). Humboldt County’s contractual right was also incorporated into Reclamation’s eight 1959 water rights permits for storage and diversion of the Trinity River issued by the predecessor of the California State Water Resources Control Board.

Current flow releases into the Trinity River are based on the framework established in the 2000 record of decision (ROD) implementing the final environmental impact statement (EIS) for the Trinity River Mainstem Flow Evaluation Report (USFWS and the HVT 1999, USDOJ 2000). Among other restoration actions, the ROD defined five water year types and established annual release volumes ranging from 368 thousand acre-feet (TAF) to 816 TAF, with specific daily flow patterns based on water year type. These flows are referred to as ROD flows or restoration releases, and generally describe Reclamation’s obligations for releases under Proviso 1.

Since 2018, Humboldt County has been developing a Water Management Plan that describes a range of proposed annual Contract Water release scenarios capable of benefiting fisheries in the Trinity River and lower Klamath River. Contract Water would be released annually in addition to ROD water. The primary goal of annual Contract Water releases is to expand a harvestable surplus of Tribal, recreational, and commercial fisheries that exceeds the legal obligations associated with Proviso 1 of the Trinity River Division Act, Tribal Trust, and other laws. The Water Management Plan must contain sufficient detail that Reclamation can conduct an analysis and determine what additional actions may be required to make Humboldt County’s water contract operational.

Since July of 2022, Humboldt County has held workshops with interested parties to review data and modeling tools, develop release scenario objectives, define release scenario volumes, timing, and triggers, and elicit feedback on development of the Water Management Plan. Workshops completed to date include:

- Workshop 1: Introduction, project background, and review of baseline conditions and modeling framework.

- Workshop 2: Evaluate limiting factors to juvenile Chinook Salmon productivity in the Trinity River and develop Contract Water release objectives.
- Workshop 3: Develop four initial Contract Water release scenarios.
- Workshop 4: Review model results of four initial Contract Water release scenarios and develop refined scenarios.
- Workshop 5: Review model results of refined Contract Water release scenarios and discuss a decision-making framework for annual use of Contract Water.

This Modeling Report summarizes the overall analytical framework and modeling methodology used to assess four initial and three refined Contract Water release scenarios. It is the second¹ in a series of technical documents that will form the basis of the Water Management Plan. This report is organized into six main sections:

- **Chapter 1. Introduction:** provides background for the project and summarizes work to date leading up to application of the modeling tools.
- **Chapter 2. Modeling and Technical Analysis Framework:** summarizes the modeling approach for the project, including the baseline hydrologic, climate change, and regulatory conditions that will be assumed in the technical analysis.
- **Chapter 3. Model Assumptions and Modifications:** summarizes the modeling tools, main assumptions, and modifications needed within each tool to simulate Contract Water release scenarios.
- **Chapter 4. Release Scenario Timeseries Development:** summarizes the objectives of seven unique annual releases scenarios of Contract Water, and describes the methods used to develop input time series of each scenario for the modeling tools.
- **Chapter 5. Model Results:** summarizes modeling results using figures, tables, and narrative description.
- **Chapter 6. Summary:** presents summary findings from the analysis.
- **Chapter 7. References:** includes a list of references cited in this report.

¹ The first technical document is the Baseline Conditions Report (Humboldt County, 2022)

2 MODELING AND TECHNICAL ANALYSIS FRAMEWORK

A framework of integrated analyses including hydrologic operations, hydrodynamics, water quality, and fisheries analyses is required to provide information to comparatively assess the effects of Contract Water releases on several resources, including water supply, surface water, water temperature, and aquatic resources. Releases of Contract Water require operational changes to the TRD of the CVP to increase the amount of water that is annually released into the Trinity River. These operational changes and other external factors, such as climate and sea-level changes, influence the future conditions of physical parameters, including reservoir storage, reservoir water temperature, river flow, Delta flows, Delta exports of CVP supplies, river temperature, and water quality. These physical parameters, primarily flow regimes and water temperature, influence the future conditions of salmonid habitat and populations. Evaluation of physical conditions and fisheries response is the primary focus of this modeling analyses.

2.1 Overview

A set of existing numerical modeling tools was adapted to analyze Contract Water release scenarios. An overview schematic of the modeling framework is shown in Figure 2-1, with component models, inputs, and outputs shown as boxes and linkages between the components shown as arrows. The modeling framework adapts core elements of the Decision Support System (DSS) proposed by the Trinity River Restoration Program (TRRP) Science Advisory Board (Buffington et al., 2014). The DSS is a series of linked physical and biological models that simulate the management of flow in the Trinity River and the subsequent effects on water temperature, sediment, habitat availability, and fish production. Some form of the DSS has been used to assess flow modifications proposals over the past five years, including annual TRRP hydrographs recommended to the Trinity Management Council (Buxton 2021, 2022) and the Trinity River Winter Flow Project (TRRP and Reclamation 2022).

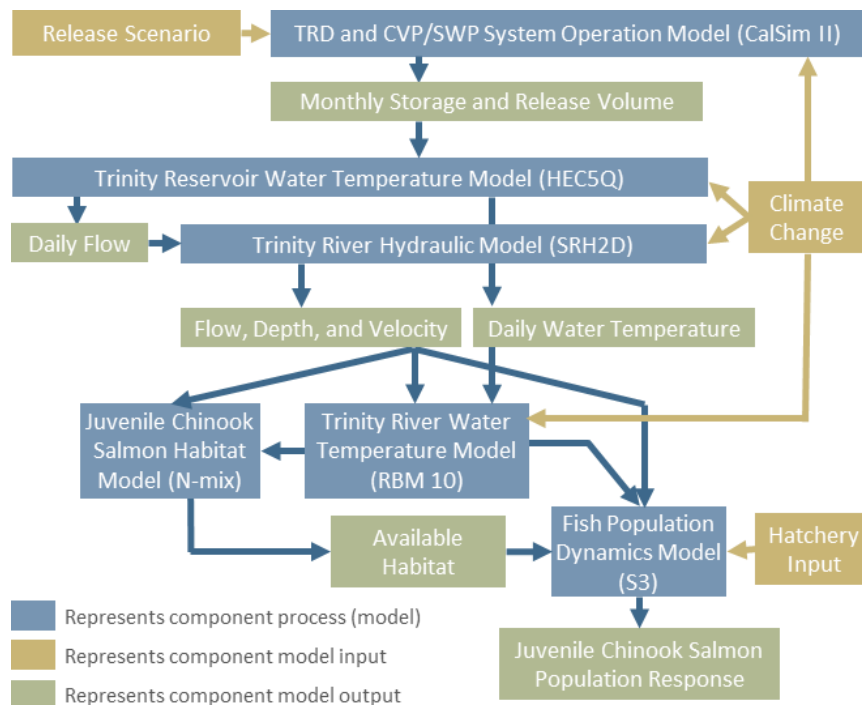


Figure 2-1. Modeling and Technical Analysis Framework for Analyzing Contract Water Release Scenarios

The main elements of the modeling framework are as follows:

- Historical hydrology is perturbed to reflect future climate change and is routed through the CalSim II model. The model simulates operation of the major CVP and State Water Project (SWP) facilities, including different assumed operations for each Contract Water release scenario, and generates estimates of river flows, reservoir storage, water deliveries, and other parameters. CalSim II simulates system operations for an 82-year period, from 1922 – 2003, using a monthly time step. The model uses historical hydrology perturbed by future climate change, but assumes that facilities, land use, water supply contracts, and regulatory requirements are constant over this period, representing a fixed set of conditions (existing or future).
- A HEC-5Q water temperature model for the primary integrated reservoir and river systems (i.e., Trinity Reservoir and Trinity River, lower Sacramento River, Clear Creek, Shasta Dam and Sacramento River) uses the CalSim II reservoir storage, reservoir releases, river flows, and meteorological conditions to estimate daily reservoir release and river temperatures for each release scenario. The HEC-5Q model estimates water temperatures for the Trinity River at Lewiston, and for the Sacramento River at various points from Shasta Dam through the Sacramento San-Joaquin Delta.
- Lewiston Dam release water temperatures are used as inputs to River Basin Model 10 (RBM10), a one-dimensional (1D) water temperature model that predicts daily water temperatures along the length of the Trinity River. The version of RBM10 applied for this modeling effort uses daily tributary inflow and water temperature inputs from the Long-Term Plan for Protecting Late-Summer Adult Salmon in the Lower Klamath River Environmental Impact Statement (Klamath LTP EIS) (Reclamation 2017).
- Outputs from an existing two-dimensional (2D) flow hydraulic and mobile-bed sediment transport model, Sedimentation and River Hydraulics model (SRH-2D), are used to evaluate river hydraulics including water surface elevations, flow velocity, shear stress, and sediment mobilization. The SRH-2D model was initially developed in 2016 using topography and bathymetry surveyed in 2011 and 2012 (Bradley 2016), then updated in 2018 using topography and bathymetry surveyed in 2016 (Bradley 2018). Additional empirical relationships are used to evaluate coarse bedload transport in the Restoration Reach (Gaeuman and Stewart, 2017).
- A Chinook Salmon spawning habitat model (Goodman et al. 2018) and a juvenile Chinook Salmon microhabitat model (Som et al. 2018) both use depth, velocity, and other hydrodynamic outputs from the SRH-2D model of the Restoration Reach to predict spawning habitat and juvenile capacity.
- Stream Salmonid Simulator (S3) is a deterministic life-stage-structured population model that simulates growth, movement, and survival between spawning and outmigration or ocean entry. Model inputs include water temperature and discharge from RBM10, hatchery and tributary abundances, spawning distribution/abundance, and micro-habitat quality. Model outputs include juvenile fish abundance, size, and biomass. The S3 model used for this analysis was constructed and parameterized for spring-run and fall-run Chinook Salmon of the Trinity River (Perry et al. 2018a).

2.2 Key Modeling Framework Assumptions

The following set of assumptions are common to the modeling framework. Model specific assumptions (e.g., regulatory assumptions regarding CVP and SWP operations in CalSim II) are described in detail in each model description in the appendix.

2.2.1 Contract Water Release Assumptions

For modeling purposes, a baseline condition (i.e., No Project) and several Contract Water release scenarios (i.e., Alternatives) are considered. The baseline condition reflects TRD water management consistent with current regulatory and operational regimes, while the release scenario conditions integrate a single Contract Water release scenario into the operation of the TRD. This operation assumes Contract Water releases are made from Proviso 2 water, i.e., a separate annual volume above and beyond the Proviso 1 obligations currently modeled in CalSim II. Contract Water releases are assumed to be additive to the ROD flows currently released from Lewiston Dam, i.e., they are used to supplement ROD flows in any given month. Release scenarios do not contemplate shifting the timing of current ROD flows.

2.2.2 Location Focus

Commercial, Tribal, and sport fisheries depend on healthy populations of Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*O. kisutch*), and steelhead (*O. mykiss*). These fish species are anadromous, meaning they are born in freshwater but spend most of their lives in saltwater before returning to freshwater to spawn. The Restoration Reach of the Trinity River, or the 40 river miles below Lewiston Dam that have been the focus of mechanical restoration projects since the 2000 ROD, provides spawning and rearing habitat for these species (USFWS and HVT 1999). The Restoration Reach is also the spatial domain where the most advanced biological modeling tools for the Trinity River have been developed. These tools are the best available to analyze whether Contract Water releases improve spawning and rearing habitat and create greater salmonid populations. Thus, the technical analysis will focus on the Trinity River in the Restoration Reach, which is in Trinity County. Contract Water releases that improve anadromous fish species habitat are anticipated to increase fish populations throughout the entire Trinity River, and the resulting fishable surplus would benefit the population of Humboldt County along with the populations of other counties. The TRD location within the Trinity River watershed is shown in Figure 2-2. Major tributaries and other features of Restoration Reach of the Trinity River included in the modeling are shown in a more detailed map in Figure 2-3.

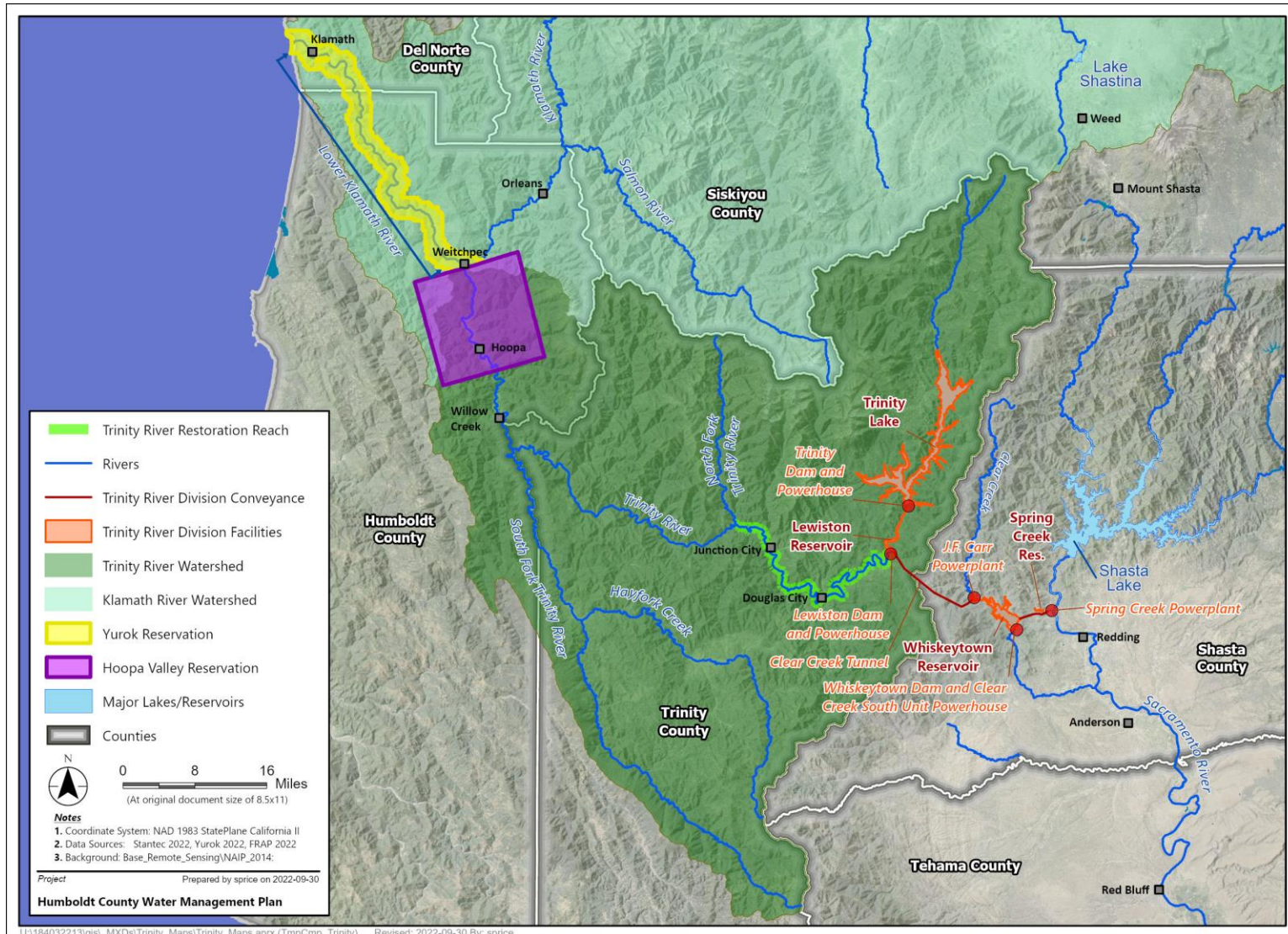


Figure 2-2. Major Facilities, Features, and Boundaries Associated with the Trinity River Division.

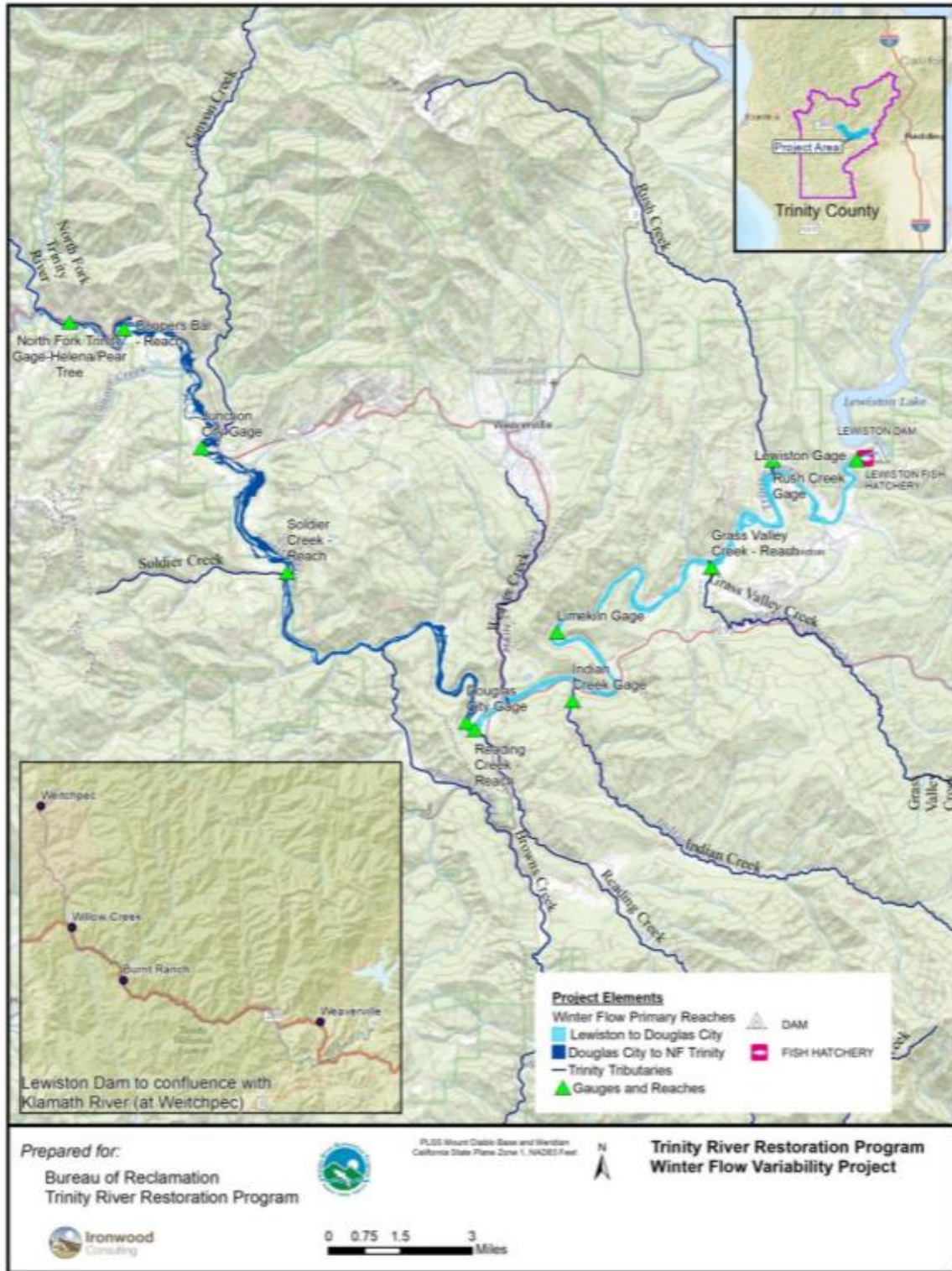


Figure 2-3. The Restoration Reach of the Trinity River (TRRP and Reclamation 2022).

2.2.3 Simulation Period and Model Output

Each model contains an established simulation period used to model operations, physical processes, and biological responses (Table 2-1). For CalSim II, model outputs are produced as a monthly timeseries. HEC-5Q converts monthly CalSim II outputs into daily inputs based on a pre-processing tool, and then produces a daily timeseries of outputs. RBM10 routes daily flows and water temperatures from HEC-5Q down the Trinity River, producing a daily timeseries of outputs. The base simulation period for analysis of Contract Water release scenarios was the overlapping period of record for these three models, 1980-2003. Both SRH-2D and the habitat models rely on input values that reflect a specific daily value. These are not timeseries models – rather, for a given daily input value, they produce a daily output value. The S3 model uses daily input values to simulate growth, movement, and survival of juvenile salmonids. The model then simulates density-dependent population dynamics that are driven in part by pre-defined input spawner abundance values. Because there are limited spawner abundance estimates available prior to 2005, since the model does not explicitly reflect a historical condition prior to 2005, and no water year correlation with spawner abundance, a single spawner abundance input scenario was selected for each year using flow conditions from 1980 – 2003.

Table 2-1. Simulation Period and Output Type for Each Model

Model	Simulation Period	Output Type
CalSim II	1922 – 2003	Timeseries of monthly storage volume and release volume from Trinity Reservoir and Lewiston Reservoir
HEC-5Q	1922 – 2003	Timeseries of mean daily release rate and water temperatures from Lewiston Reservoir
RBM10	1980 – 2003*	Timeseries of mean daily water temperature along the Restoration Reach
SRH-2D and Sediment models	N/A	Instantaneous flow, depth, and velocity within specific channel segments based on an input flow value**, coarse bedload transport, partial bed mobilization**
Habitat models	N/A	Daily habitat outputs within specific channel segments based on daily flow, depth, water temperature, and velocity inputs**
S3	Annual	Annual population outputs, summarized by water year type at relatively high spawner abundance when the effects of increasing habitat would be most apparent

Notes:

* The RBM10 modeling period ends in 2003 to be consistent with the operations, reservoir water temperature, and reservoir release temperature models which operate over a simulation period of 1922 – 2003. The current RBM10 model can simulate water temperatures up to 2015.

** Outputs are based on static Trinity River topography and bathymetry that reflect channel conditions either in 2011 and 2012 (as applied in the habitat models) based on Bradley 2016, or channel conditions in 2016 (as applied in the partial bed mobilization analysis) based on Bradley 2018. Habitat restoration projects completed since 2018 represent proportionally a very small length of the total reach length. It was assumed the corresponding changes to hydraulics within the Restoration Reach from these projects are negligible, and model outputs thus reflect the current bathymetric template of the Trinity River.

The water year types and modeled annual Trinity Reservoir inflow for the 1980 – 2003 simulation period are shown in Figure 2-4 (annual modeled inflows reflect future climate change conditions as described in Section 2.2.5). The simulation period captures several extremely wet years in the early 1980s and mid- to late-1990s, as well as a significant drought period that occurred from water years 1987 through 1982. A comparison of the water year types from 1980 – 2003 to the full historical period of record, 1912 – 2021, shows that wet and dry periods are represented relatively well in the abbreviated simulation period (Table 2-2).

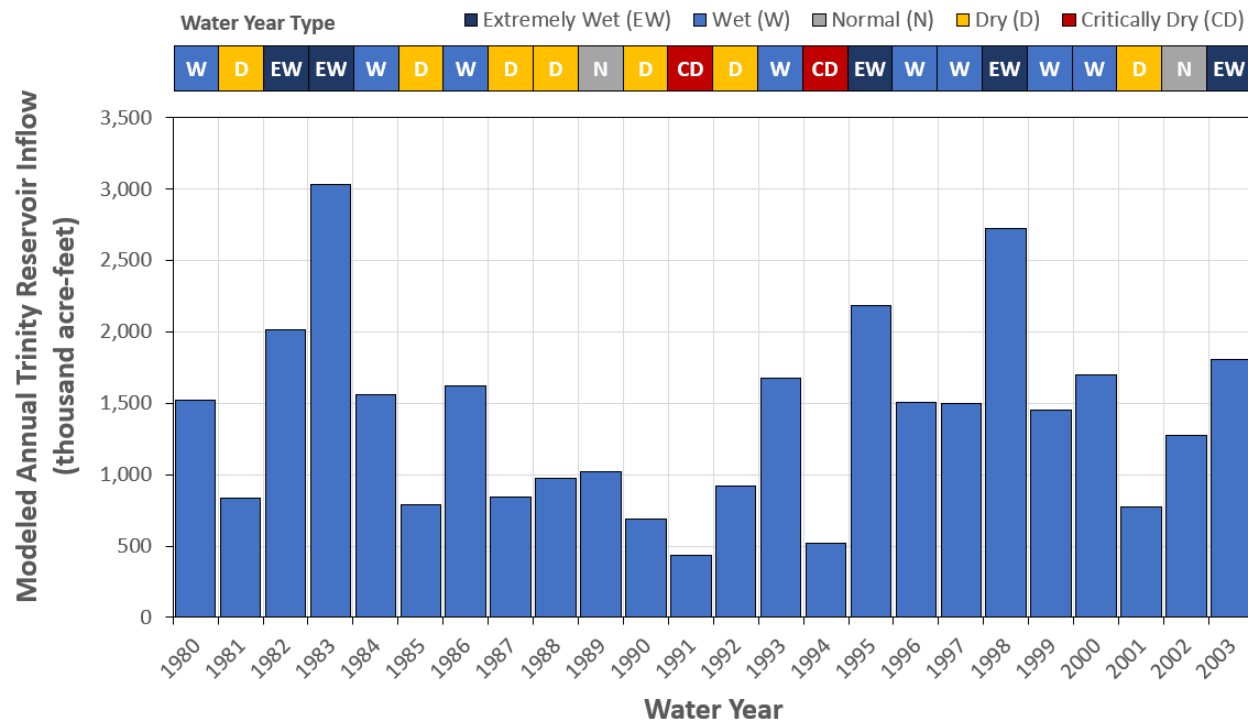


Figure 2-4. Modeled Annual Trinity Reservoir Inflow and Water Year Type in the Simulation Period.

Table 2-2. Water Year Type Distribution in the Simulation Period and the Historical Record

Time Period	1980 – 2003		1912 – 2021	
	Number of Years	Percentage of Years	Number of Years	Percentage of Years
Extremely Wet	5	21%	14	13%
Wet	8	33%	33	31%
Normal	2	8%	18	17%
Dry	7	29%	28	26%
Critically Dry	2	8%	13	12%

Key: % = percentage

2.2.4 Species Focus

An advanced set of modeling and analytical tools has been developed primarily for analyzing the effects of flow management on Chinook Salmon. The main assumption is that releases that benefit Chinook Salmon are generally beneficial to the other anadromous fish species in the Trinity River. The technical analysis focuses on assessing the effects of Contract Water releases on juvenile Chinook Salmon. Other fish species which are highly prevalent in the Trinity River include Coho Salmon, steelhead, and lamprey. A summary of the generalized life history timing for the anadromous species, as reported by the TRRP (TRRP 2023), is included in Table 2-3.

Table 2-3. Generalized Life History Timing for Chinook Salmon, Coho Salmon, and Steelhead in the Trinity River (adapted from TRRP 2023).

Species/Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Chinook Salmon													
Adult Migration					Spring-run								
									Fall-run				
Spawning									Spring-run				
											Fall-run		
Incubation	Spring-run										Spring-run		
	Fall-run										Fall-run		
Emergence	Spring- and Fall-run												
Rearing	Spring-run												
	Fall-run												
Outmigration			Spring- and Fall-run										
Coho Salmon													
Adult Migration													Pink
Spawning	Pink											Pink	
Incubation	Pink											Pink	
Emergence			Pink										
Rearing	Pink												
Outmigration			Pink										
Steelhead													
Adult Migration					Summer-run								
									Fall-run				
	Winter-run												Winter-run
Spawning	All runs												
Incubation	All runs												
Emergence				All runs									
Rearing	All runs												
Outmigration			All runs								All runs		

2.2.5 Climate Change Considerations

Future climate change assumptions are consistent with those used in modeling to support the Coordinated Long-Term Operation of the Central Valley Project and State Water Project EIS (LTO EIS) (Reclamation 2015) and the Klamath LTP EIS (Reclamation 2017). In those modeling efforts, several climate change scenarios were developed from an ensemble of 112 bias corrected, spatially downscaled global climate model (GCM) simulations from 16 climate models of different emission scenarios. The GCMs were developed and refined in 2006 as part of the Coupled Model Intercomparison Project Phase 3 (CMIP3) and were used to simulate future projected hydrologic and meteorological changes over a 30-year climatological period centered on 2025 (i.e., 2011-2040).

To summarize these 112 scenarios, Reclamation developed five statistically representative climate change scenarios: (1) drier, less warming, (2) drier, more warming, (3) wetter, more warming, (4) wetter, less warming, and (5) a central tendency or central position of climate change. For the Water Management Plan, the central tendency scenario is selected to model the baseline and Contract Water release scenario conditions in 2030, consistent with the LTO and with the future conditions assessed in the Klamath LTP EIS. To incorporate climate change into the hydrologic and meteorological conditions of CalSim II and other models, historical streamflow and air temperature are perturbed by 2030 climate change conditions.

As applied in the LTO EIS and Klamath LTP EIS, climate change effects on hydrology were modeled by perturbing historical monthly runoff and streamflow using a change factor developed from statistical analysis of hydrologic models that used climate change perturbed precipitation and air temperature as inputs. After determining the adjusted runoff and stream flows, water year types and other hydrologic indices that govern water operations or compliance were adjusted to be consistent with the new hydrologic regime. Changes in reservoir inflows, key valley floor accretions, and water year types and hydrologic indices were translated into modified input time series for the CalSim II model.

As applied in the Klamath LTP EIS, climate change effects on water temperature were primarily implemented by using climate change perturbed air temperatures as water temperature model inputs. To implement this process, historical air temperature time series were perturbed by a change factor developed from statistical analysis of climate change perturbed air temperature.

2.3 Appropriate Use of Model Results

Modeling used in this report is for a planning analysis conducted to understand long-term changes in local, regional, and statewide water systems and biological populations due to a proposed change. The numerical models developed and applied in this analysis are generalized and simplified representations of complex water resources systems with uncertainty in inputs and boundary conditions. The models are not predictive models in how they are applied for this analysis, and therefore, results cannot be used to predict a future state of a system at a specific point in time. Even so, the models used are informative and helpful in understanding the performance and potential impacts (both positive and negative) of the operation of a project, its interaction with the water resources system under consideration, and its positive and negative potential effects relative to Alternative operations. Even though some of the models used in this planning analysis (e.g., S3) are calibrated and validated to represent physical processes, all the models used in the analysis should primarily be used to understand potential long-term average trends and effects of an alternative.

An appropriate interpretation of model results, and the method employed in this analysis, is development and presentation of seasonal patterns from long-term averages and water year-type averages. Statistics are computed and presented based on long-term, monthly, and water year-type averages, and results are presented as computed differences between long-term, monthly, or water year-type averages of model results from two or more scenarios. Comparative analysis which uses the differences between these long-term averages (e.g., comparisons of long-term average water deliveries or reservoir storage levels) is used to assess effects of the alternatives. Model results are not used to compute absolute differences or evaluate impacts at a point in time between an alternative and an existing condition (e.g., computing differences between alternatives for a particular month and year within the period of record of simulation). Likewise computing absolute differences between model results from a baseline or alternative condition at a specific point in time and a specific threshold value or standard is an inappropriate use of model results.

3 MODEL ASSUMPTIONS AND MODIFICATIONS

This section provides more detail on each individual model and describes the assumptions and modifications made to simulate baseline and Contract Water scenarios.

3.1 CalSim II

CalSim II was jointly developed by Reclamation and the California Department of Water Resources (DWR) for performing planning studies related to CVP and SWP operations. The primary purpose of CalSim II is to evaluate the water supply reliability of the CVP and SWP under existing and future conditions (e.g., 2022, 2030), which can vary in terms of assumed future facilities and modes of facility operations. Geographically, the model covers the drainage basin of the Delta, CVP (including imports from the Trinity River watershed), and SWP, and SWP deliveries to the San Francisco Bay Area, Central Coast, Southern California, and the Tulare Basin.

3.1.1 Baseline Assumptions

CalSim II typically simulates system operations for an 82-year period using a monthly time step. The model assumes that facilities, land use, water supply contracts, and regulatory requirements are constant over this period, representing a fixed set of conditions (existing or future). The historical flow record of October 1921 to September 2003, adjusted for the influence of land-use change and upstream flow regulation, is used to represent a range of possible water supply conditions. Often, a future condition is represented by augmenting the adjusted historical flow record to incorporate the effects of climate change as predicted by specific global climate change models. Results from a single CalSim II simulation may not necessarily correspond to actual system operations for a specific month or year, but they are representative of general water supply conditions. Model results are best interpreted using various statistical measures such as long-term or year-type averages.

A benchmark CalSim II model is maintained and updated on a semi-regular basis by Reclamation and DWR. The benchmark model reflects the most recent operational and regulatory assumptions used by Reclamation in planning studies. A benchmark CalSim II model dated 04/18/2022 was obtained from Reclamation for use in this project. A brief description of the main assumptions for the baseline and Contract Water release scenarios is included in Table 3-1.

Table 3-1. Cal-Sim II Assumptions for the Baseline and Contract Water Release Scenarios

Regulation or Assumption	Baseline	Scenarios
GENERAL		
Planning horizon ^a	Year 2021	Same as Baseline
Period of simulation	82 years (1922-2003)	Same as Baseline
HYDROLOGY		
Climate Change (See Section 2.2.5)	Hydrology and meteorological conditions based on projected changes over the 30-year climatological period centered on 2025 (i.e., 2011-2040)	Same as Baseline
Sea Level Rise	15 cm	Same as Baseline
Inflows/Supplies	Modified inflows based on historical hydrology projected 2020 modifications for operations upstream of the rim reservoirs	Same as Baseline
Level of development	Projected 2030 level ^b	Same as Baseline
DEMANDS, WATER RIGHTS, CVP/SWP CONTRACTS		
Sacramento River Region (excluding American River)		
CVP ^c	Land-use based, full build-out of contract amounts, except for Settlement Contractors represented with historical diversions.	Same as Baseline

Regulation or Assumption	Baseline	Scenarios
SWP (FRSA) ^d	Land-use based, limited by contract amounts	Same as Baseline
Non-project	Land use based, limited by water rights and SWRCB Decisions for Existing Facilities	Same as Baseline
Antioch Water Works	Pre-1914 water right	Same as Baseline
Federal refuges	Firm Level 2 water supply needs	Same as Baseline
Sacramento River Region - American River^e		
Water rights	Year 2025, full water rights	Same as Baseline
CVP	Year 2025, full contracts except for Settlement Contractors at historical diversions, including Freeport Regional Water Project	Same as Baseline
San Joaquin River Region^f		
Friant Unit	Limited by contract amounts, based on current allocation policy	Same as Baseline
Lower Basin	Land-use based, based on district level operations and constraints	Same as Baseline
Stanislaus River	Land-use based, Stepped Release Plan (SRP)	Same as Baseline
San Francisco Bay, Central Coast, Tulare Lake and South Coast Regions (CVP/SWP project facilities)		
CVP ^c	Demand based on contract amounts	Same as Baseline
CCWD ^g	195 TAF/yr CVP contract supply, water rights and in-Delta transfers	Same as Baseline
SWP ^{d,h}	Demand based on Table A amounts	Same as Baseline
Article 56	Based on 2001-08 contractor requests	Same as Baseline
Article 21	MWD demand up to 200 TAF/month from December to March subject to conveyance capacity, KCWA demand up to 180 TAF/month and other contractor demands up to 34 TAF/month in all months, subject to conveyance capacity	Same as Baseline
North Bay Aqueduct (NBA)	77 TAF/yr demand under SWP contracts, up to 43.7 cfs of excess flow under Fairfield, Vacaville and Benecia Settlement Agreement	Same as Baseline
Federal refuges	Firm Level 2 water needs	Same as Baseline
FACILITIES		
Systemwide		
Systemwide	Existing facilities	Same as Baseline
North Coast Region		
Trinity Lake	Existing, 2,448 TAF capacity	Same as Baseline
Sacramento River Region		
Shasta Lake	Existing, 4,552 TAF capacity	Same as Baseline
Red Bluff Diversion Dam	Diversion dam gates out all year. Pumping Plant operated to deliver CVP water with capacity of 2,000 cfs.	Same as Baseline
Hamilton City Pump Station	Pumping plant with capacity of 3,000 cfs.	Same as Baseline
Fremont Weir	Notched Fremont Weir as represented in Yolo Bypass Salmonid Habitat Restoration and Fish Passage EIS/EIR Alternative 1 (preferred alternative)	Same as Baseline
Colusa Basin	Existing conveyance and storage facilities	Same as Baseline
Lake Oroville	Existing, 3,538 TAF capacity	Same as Baseline

Regulation or Assumption	Baseline	Scenarios
Upper American River ^{e,i}	PCWA American River Pump Station	Same as Baseline
Folsom Lake	Existing, 976 TAF capacity	Same as Baseline
American River	Existing Folsom Dam including auxiliary spillway	Same as Baseline
Lower Sacramento River	Freeport Regional Water Project ^l	Same as Baseline
San Joaquin River Region		Same as Baseline
Millerton Lake (Friant Dam)	Existing, 520 TAF capacity	Same as Baseline
Lower San Joaquin River	City of Stockton Delta Water Supply Project, 30-mgd capacity. SJRRP Recapture simulated at West Stanislaus ID, Patterson ID, and Banta Carbona ID	Same as Baseline
SWP Banks Pumping Plant (South Delta) ^k	Physical capacity is 10,300 cfs but 6,680 cfs permitted capacity in all months. Pumping can be up to 10,300 cfs during Dec 15 – Mar 15 depending on Vernalis flow conditions; additional capacity of 500 cfs (up to 7,180 cfs) allowed Jul – Sep for reducing impact of Spring Outflow Action on SWP	Same as Baseline
CVP C.W. Bill Jones Pumping Plant (Tracy PP)	Permit capacity is 4,600 cfs in all months (allowed for by the Delta-Mendota Canal–California Aqueduct Intertie)	Same as Baseline
Upper Delta-Mendota Canal Capacity	Existing plus 400 cfs Delta-Mendota Canal–California Aqueduct Intertie	Same as Baseline
CCWD Intakes	Los Vaqueros Reservoir with existing storage capacity (160 TAF), and existing intakes except for Mallard Slough Intake. Updated to be consistent with latest Los Vaqueros modeling	Same as Baseline
Suisun March Salinity Control Gates (SMSCG)	Delta salinity conditions are adjusted for months in which the salinity control gate is operated (see operations)	Same as Baseline
San Luis Reservoir	Existing, 2,041 TAF capacity	Same as Baseline
San Francisco Bay Region		
South Bay Aqueduct (SBA)	SBA rehabilitation, 430 cfs capacity from junction with California Aqueduct to Alameda County FC&WCD Zone 7 diversion point	Same as Baseline
South Coast Region		
California Aqueduct East Branch	Existing capacity	Same as Baseline
REGULATORY STANDARDS		
North Coast Region		
Trinity River		
Minimum flow below Lewiston Dam	Trinity EIS Preferred Alternative (369-815 TAF/yr)	Same as Baseline
Trinity River Fall Augmentation Flows ^o	420 cfs August 1 through September 30 in all but wet years	Same as Baseline
Trinity Reservoir end-of-September minimum storage	Trinity EIS Preferred Alternative (600 TAF as able)	Same as Baseline
Proviso 2 releases to Trinity River	Not included	Based on Contract Water release scenarios defined in Section 4
Sacramento River Region		

Regulation or Assumption	Baseline	Scenarios
Clear Creek		
Minimum flow below Whiskeytown Dam	Downstream water rights, 1963 USBR Proposal to USFWS and NPS; and 200 cfs October through May or 150 cfs in Critical years and 150 cfs June through September with 10 TAF for channel maintenance in February of BN, AN and Wet years and 10 TAF for Spring pulse flows in June of non-Critical years; in June of Critical years, pulse of 900 cfs.	Same as Baseline
Upper Sacramento River		
Shasta Lake end-of-September minimum storage	1900 TAF in non-critically dry years (not explicitly modeled - achieved through project allocation profiles when hydrologically feasible)	Same as Baseline
Minimum flow below Keswick Dam	SWRCB WR 90-5; and stabilize fall flows to reduce redd dewatering and rebuild cold water pool; and spring pulse flow up to 150 TAF if projected May 1 storage > 4.1 MAF	Same as Baseline
Feather River		
Minimum flow below Thermalito Diversion Dam	2006 Settlement Agreement (700 / 800 cfs)	Same as Baseline
Minimum flow below Thermalito Afterbay outlet (maintained down to mouth of Feather)	1983 DWR, DFG Agreement (750-1,700 cfs)	Same as Baseline
Yuba River		
Minimum flow below Daguerre Point Dam	D-1644 Operations (Lower Yuba River Accord) ^m	Same as Baseline
American River		
Minimum flow below Nimbus Dam	American River Flow Management Standard, per 2017 Water Forum Agreement with a planning minimum end of December storage target of 275 TAF	Same as Baseline
Minimum Flow at H Street Bridge	SWRCB D-893	Same as Baseline
Lower Sacramento River		
Minimum flow near Rio Vista	SWRCB D-1641	Same as Baseline
San Joaquin River Region		
Mokelumne River		
Minimum flow below Camanche Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (100-325 cfs)	Same as Baseline
Minimum flow below Woodbridge Diversion Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (25-300 cfs)	Same as Baseline
Stanislaus River		Same as Baseline
Minimum flow below Goodwin Dam	Flows per New Melones SRP	Same as Baseline
Minimum dissolved oxygen	SWRCB D-1422	Same as Baseline
Merced River		
Minimum flow below Crocker-Huffman Diversion Dam	Cowell Agreement	Same as Baseline
Minimum flow at Shaffer Bridge	FERC 2179 (25-100 cfs) with 12.5 TAF in October based on 2002 Merced ID and CDFW Memorandum of Understanding	Same as Baseline

Regulation or Assumption	Baseline	Scenarios
Tuolumne River		
Minimum flow at Lagrange Bridge	FERC 2299-024, 1995 (Settlement Agreement) (94-301 TAF/yr)	Same as Baseline
San Joaquin River		
San Joaquin River below Friant Dam/ Mendota Pool	San Joaquin River Restoration-full flows, not constrained by current river capacity, model implementation includes recapture in the San Joaquin River and in the Delta	Same as Baseline
Maximum salinity near Vernalis	Stanislaus contribution per New Melones SRP	Same as Baseline
Minimum flow near Vernalis	Stanislaus contribution per New Melones SRP	Same as Baseline
Sacramento River–San Joaquin Delta Region		
Delta Outflow Index (Flow, NDOI)	SWRCB D-1641 and for Summer/Fall Delta Smelt habitat operate to meet X2 of 80 km for September and October of AN, and Wet years with transitional flows in last half of August. SWP to allow up to 150 TAF of Delta outflow in April and May. Spring outflow action shall not exceed 150 TAF and is subject to a 44,500 cfs Delt Outflow off-ramp. SWP to release 100 TAF block of water in Jun through Sep of Wet and Above Normal years.	Same as Baseline
Delta Cross Channel gate operation	Gate operations per Multi Year Study Program; model representation as SRWCB D-1641 with additional days closed from Oct 1 – Jan 31 based on NMFS BO (Jun 2009) Action IV.1.2 (closed during flushing flows from Oct 1 – Dec 14 unless adverse water quality conditions would result)	Same as Baseline
South Delta export limits (Jones PP and Banks PP)	SWRCB D-1641 Vernalis flow-based export limits Apr 1 – May 31, (additional 500 cfs allowed for Jul – Sep for reducing impact on SWP)	Same as Baseline
Combined Flow in Old and Middle River (OMR)	OMR target of -5,000 cfs January through June except for 5 days of -2,000 cfs when turbidity bridge occurs (turbidity bridge consideration only January through March) and 7 days of -6,000 cfs when increased pumping due to storm is possible, followed by “first flush” action if it occurs in December or January (14 days of -2,000 cfs), and OMR target of -3,500 cfs in March, April, and May of non-Critical years. Health and Safety off-ramp when exports are low.	Same as Baseline
OPERATIONS CRITERIA: RIVER-SPECIFIC		
Sacramento River Region		
Upper Sacramento River: Flow objective for navigation (Wilkins Slough)	Flow objective for Wilkins Slough based on month, CVP allocation, and Shasta storage condition to reflect CVP operations for local delivery	Same as Baseline
American River: Folsom Dam flood control	Fixed 400 TAF flood control diagram	Same as Baseline
San Joaquin River Region		

Regulation or Assumption	Baseline	Scenarios
Stanislaus River: Flow below Goodwin Dam	Flows per New Melones SRP	Same as Baseline
San Joaquin River: Salinity at Vernalis	Grasslands Bypass Project (full implementation)	Same as Baseline
Sacramento – San Joaquin River Delta Region		
Suisun Marsh Salinity Control Gates	Operate to meet SWRCB D-1641 water quality standards in Montezuma Slough during salinity control season October through May; and for Summer/Fall Delta Smelt habitat operate for up to 60 days June through October of Below Normal, Above Normal, and Wet years. SWP facilitates operations for up to 60 days in June through October of Dry years.	Same as Baseline
OPERATIONS CRITERIA: SYSTEMWIDE		
CVP water allocation		
Settlement / Exchange	100% (75% in Shasta critical years)	Same as Baseline
Refuges	100% (75% in Shasta critical years)	Same as Baseline
Agriculture Service	100%-0% based on supply, South-of-Delta allocations are additionally limited due to D-1641 and OMR action	Same as Baseline
Municipal & Industrial Service	100%-50% based on supply, South-of-Delta allocations are additionally limited due to D-1641 and OMR action	Same as Baseline
SWP water allocation		
North of Delta (FRSA)	Contract specific	Same as Baseline
South of Delta (including North Bay Aqueduct)	Based on supply; equal prioritization between Ag and M&I based on Monterey Agreement; allocations are additionally limited due to D-1641 and OMR action and Spring Outflow Action.	Same as Baseline
CVP-SWP coordinated operations		
Sharing of responsibility for in-basin-use	Revised Coordinated Operations Agreement	Same as Baseline
Sharing of surplus flows	Revised Coordinated Operations Agreement	Same as Baseline
Sharing of restricted export capacity for project- specific priority pumping	Revised Coordinated Operations Agreement	Same as Baseline
Water transfers	Acquisitions by SWP contractors are wheeled at priority in Banks Pumping Plant over non-SWP users; LYRA included for SWP contractors	Same as Baseline
Sharing of export capacity for lesser priority and wheeling-related pumping	Cross Valley Canal wheeling (max of 128 TAF/yr), CALFED ROD defined Joint Point of Diversion (JPOD)	Same as Baseline
San Luis Reservoir	San Luis Reservoir is allowed to operate to a minimum storage of 100 TAF	Same as Baseline
CVPIA 3406(b)(2)^{l,n}		
Policy Decision	N/A	Same as Baseline
Allocation	No B2 Allocation modeled	Same as Baseline
Actions	Pre-determined upstream fish flow objectives below Whiskeytown Dam	Same as Baseline
Accounting ^m	No B2 Accounting modeled	Same as Baseline
WATER MANAGEMENT ACTIONS		

Regulation or Assumption	Baseline	Scenarios
Water Transfer Supplies (long term programs)		
Lower Yuba River Accord ^m	Yuba River acquisitions for reducing impact of D-1641 and OMR Action export restrictions on SWP	Same as Baseline
Phase 8	None	Same as Baseline
<p>Key: cm = centimeter, CVP = Central Valley Project, EIS = Environmental Impact Statement, ITP = incidental take permit, LTO = Long-Term Operation, NMFS = National Marine Fisheries Service, ROC on LTO = Reinitiation of Consultation on the Long-Term Operation of the CVP and SWP, RPA = reasonable and prudent alternative, SWP = State Water Project, TAF = thousand acre-feet, USFS = United States Fish and Wildlife Service</p> <p>Notes:</p> <p>a These assumptions have been developed under the direction of the Bureau of Reclamation (Reclamation) management team for the Re-initiation of Consultation on long-term operations of the Central Valley Project (CVP) and State Water Project (SWP).</p> <p>b The Sacramento Valley hydrology used in the Future Conditions CALSIM II model reflects 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation. Development of future-level projected land-use are being coordinated with the California Water Plan Update for future models.</p> <p>c Refer to Attachment 5 CalSim II Model Delivery Specifications for contract specific details</p> <p>d Refer to Attachment 5 CalSim II Model Delivery Specifications for contract specific details</p> <p>e Assumptions regarding American River water rights and CVP contracts with the Sacramento River Water Reliability Project are documented in the Delivery Specifications attachments. The Sacramento Area Water Forum agreement, its dry year diversion reductions, Middle Fork Project operations and water is not included. Refer to Attachment 5 CalSim II Model Delivery Specifications for contract specific details</p> <p>f The CALSIM II representation of the San Joaquin River reflects the difficulties on-going groundwater overdraft problems. The 2030 level of development representation of the San Joaquin River Basin does not make any attempt to offer solutions to groundwater overdraft problems. In addition a dynamic groundwater simulation is not yet developed for the San Joaquin River Valley. Groundwater extraction/ recharge and stream-groundwater interaction are static assumptions and may not accurately reflect a response to simulated actions. These limitations should be considered in the analysis of results.</p> <p>g The actual amount diverted is operated in conjunction with supplies from the Los Vaqueros project. The existing Los Vaqueros storage capacity is 160 TAF. Associated water rights to fill Los Vaqueros with Delta excess flows are included, but CCWD's water right permit and water right license on Mallard Slough are not included.</p> <p>h It is assumed that SWP Contractors can take delivery of all Table A allocations and Article 21 supplies. Article 56 provisions are assumed and allow for SWP Contractors to manage storage and delivery conditions such that full Table A allocations can be delivered. Detailed analysis of the South Coast and Tulare regions support these assumptions. NBA Article 21 deliveries are dependent on excess conditions only, all other Article 21 deliveries also require that San Luis Reservoir be at capacity and that Banks PP and the California Aqueduct has available capacity to divert from the Delta for direct delivery.</p> <p>i PCWA American River pumping facility upstream of Folsom Lake is included.</p> <p>j Mokelumne River flows are modified to reflect modified operations associated with EBMUD supplies from the Freeport Regional Water Project.</p> <p>k Current ACOE permit for Banks PP allows for an average diversion rate of 6,680 cfs in all months. Diversion rate can increase up to 1/3 of the rate of San Joaquin River flow at Vernalis during Dec 15th – Mar 15th up to a maximum diversion of 10,300 cfs, if Vernalis flow exceeds 1,000 cfs.</p> <p>l Delta actions, under USFWS discretionary use of CVPIA 3406(b)(2) allocations, are no longer dynamically operated and accounted for in the CALSIM II model. The Combined Old and Middle River Flow and Delta Export restrictions under the FWS BO (Dec 15th 2008) and the NMFS BO (June 4th 2009) severely limit any discretion that would have been otherwise assumed in selecting Delta actions under the CVPIA 3406(b)(2) accounting criteria. Therefore, it is anticipated that CVPIA 3406(b)(2) account availability for upstream river flows below Whiskeytown, Keswick and Nimbus Dams would be very limited. The future of these operations is uncertain. For these baseline simulations, upstream flows on the Clear Creek and Sacramento River are pre-determined based on CVPIA 3406(b)(2) based operations from the Aug 2008 BA Study 7.0 and Study 8.0 for Existing and Future Conditions respectively. The procedures for dynamic operation and accounting of CVPIA 3406(b)(2) are not included in the CALSIM II model.</p> <p>^m D-1644 and the Lower Yuba River Accord is assumed to be implemented. The Yuba River is not dynamically modeled in CALSIM II. Yuba River hydrology and availability of water acquisitions under the Lower Yuba River Accord are based on modeling performed and the Lower Yuba River Accord EIS/EIR study team.</p> <p>ⁿ In cooperation with Reclamation, National Marine Fisheries Service, Fish and Wildlife Service, and Ca Department of Fish and Game, the Ca Department of Water Resources has developed assumptions for implementation of the FWS BO (Dec 15th 2008) and NMFS BO (June 4th 2009) in CALSIM II. The FWS BO and NMFS BO assumptions are documented in the Appendix 5A of the LTO EIS (Reclamation 2015b).</p> <p>^o This assumed operation is not consistent with Klamath LTP EIS (Reclamation 2017). For implementation in the technical analysis, no attempt was made to repattern the 450 cfs monthly release to match the Klamath LTP EIS.</p>		

3.1.2 Modifications for Release of Contract Water

The benchmark CalSim II model was modified to enable release of Contract Water for different scenarios. Three general categories of modifications were made to assess potential methods of accounting for reductions in TRD exports due to the release of Contract Water, described further below. Detailed descriptions of the release scenarios are described in Section 4.

- Minimize effects on CVP contractor delivery by allowing releases from Lake Shasta to increase (Scenarios 1-3, 5)
 - Exports of water from the TRD to the CVP were reduced due to lower Trinity Reservoir and Lake Shasta storage levels.
 - Lake Shasta releases were allowed to increase to offset TRD export reductions and maintain similar flows as the baseline in the Sacramento River. This resulted in slightly lower Lake Shasta storage levels.

- Minimize effects on Lake Shasta storage by modifying CVP contractor deliveries (Scenarios 4 and 6)
 - For Scenario 4, CVP South of Delta (SOD) and North of Delta (NOD) Ag allocations were reduced by similar amounts to minimize the number of dead pool months below 5 for Shasta, Trinity, and Folsom. Exports of water from the TRD to the CVP were reduced due to lower Trinity Reservoir and Lake Shasta storage levels.
 - For Scenario 6, CVP NOD Ag allocations were reduced to offset reduced exports from the TRD and maintain similar flows in the Sacramento River as the baseline.
 - Lake Shasta releases were maintained relatively similar to the baseline, resulting in smaller relative differences in Lake Shasta storage levels.

- Explicitly remove Contract Water from CVP storage calculations (Scenario 7)
 - To account for 50 TAF of Contract Water being held cumulatively each year as carryover, a separate storage account for Contract Water was created and held separate from storage used to contribute to the Sacramento Basin CVP operations. Water going into this account came from reductions in TRD exports to the CVP.
 - When Trinity Reservoir physically spilled or made a safety-of-dams release, the minimum of the volume of spill above the monthly ROD release volume or the volume of water in Contract Water carryover storage account was added to the Lewiston Reservoir instream flow requirement. In sum, the Carryover Storage account was the first water to spill out of Trinity Reservoir.
 - CVP NOD and SOD Ag allocations were reduced to offset reduced exports from the TRD and maintain similar flows in the Sacramento River as the baseline.

3.2 HEC-5Q

The Trinity-Sacramento River HEC-5Q Water Quality model is a HEC-5Q-based (one-dimensional) reservoir and river water quality and temperature model of the Trinity and Upper Sacramento River system including Trinity Dam and Reservoir, Trinity River to Lewiston Reservoir, Lewiston Dam and Reservoir, Clear Creek Tunnel, Whiskeytown Dam and Reservoir, Clear Creek below Whiskeytown Dam, Spring Creek Tunnel, Shasta Dam and Reservoir, Keswick Dam and Reservoir, Sacramento River from Keswick to Knights Landing, Red Bluff Diversion Dam, Black Butte Dam, and downstream Stony Creek. Figure 3-1 shows a schematic of the Trinity-Sacramento River HEC-5Q model and shows all of the reservoir and river control points where temperatures are simulated. The Trinity-Sacramento River HEC-5Q model was developed using integrated HEC-5 and HEC-5Q models. The HEC-5 component of the model simulates reservoir and river flow operations (usually daily). The HEC-5Q component is a 1-dimensional (1-D) water quality model that simulates reservoir and river temperatures and other water quality parameters based on the flow inputs and meteorological parameters. The model operates on a 6-hour time step to capture diurnal temperature fluctuations.

A version of the Trinity-Sacramento River HEC-5Q model was obtained from Reclamation to conduct an analysis of alternatives for the Klamath LTP EIS (Reclamation 2017). The model version was from November 2019 and included recent updates, calibration and verification, and modified meteorological and equilibrium temperature data to incorporate a 2030 level of climate change, consistent with the climate change approach used in the LTO EIS (Reclamation 2015). One of the major updates includes improved temperature continuity around Lewiston Reservoir and diversion temperatures to Clear Creek Tunnel. The model is set up to simulate the full CalSim II model 82-year simulation period (water years 1922 through 2003) on a 6-hour time step using daily flow data, which includes a spreadsheet pre-processing tool to disaggregate the mean monthly CalSim II reservoir operations and stream flows to daily values for use in the simulation. The 6-hour time step allows for analysis of diurnal temperature fluctuations required for the fishery analysis. The model can also provide the temperature profiles for Trinity, Lewiston, and other selected reservoirs in the model.

Trinity Dam has no specific temperature control device but includes an auxiliary outlet that allows access to the reservoir pool that cannot be accessed by the power outlets. This auxiliary outlet is only used in actual operations under emergency situations to control temperatures in the Trinity River when they exceed specific targets in the summer/fall months. The HEC-5Q model uses a tailwater temperature target of 49 degrees Fahrenheit (°F) between August 15th and October 31st when temperature management is most important. If release temperatures from the power outlets exceed this temperature target during this period, the auxiliary outlet is operated to blend with the releases from the power outlets to achieve the temperature target. A temperature target of 60°F is used for the remaining period. More detail is provided in the Appendix 6B, Section C of the 2015 LTO EIS (Reclamation 2015).

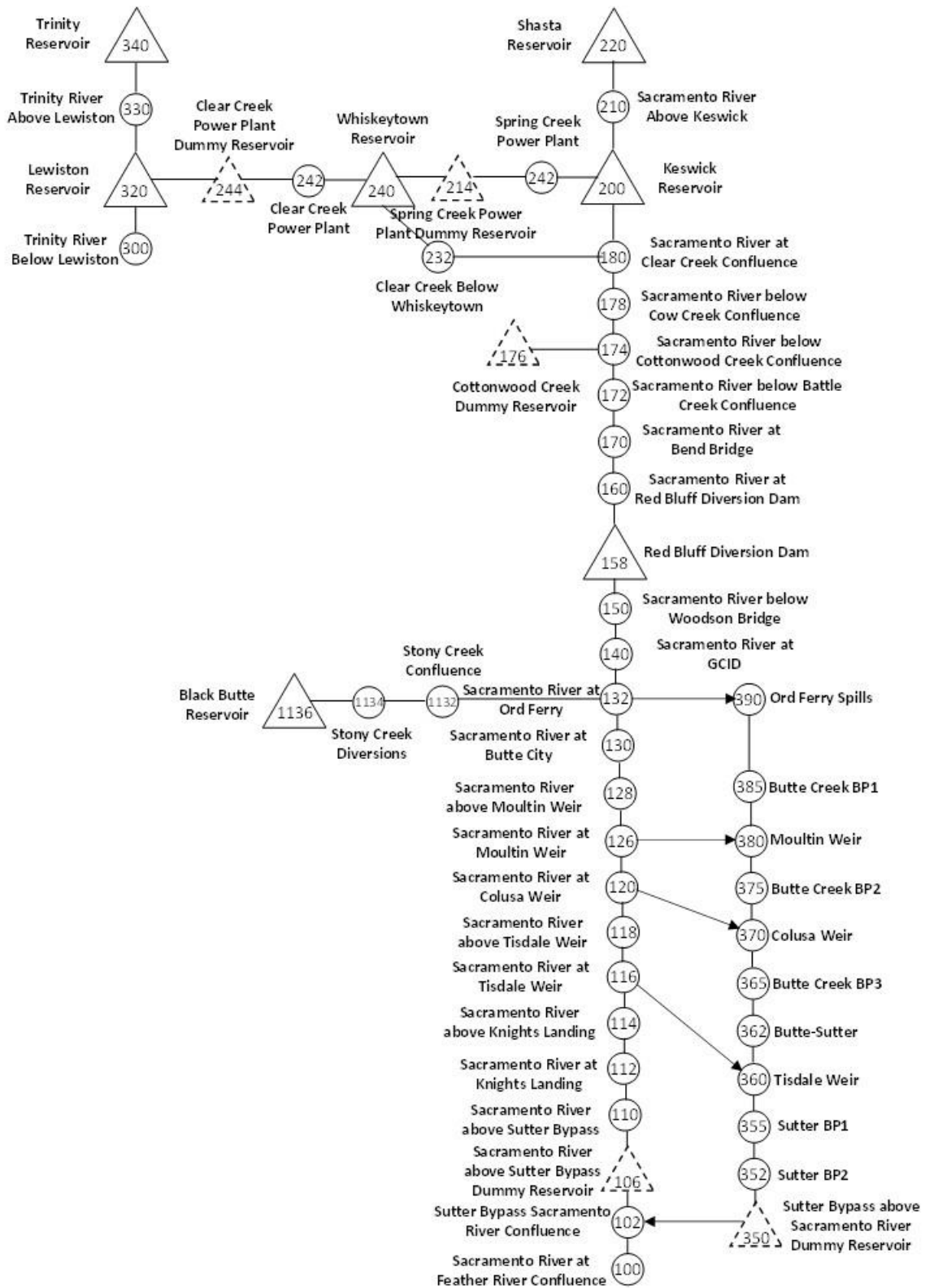


Figure 3-1. Schematic of Trinity-Sacramento River HEC-5Q Model.

Reclamation uses temperature control curtains at Lewiston Reservoir to modify reservoir release temperatures. Water from the Trinity River Basin is diverted into the Sacramento River Basin through two tunnels and three reservoirs. Trinity River water is diverted from Lewiston Reservoir through Clear Creek Tunnel to the Judge Francis Carr powerplant and discharged into Whiskeytown Reservoir. From there, water flows through the reservoir, into Spring Creek Tunnel and through Spring Creek Powerplant. Spring Creek Powerplant discharges into Keswick Reservoir where it combines with Sacramento River water released from Shasta Dam. Water released from Keswick Dam enters the upper Sacramento River. Over the course of this diversion and prior to curtain installation, Trinity River water temperatures were commonly increased 10 to 13°F (Vermeyen 2000). To provide cold water releases, Reclamation uses two flexible temperature curtains in Lewiston Reservoir to control mixing and provide for withdrawal at a specified elevation.

Two flexible curtains made of 60 mil Hypalon material were installed in Lewiston Reservoir in 1992. One curtain was designed to hold back warmer surface water while accessing colder water near the bottom for release to Clear Creek Tunnel and ultimately the lower Sacramento River Basin. The second curtain was designed to provide warmer surface withdrawals (when operating in overdraw mode) for Lewiston fish hatchery. Figure 3-2 shows the schematic of the Lewiston Reservoir flexible curtain and its components (USDOI 2020). Figure 3-3 shows the relative elevations of the features proximate to Lewiston Dam, along with the operating range of the reservoir and the downstream elevation of Trinity River (Reclamation 2012).

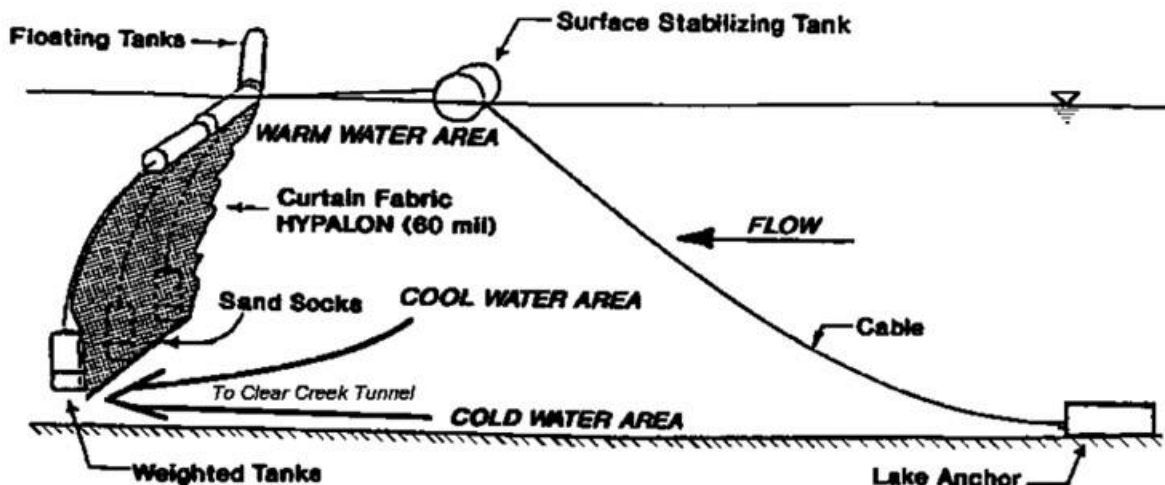


Figure 3-2. Schematic of the Lewiston Reservoir Flexible Temperature Curtain and its Components.

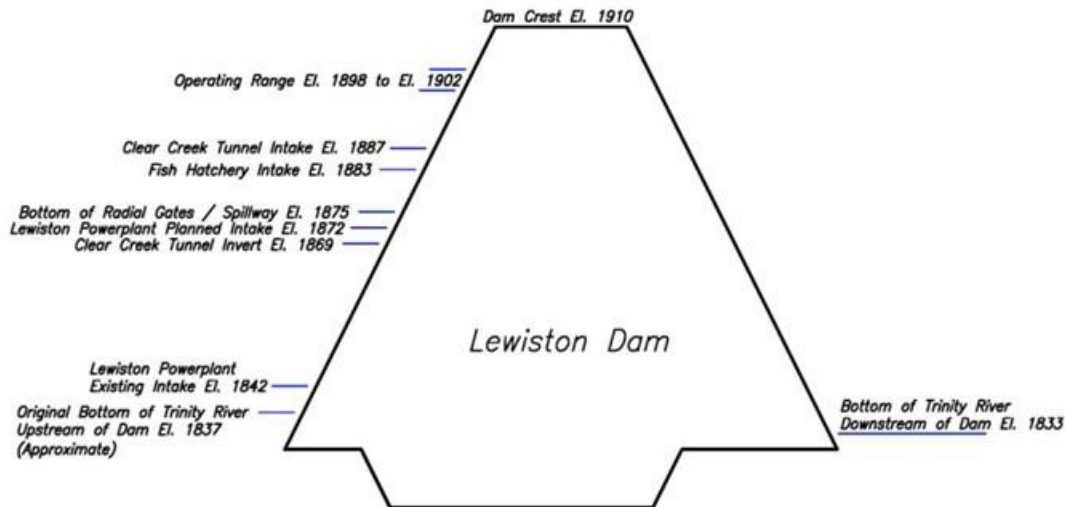


Figure 3-3. Lewiston Dam Elevation Diagram.

There are several limitations to the HEC-5Q models and the simulated water temperatures, both in their capability to simulate observed water temperatures and as applied in this modeling analysis. Calibration of the HEC-5Q model was focused on simulating daily average observed temperatures, primarily in the warmer periods, and the model adequately represents the thermal responses to the hydrologic and meteorological changes. Even though the HEC-5Q models simulate water temperatures on a sub-monthly timescale, given that they are driven by the monthly CalSim II results as inputs, the use of modeled temperatures should generally be limited to monthly average values, even though short-term fluctuations may be real and important to biological resources. If sub-monthly results are to be used, it is important to understand that the HEC-5Q models adheres to the CalSim II monthly volumes of reservoir storages, releases, and diversions. HEC-5Q models do not alter operations (other than temperature control device gate settings) to meet a temperature objective downstream in the river, and there is no feedback to CalSim II to alter the storage or release volumes.

3.3 River Basin Model 10

River Basin Model 10 (RBM10) is a one-dimensional (1D) water temperature model that predicts daily water temperatures along the longitudinal profile of a river. The model uses a simple equilibrium flow model, assuming discharge in each river segment on each day is transmitted downstream instantaneously, and a heat-budget formulation that quantifies heat flux at the air-water interface using daily mean meteorological data. A version of the model was developed to simulate 112.2 river miles of the Trinity River. The modeling domain was divided into eight reaches ranging in length from 8.8 to 20.6 miles, which were calibrated and validated separately with observed water temperature data collected irregularly from 1980 to 2013 (Jones et al. 2016). The same model was modified to account for climate change conditions centered around the year 2030 and used to simulate future water temperatures in the Trinity River for the Klamath LTP EIS (Reclamation 2017).

This RBM10 model was used to support the technical analysis and to provide flow and water temperature inputs to S3. For this analysis, RBM10 input files constructed for the Klamath LTP EIS (Reclamation 2017) were modified. Specifically, inputs to RBM10 included Lewiston Dam releases and water temperatures as simulated by CalSim II and HEC-5Q for the baseline and 7 Contract Water release scenarios. All other model inputs including meteorological data (e.g.,

daily air temperature and solar radiation) and tributary boundary conditions (daily tributary inflow and water temperature) were identical to the RBM10 analysis performed for the Klamath LTP EIS (Reclamation 2017). RBM10 was run to output water temperature and discharge at 17 locations (approximately 5 km intervals) between Lewiston Dam and the confluence with the North Fork Trinity River. These outputs served as flow and temperature inputs for S3.

3.4 Sediment Models

Sediment metrics were evaluated using a methodology similar to the Winter Flow Report (TRRP and Reclamation 2022) to quantify and evaluate the annual and total coarse bedload transport and annual partial stream bed mobilization created by each flow scenario. Daily flow releases at Lewiston under each scenario were combined with the daily flow for the seven major tributaries between Lewiston Dam and North Fork Trinity in the Trinity watershed (see tributaries in Figure 2-3) which were modeled in RBM10 for the Klamath LTP EIS (Reclamation 2017). The Winter Flow Report analysis used the hydrologic record from years 2004-2019, and the analysis only included years where a geomorphic pulse flow synchronization occurred (6 of 17 years); this analysis used the entire daily hydrograph for all years modeled, 1980-2003, to compare each scenario to the baseline.

3.4.1 Coarse Bedload Transport

Sediment supply and transport has been closely monitored in the Restoration Reach by the TRRP since 2004. There are four sediment monitoring stations: Trinity River at Lewiston (TRAL), Trinity River at Grass Valley Creek (TRGVC), Trinity River at Limekiln Gulch (TRLG), and Trinity River at Douglas City (TRDC) (Figure 3-4). Between 2004 and 2015, seven annual and one long-term historical rating curves were developed at each of the four stations which can be used to estimate sediment transport at different discharges. The most recent sediment rating curves developed for the four sediment monitoring stations for the 2015 water year were used in this analysis. The sediment rating curves and equations from Gaeuman and Stewart (2017) used in this analysis relating the coarse bedload (gravel-sized sediment with diameter >8mm) transported to the discharge are summarized in Figure 3-5.

The spatial extent of the Restoration Reach was subdivided into six reaches to analyze sediment mobilization. The daily flow at each reach was a sum of the flow for all modeled inputs above that reach and sediment monitoring station rating curves were assigned to each reach based on proximity, as summarized in Table 3-2. The amount of coarse bedload transport estimates the total amount of sediment greater than 8mm in diameter that would be transported and is an indicator of the amount of geomorphic work that would potentially be performed by each scenario relative to the baseline.

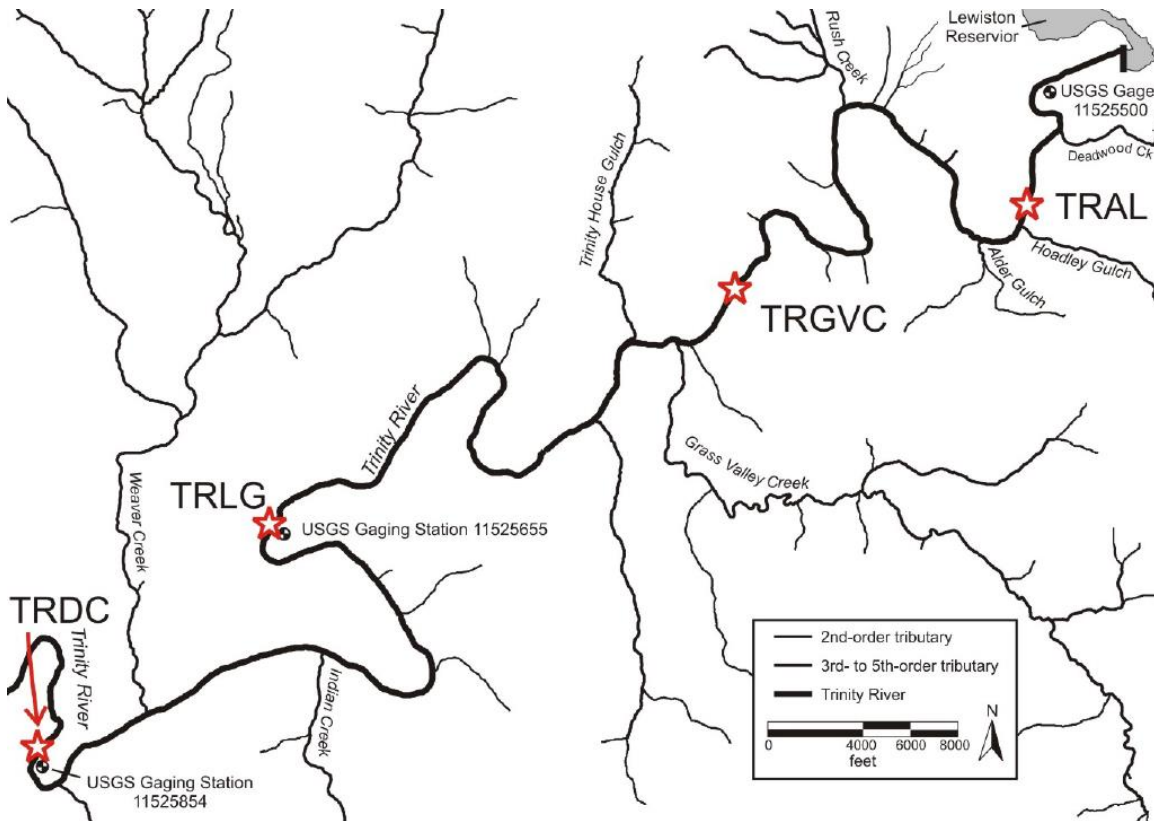


Figure 3-4. Location of the Four Sediment Monitoring Stations within Restoration Reach of the Trinity River, CA.

Note: TRAL = Trinity River at Lewiston; TRGVC = Trinity River at Grass Valley Creek; TRLG = Trinity River at Limekiln Gulch; TRDC = Trinity River at Douglas City (Gaeuman and Stewart 2017).

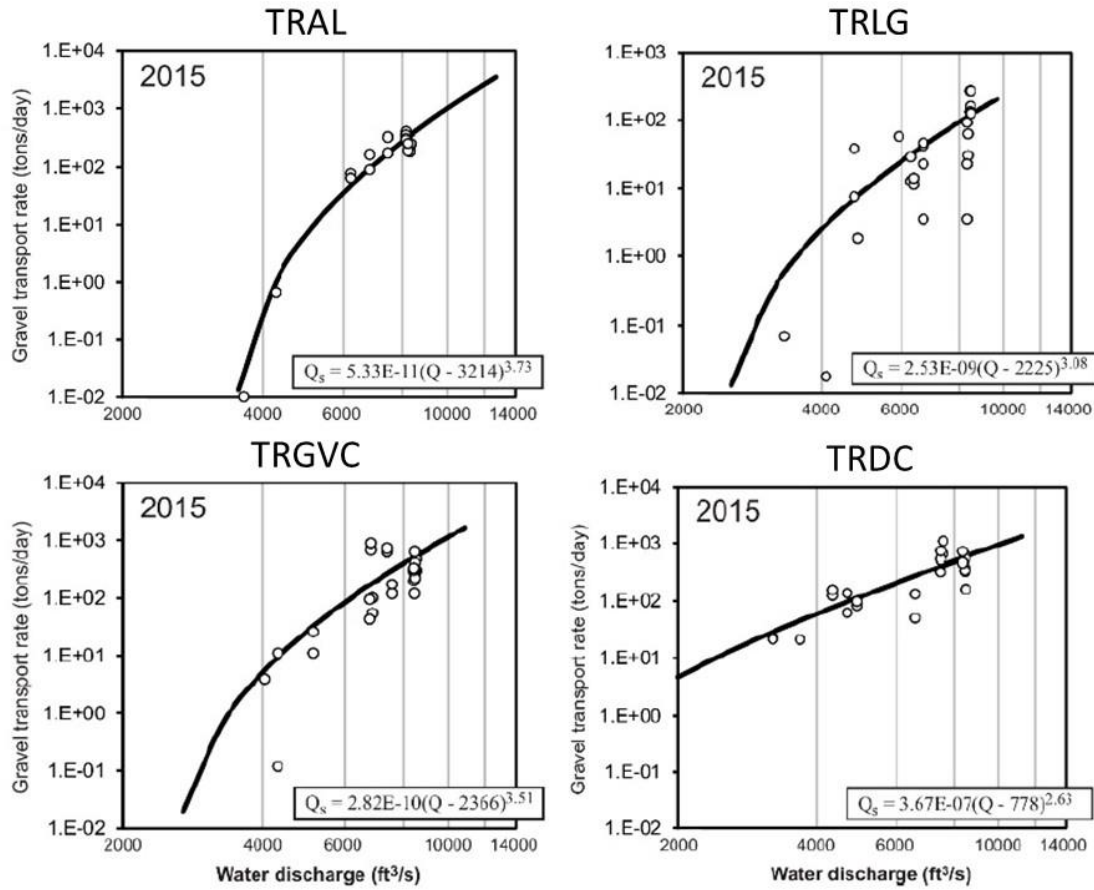


Figure 3-5. Rate of Coarse Bedload (gravel-sized sediment >8mm diameter) Transport in Tons/Day with Discharge (Q) in Cubic Feet per Second.

Note: Observations at each sediment station from the 2015 water year represented as points, with the rating curve equation displayed on each graph. TRAL = Trinity River at Lewiston; TRGVC = Trinity River at Grass Valley Creek; TRLG = Trinity River at Limekiln Gulch; TRDC = Trinity River at Douglas City (Gaeuman and Stewart 2017).

Table 3-2. Reaches, Sediment Monitoring Stations, and Flow Inputs Used to Calculate the Bedload Transport Metric.

Reach	Sediment Monitoring Station	Average Daily Flow
Lewiston Dam to Rush Creek	TRAL	Lewiston
Rush to Grass Valley Creek	TRGVC	Lewiston + Rush
Grass Valley to Indian Creek	TRLG	Lewiston + Rush + GVC
Reading to Browns Creek	TRDC	Lewiston + Rush + GVC + Indian + Weaver + Reading
Soldier to Canyon Creek	TRDC	Lewiston + Rush + GVC + Indian + Weaver + Reading + Browns
Cooper’s Creek to North Fork Trinity River	TRDC	Lewiston + Rush + GVC + Indian + Weaver + Reading + Browns + Canyon

Key: GVC = Grass Valley Creek

3.4.2 Partial Bed Mobilization

The fractional area of streambed that experiences partial mobilization quantifies the maximum annual amount of streambed that would experience Shields stress values high enough to reset the macroinvertebrate community and increase food availability for juveniles. To quantify partial bed mobilization, this analysis used the same method as the Winter Flow Report, which relied on outputs from SRH-2D coupled with grain size maps generated by Alvarez et. al (2015) to create rating curves of discharge and percent of bed mobilized.

SRH-2D is a two-dimensional flow hydraulic and mobile-bed sediment transport model for river systems. SRH-2D is used to evaluate river hydraulics including water surface elevations, flow velocity, shear stress, and sediment mobilization. In 2015, a two-dimensional SRH-2D model was developed of the Trinity River from Lewiston Dam to the junction with the North Fork Trinity River at the request of the TRRP. The model predicts the spatial patterns of water depth, velocity, and shear stress, which have been used as input values to other models that estimate the location, quantity, and quality of salmonid habitat. The SRH-2D model has also been used to select sites on the river for habitat restoration work, to evaluate proposed restoration designs, and as the hydraulic input to a fish production model. The initial version of the model was based on topography and bathymetry surveyed in 2011 and 2012 (Bradley 2016). The Trinity River was re-surveyed in 2016, and the hydraulic model was updated to reflect changes in river morphology, both natural and constructed, between the two bathymetric surveys. The model has been recalibrated based on new observations of water surface elevation and run for approximately 20 different discharges (Bradley 2018).

The SRH-2D hydraulics outputs for shear stress from the Bradley (2018) model were combined with a grain size map generated by Alvarez et. al (2015) to create maps of the spatially explicit Shields values at varying discharges. These Shields stress maps were generated for seven reaches, delineated by the extent at the Maximum Fisheries Flow, at eight different discharges (summarized in Table 3-3). From these data, curves analyzing the relationship between discharge and percent area of the bed mobilized assuming a necessary Shields stress value of $\tau^* > 0.03$ and $\tau^* > 0.045$ to mobilize the bed were generated by Gaeuman et al. (2023). Shields stress values of 0.03 - 0.045 are assumed to be sufficient to affect the macroinvertebrate community (Wilcock and McArdeell 1993), and the more conservative value of 0.045 was used for this assessment. The curves shown in Figure 3-6 were used with the daily hydrographs—linear interpolation between the points was used to estimate the fractional area based on the discharge. Below 4,000 cfs the fraction of bed mobilized is assumed to be 0—4,000 cfs is near the threshold discharge needed to initiate gravel transport in the Trinity River (Gaeuman et al. 2017), and there were no discharges lower than 4,000 cfs modeled in SRH-2D. Since the partial bed mobilization metric applies only to the maximum annual flow to determine the fraction of streambed mobilized for the year, this assumption was deemed sufficient to capture the metric appropriately, given that the maximum annual flow at all reaches was typically greater than 4,000 cfs, except in Critically Dry water years 1991 and 1994.

The results are described on an annual basis by taking the maximum bed disturbed fraction for the year at each reach which becomes the fraction of bed mobilized for that year. This result was then averaged across the reaches, averaged across all years for each reach, and described in terms of percent change between the Baseline and each Scenario using Equation (1) below.

$$\% \text{ change} = \frac{\text{Scenario} - \text{Baseline}}{\text{Baseline}} * 100 \quad (\text{Eq. 1})$$

Table 3-3. Reaches Delineated at the Maximum Fisheries Flow indicated and Flow Inputs Used to Calculate the Partial Streambed Mobilization Metric.

Segment	Reach	Maximum Fisheries Flow (cfs)	Average Daily Flow
1	Lewiston Dam to Rush Creek	11,000	Lewiston
2	Rush to Grass Valley Creek	12,096	Lewiston + Rush
3	Grass Valley to Indian Creek	13,692	Lewiston + Rush + GVC
4	Indian to Weaver Creek	15,771	Lewiston + Rush + GVC + Indian
5	Weaver to Browns Creek	17,544	Lewiston + Rush + GVC + Indian + Weaver + Reading
6	Browns to Canyon Creek	21,336	Lewiston + Rush + GVC + Indian + Weaver + Reading + Browns
7	Canyon Creek to North Fork Trinity	23,207	Lewiston + Rush + GVC + Indian + Weaver + Reading + Browns + Canyon

Key: GVC = Grass Valley Creek

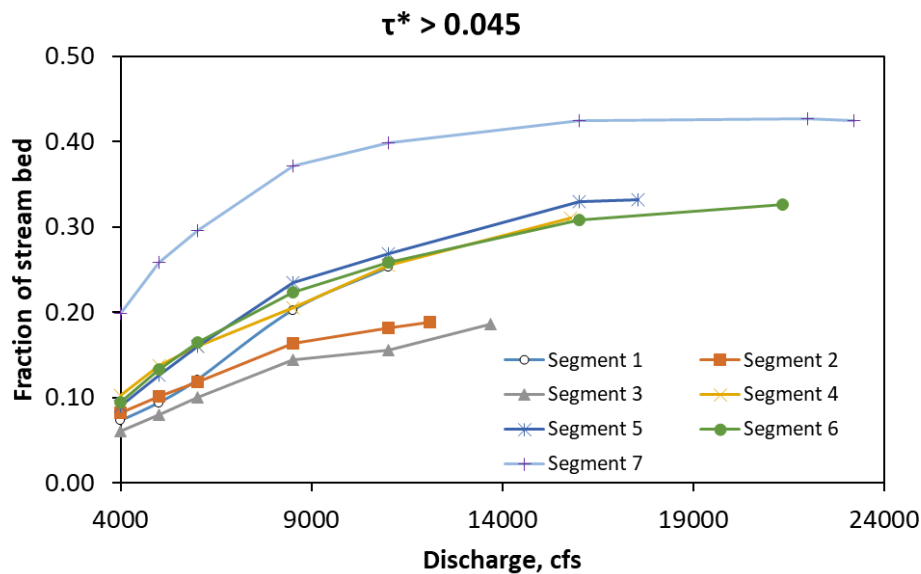


Figure 3-6. Fraction of Stream Bed Mobilized for Each Segment with Discharge, Assuming Shields Stresses (τ^*) of Greater Than 0.045 Mobilize Bed (Gaeuman et al. 2023).

3.5 Habitat Models

Two Chinook Salmon habitat models were used to support the technical analysis in the Water Management Plan: a spawning habitat model (Goodman et al. 2018) and a juvenile microhabitat model (Som et al. 2018). Both models use depth, velocity, and other hydrodynamic metric output from the SRH-2D hydrodynamic model of the Restoration Reach to predict spawning habitat and juvenile capacity (Bradley 2016). The spawning habitat model estimates the probability that a cell in the 2D model is spawning habitat, while the juvenile Chinook Salmon microhabitat model estimates the expected mean abundance in a 2D cell.

Both habitat models are used in S3 to drive density-dependent population dynamics. Results from applying the habitat models to the 2D hydrodynamic model are summarized for each of the 356 meso-habitat units forming the S3 spatial domain. Spawning habitat is summarized into a daily time series of available spawning habitat (in square meters) in each habitat unit. The amount of available spawning habitat affects redd superimposition probability, which in turn drives egg survival. For juveniles, carrying capacity of fry and parr is estimated by predicting the 95th

percentile as an upper bound for abundance. This process produces a daily time series of fry and parr capacity for each habitat unit. In turn, carrying capacity drives density dependent fish movement, with the probability of moving increasing as the ratio of abundance to capacity increases. Further details on the how these habitat models are implemented can be found in Perry et al. (2018a).

3.6 Stream Salmonid Simulator

Stream Salmonid Simulator (S3) is a deterministic life-stage-structured population model that simulates growth, movement, and survival of Chinook Salmon from spawning through outmigration to the ocean. S3 was constructed and parameterized for spring-run and fall-run Chinook Salmon of the Restoration Reach of the Trinity River (Perry et al. 2018a) and was used to support this technical analysis. The S3 model is predicated on the idea that flow affects temperature and habitat availability for fish (as determined by the micro-habitat model), which in turn, influences density-dependent processes such as fish movement. Model inputs include water temperature, discharge, the number of juveniles from hatchery and tributary sources, as well as the spawning distribution and abundance within the mainstem Trinity River. Using these inputs, S3 simulates the demographics and vital rates of an annual juvenile Chinook Salmon population to provide outputs for abundance, size, and biomass of the fish at a given location of the river. The following sections briefly describe the S3 model, and the inputs used to assess the effect of the Contract Water release scenarios on annual juvenile Chinook Salmon production within the Restoration Reach of the Trinity River.

3.6.1 Habitat Template and Physical Inputs for S3

The spatial domain of the S3 model is defined by a one-dimensional representation of discrete meso-habitat units (MHUs). MHUs are spatially referenced by their upstream and downstream boundaries measured as the distance in river kilometers from the Klamath River confluence. The length of an MHU is simply the difference between its upstream and downstream boundaries. The Restoration Reach was partitioned into 356 contiguous MHUs classified by meso-habitat types of runs, riffles, and pools (Perry et al. 2018a). To define the quality and quantity of fish habitat within each MHU, output from the SRH-2D hydraulic model (Bradley 2016) and habitat models (Goodman et al. 2018, Som et al. 2018) were used. Each MHU was represented as a polygon (Perry et al. 2018a), which allowed for assignment of cells from the finer-scale hydraulic model to each MHU. Output from the habitat models were then applied to the cells of the 2D hydraulic model and summarized over each MHU to construct the one-dimensional habitat inputs required by the S3 model (Perry et al. 2018a, b).

3.6.2 Biological Inputs for S3

The S3 model relies on the two primary forms of biological inputs to simulate population dynamics: (1) female spawners and (2) juvenile fish entering from tributaries and hatchery releases. This section defined model assumptions for the spatial and temporal distribution of spawners and the release of hatchery fish and juvenile fish from tributaries into the Trinity River S3 model.

3.6.2.1 Spawner Abundance and Distribution

To develop inputs for the number of female spawners, spawner survey data (Chamberlain et al., 2012) was summarized as a weekly time-series of redd counts by survey reach. Of the 14-spawning survey reaches between Lewiston Dam and the Klamath River confluence, 7 reaches fall within the Restoration Reach used for this analysis (Perry et al. 2018b). Model simulations tracked two subpopulations of early (spring) and late (fall) spawning female Chinook Salmon in

the same manner as Perry et al. (2018b). To construct model inputs, the reach-level redd survey data was mapped to each MHU and the weekly redd counts were converted to daily redd counts by dividing weekly counts by seven. Within each survey reach, daily redds were then distributed to MHUs proportional to the distribution of daily suitable habitat area for redds in each survey reach.

The baseline and seven Contract Water release scenarios were simulated using the observed spawner distribution and abundance for brood year 2007. Spawner abundance in 2007 was 4,794 spring and fall run Chinook Salmon, representing the 93rd percentile over the 14 years of data (2005 – 2018) currently available for S3 simulation (Figure 3-7). Brood year 2007 was the second highest spawner abundance over these data. This relatively high spawner abundance was selected to investigate density dependence in model simulations. At low spawner abundance and in turn, low juvenile Chinook Salmon abundance, the effect of water releases on fish habitat would be moot.

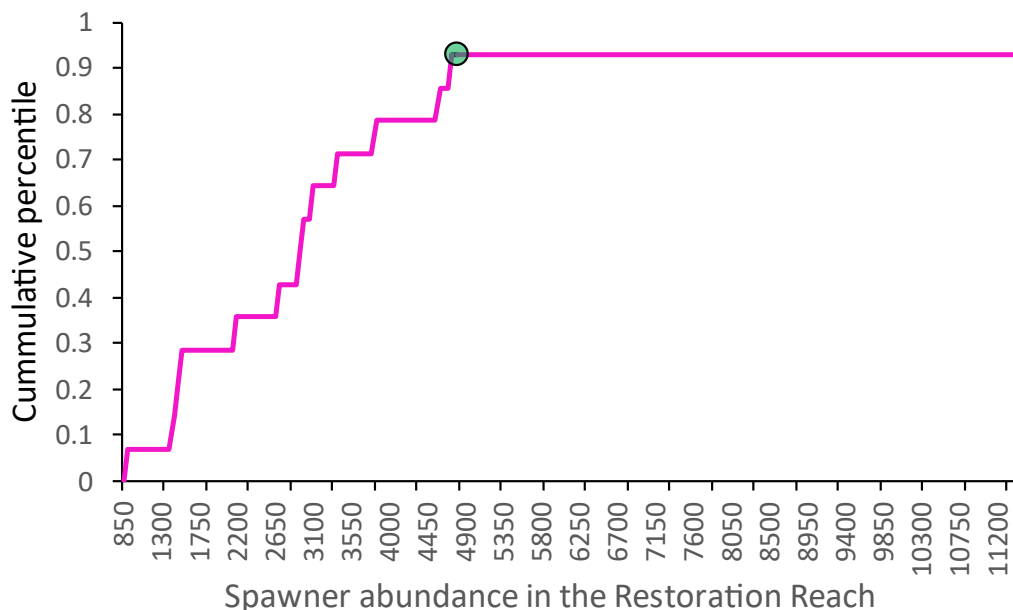


Figure 3-7. Cumulative Percentile of Female Spawner Abundance for Spring and Fall Run Chinook Salmon in the Restoration Reach of the Trinity River, CA.

Note: The circled location represents the 93rd percentile in spawner abundance (4,794 fish) used to simulate Water Contract release scenarios.

The spatial and temporal distributions of spawning females dictate the initial biological conditions for annual S3 simulations. Using the same spatial and temporal distribution of spawning fish in our simulations controls for year-to-year variability in population dynamics that results from variation in annual spawning abundance and distribution. The 2007 brood year used in S3 simulated Contract Water release scenarios was typical of the spatial and temporal distribution of Chinook Salmon spawning for the Trinity River (Figure 3-8). Fish spawned at the highest densities just below Lewiston dam (river kilometer 180.6) with spring and fall-run Chinook Salmon having a very similar spatial spawning distribution. Because spring- and fall-run Chinook Salmon are defined by a cutoff date of November 1st (Borok et al., 2014), the temporal distribution of spawning determines the abundance of spring- versus fall-run Chinook Salmon.

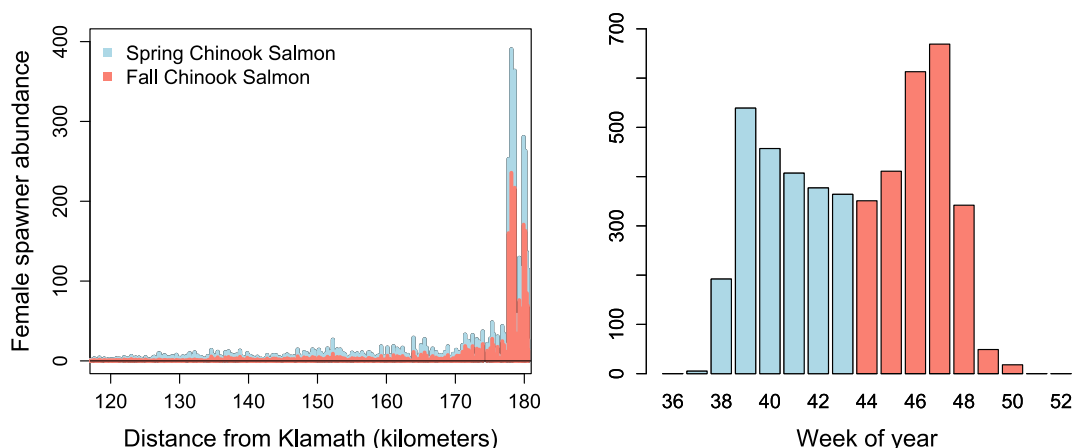


Figure 3-8. The Spatial (left) and Temporal (right) Distributions for Female Spring and Fall Chinook Salmon Spawner Abundance within the Restoration Reach of the Trinity River, CA, during the 2007 Brood Year Used to Simulate and Assess Contract Water Release Scenarios.

3.6.2.2 Juveniles from Tributary and Hatchery Sources

Data on the numbers and sizes of juveniles that entered the Trinity River from tributary and hatchery source populations during migration year 2008 was selected to assess Contract Water release scenarios because this year follows the historical events that followed the 2007 brood year that was chosen for spawning.

One of the four major tributaries to the Trinity River, Canyon Creek, is thought to contribute to the abundance of juvenile Chinook Salmon above the Pear Tree fish trap (Figure 2-3). The estimated juvenile Chinook Salmon abundance and size at emigration from Canyon Creek reported by Plumb et al. (2023) was used in S3 simulations of Contract Water releases. However, these fish are not included in the summary of S3 model output because of the proximity of Canyon Creek to Pear Tree and the little effect that flow scenarios would have over the short distance (9.3 km) to Pear Tree.

Hatchery releases of age 0 (fingerling) juvenile Chinook Spring and Fall Chinook Salmon were included as separate sub-populations in S3. Data on hatchery releases of Chinook Salmon were obtained from the Regional Mark Information System database (<http://www.rmpc.org/>; Perry et al. 2018b). Daily hatchery release numbers and weighted-mean fish weights were computed separately for spring- and fall-run Chinook Salmon input data. Simulated hatchery inputs entered the river just below the dam, and the two sub-populations were tracked separately in S3.

3.6.3 S3 Model Structure and Parameter Settings

3.6.3.1 Spawning, Egg Development and Egg Survival

The number of eggs that survive to emerge as fry is affected by several S3 parameters and submodels. The fecundity of female spawners was set to 3,135 eggs per redd to approximate the mean number of eggs observed for Chinook Salmon returning to the Trinity and Klamath River Hatcheries. The mean time from spawning to fry emergence was modeled as a function of daily water temperature and the accumulated degree days (Perry et al., 2018a, b). Variation in emergence timing was assumed to follow a normal distribution about the mean emergence date

and was controlled by the standard deviation in degree days required to hatch, which was set to 26.6-degree days.

During the incubation period, S3 includes three mechanisms that affect egg-to-fry survival: (1) baseline “natural” mortality, (2) temperature-related mortality, and (3) redd superimposition (Perry et al., 2018a). The natural mortality rate was set at 0.25 percent per day, which equates to a baseline survival rate of about 92.8 percent per month. Thermal tolerance parameters were set so that water temperatures less than or equal to 62.6°F (17°C) had no effect on egg survival, but temperatures greater than 62.6°F (17°C) imposed a daily mortality rate of 25 percent (Geist et al., 2006).

Redd superimposition is the process whereby a later arriving spawner builds a redd on top of an existing redd and dislodges or entombs the eggs laid by the earlier spawner. Superimposition is modeled in S3 as a function of habitat capacity and spawner abundance. Habitat capacity is the quotient of suitable habitat area for redds divided by the size of a redd, which was set to 4.5 m². The probability of redd superimposition is defined by redd density (redd abundance/redd capacity), which is calculated and applied daily for each habitat unit. The amount of redd mortality attributed to superimposition on day t is simply the number of redds to be recruited that day multiplied by the existing pre-recruitment redd density. However, given the propensity of Chinook Salmon to guard their redds until death, the guarding period was set to 10 days, assuming semelparous Chinook Salmon live to guard their nests for 10 days after spawning. Redds are not vulnerable to superimposition during the guarding period. Although redd scour owing to freshets is known to influence survival of eggs, mortality due to scour has not yet been implemented in the S3 model. The S3 model does not account for the desiccation and mortality of eggs due to dewatering of redds as river flows decrease.

3.6.3.2 Juvenile Survival, Movement, and Growth

When simulating fish populations with S3, some population dynamics are dictated via user defined options and parameter inputs. Juvenile fish populations in the S3 model are affected by three dynamic processes: (1) survival, (2) movement, and (3) growth. The parameter set calibrated for the S3 model reported by Perry et al. (2018b) was used, where survival processes were expressed as density-independent, yet fry and parr movement was density-dependent. Parameters for survival and movement were provided separately for hatchery and natural fish. Hatchery survival and movement parameters were equal across life stages, yet for natural fish survival and movement, parameters were provided for fry and parr life stages. In the same manner as Perry et al. (2018b), the assumed constant proportion of maximum consumption was set at $C = 0.66$ when simulating fish growth. For more detail about the S3 model see Perry et al. (2018a, b).

Table 3-4. Survival, Movement, and Consumption Parameters for the S3 Model Used to Simulate the Baseline and Contract Water Release Scenarios.

Parameter	Definition	Hatchery (fry, parr, smolt)	Natural (fry)	Natural (parr and smolt)
Survival	Density-independent daily rate	0.848	0.987	0.889
Movement	Density-dependent intercept of Beverton-Holt model for daily rate of remaining in habitat	0.279	0.476	0.010
Consumption	Density-independent daily rate	0.66	0.66	0.66

4 RELEASE SCENARIO TIMESERIES DEVELOPMENT

Based on a discussion of limiting factors and release objectives, a set of Contract Water release recommendations was developed in Workshop 2. There was consensus that Contract Water releases should end around April 15 (the typical date when the TRRP Flow Workgroup proposes elevating ROD flows) and should not be released to supplement the ROD flow snowmelt peak runoff releases in April through July. These recommendations were used in subsequent workshops to develop four initial release scenarios (Workshop 3) and three refined release scenarios (Workshop 4). The following subsections describe the main elements and objectives of each release scenario and the data used to develop input time series for the modeling tools.

4.1 Initial Release Scenario Development

Four initial scenarios developed in Workshop 3 are summarized in Table 4-1 and described in more detail in the following subsections.

Table 4-1. Four Initial Scenario Recommendations.

Scenario #	Scenario Name	Release	Timing	Trigger	Objectives
1	Building baseflow	Incrementally add baseflow each month to existing releases	Dec 15 – Apr 21/26/22*	Dec 15	<ul style="list-style-type: none"> Increase rearing habitat area and quality for Chinook Salmon^M Increase available spawning and rearing habitat for Coho Salmon/steelhead^{NM}
2	Fall pulse	Two 3,000 cfs pulses	Period 1: Oct 15 – Nov 15 Period 2: Nov 15 – Dec 15	1.5-year recurrence interval of Trinity River above North Fork for each period	<ul style="list-style-type: none"> Recruitment/entrainment of organic matter (leaf litter, insects, benthic invertebrates)^{NM} Redistribute juveniles and lamprey^{NM} Reduce redd superimposition^M Provide distribution and velocities for spawners^M Inundate tributary delta deposits^{NM} If timed with release of yearlings, improve adult attraction into the hatchery^{NM}
3	(A) One winter pulse OR (if trigger not met) (B) Two spring pulses	(A) One 6,000 cfs pulse OR (B) Two 3,000 cfs pulses	(A) Dec 15 – Feb 15 OR (B) Mar 15, Apr 15	(A) 4,500 cfs at Trinity River above North Fork OR (B) 15 th of month	<p>(A)</p> <ul style="list-style-type: none"> Sediment transport^M Reset the macroinvertebrate community^{NM} Scour channel^{NM} <p>(B)</p> <ul style="list-style-type: none"> Increase rearing habitat for Chinook Salmon^M Increase food availability for rearing Chinook Salmon^{NM} Disperse hatchery released Coho Salmon/steelhead^{NM}
4	Baseflow + pulse	All of the above	All of the above	All of the above	All of the above

*End date depends on the TRRP water year type, with April 21/26/22 corresponding to the Extremely Wet, Wet, Normal / Dry / Critically Dry water year types, respectively.

M = modeled factor; NM = non-modeled factor

Release prior to April 15 were desirable; however, this is prior to the TRRP water year type designation released in the DWR Bulletin 118. Therefore, releases were designed independent of

water year type, so that timing and magnitude of releases did not vary over the simulation period (as in Scenario 1) or were dependent on flow triggers internal to the system, such as the flow at the Trinity River at North Fork for Scenarios 2 and 3.

4.1.1 Scenario 1

Scenario 1, Building Baseflow, was designed to release Contract Water in an incrementally increasing stair-step pattern, between December 15 and the start of ROD flows in mid-April. An incrementally increasing pattern was favored over a static baseflow as it more closely mimics the natural hydrograph component of ascending winter baseflows and is similar to previous Chinook Salmon rearing habitat flows designed for the Winter Flow Project (TRRP and Reclamation 2022) and Draft Humboldt County Contract Water Study (Naman 2018; USFWS and NOAA 2018).

The monthly release pattern is the same in all simulated years, with some small differences. Because the ROD flow is initiated at different start dates in April, depending on the water year type (April 21 in Extremely Wet, Wet, and Normal year types, April 26 in Dry years, and April 22 in Critically Dry years), the ending date of Contract Water release varies with year type, varying the number of flow days and release volume of Contract Water. The Scenario 1 release pattern would require 50,114 acre-feet of Contract Water distributed across 127 flow days in Extremely Wet, Wet, and Normal years, 53,084 acre-feet over 132 flow days in Dry years, and 50,708 acre-feet over 128 flow days in Critically Dry years. The average monthly release pattern is summarized for a Critically Dry water year in Figure 4-1 and for all years in Table 4-2.

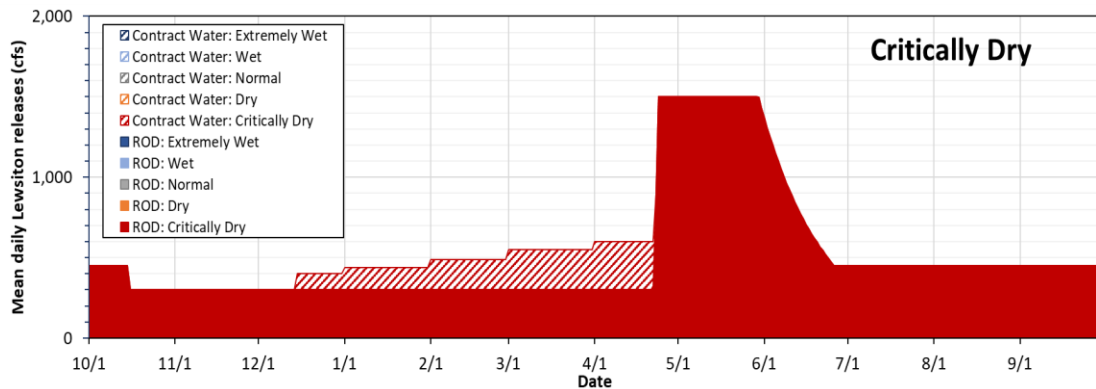


Figure 4-1. Example Combined ROD and Contract Water Releases at Lewiston in a Critically Dry Year for Scenario 1.

Table 4-2. Average Monthly ROD and Contract Water Releases at Lewiston for Scenario 1, Years 1980-2003.

Month	Average Monthly ROD Release (cfs)	Average Monthly Contract Water Release (cfs)	Average Monthly Combined Release (cfs)
October¹	373	0	373
November	300	0	300
December²	300	55	355
January	300	140	440
February	300	190	490
March	300	250	550
April³	501	222	723
May	3,578	0	3,578
June	2,168	0	2,168
July	841	0	841
August	450	0	450
September	450	0	450

Notes:

1. The October monthly average ROD release reflects a release of 450 cfs from October 1 through October 15 and a release of 300 cfs from October 16 through October 31.
2. The December monthly average Contract Water release reflects a release of 0 cfs from December 1 through December 14 and a release of 100 cfs from December 15 through December 31.
3. The April monthly average reflects a release of 300 cfs of Contract Water and 300 cfs of ROD release April 1 until the elevated Spring ROD flow is initiated (April 21 in Extremely Wet, Wet, and Normal year types, April 26 in Dry years, and April 22 in Critically Dry years).

4.1.2 Scenario 2

Scenario 2, fall pulse flow, was designed to create two 3,000 cfs peak, 13-day duration “biologic pulses” that could recruit leaf litter and food to the stream and redistribute juveniles and fall hatchery released fish to reduce redd superimposition. These pulses were believed to be too low magnitude to create geomorphic changes or significant habitat increases. One pulse would be released between October 15 and November 15 (Period 1). The trigger for the release would be the 1.5-year recurrence interval flow at the Trinity River above North Fork for that period (e.g., the 1.5-year recurrence interval of annual peak flows during the October 15 to November 15 period) being met or exceeded. If the trigger was not met, the pulse would be released the last day of the period, November 15. The second pulse would follow the same rule, with the trigger being adjusted to the 1.5-year recurrence interval flow between November 16 and December 15. If the 13-day duration of Pulse 1 extended into Period 2 (e.g., started on November 15), the Period 2 pulse was delayed until the next time the trigger occurred or December 15, whichever came first.

To develop pulse triggers, first the daily flow record at Trinity River above North Fork was estimated using the 1980-2003 RBM10 daily flow pattern produced for the major tributaries in the Trinity watershed for the Klamath LTP EIS (Reclamation 2017). The flow was a sum of the daily modeled flow at each time step for the ROD release at Lewiston, Rush Creek, Grass Valley Creek, Indian Creek, Weaver Creek, Reading Creek, Browns Creek, and Canyon Creek. The daily flow was separated into the two fall periods, and the maximum mean daily flow for each year and period was selected and used to create an annual exceedance ranking. The 1.5-year recurrence interval flow at Trinity River above North Fork was 532 cfs for Period 1 and 1,147 cfs for Period 2.

This biologic pulse release was designed as a 13-day pattern, which assumed the baseflow release at Lewiston is 300 cfs during the fall periods. It was created by modifying the geomorphic pulse

pattern release designed for the Draft Humboldt County Contract Water Study (Naman 2018; USFWS and NOAA 2018). On day 1, the total flow at Lewiston was increased to 1,000 cfs, then to a peak of 3,000 cfs on day 2. The ramp down rate was defined by

$$Q_i = Q_o e^{kt} \tag{Eq. 2}$$

where Q_i is equal to the release rate at Lewiston on day i , Q_o is the initial peak flow, $k = -0.192$, and t is the number of days from Q_o . The ramp up rate (1,350 cfs/day; $k = 1.151$), peak, and ramp down rate are all within acceptable criteria for ramping rates and safety of dams as defined in the Trinity River Mainstem Fishery Restoration Final EIS/EIR (USDOI 2000) and the TRRP Flow Workgroup recommendations (Buxton 2018). The total Contract Water volume required for this pattern is 49,755 acre-feet.

The daily release pattern is shown in Table 4-2 for a Dry water year and the 13-day daily flows are listed in Table 4-3. The focus of the analysis on habitat and fisheries populations is focused on the time period of 1980 – 2003. However, CalSim II and HEC-5Q require inputs from 1922 – 2003. No flows were modeled for the Trinity River at North Fork prior to 1980, so to extend the release series to the 1922-1979 period for modeling in HEC-5Q and CalSim II, an assumption was made that pulse releases always occurred at the ends of each period on November 15 and December 15.

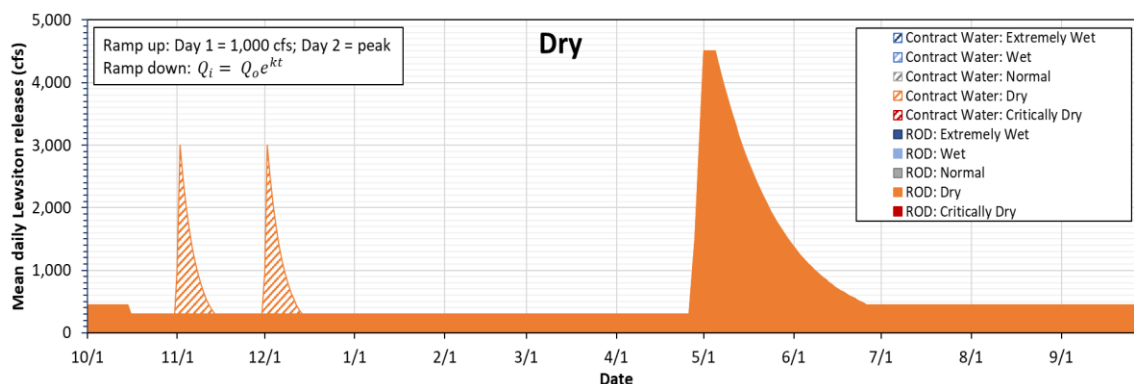


Figure 4-2. Example Combined ROD and Contract Water Releases at Lewiston in a Dry Year for Scenario 2.

Table 4-3. Fall Pulse 13-Day Release Pattern at Lewiston.

Day of Pulse	Mean Daily ROD Release (cfs)	Mean Daily Contract Water Release (cfs)	Mean Daily Combined Release at Lewiston (cfs)
1	300	700	1,000
2	300	2,700	3,000
3	300	2,176	2,476
4	300	1,744	2,044
5	300	1,387	1,687
6	300	1,092	1,392
7	300	849	1,149
8	300	649	949
9	300	483	783
10	300	346	646
11	300	233	533
12	300	140	440
13	300	63	363

4.1.3 Scenario 3

Scenario 3, winter pulse or spring pulses, was designed to add a geomorphically significant pulse of 6,000 cfs, synchronized with a flow trigger of 4,500 cfs at the Trinity River above North Fork, which is the same trigger used to initiate the pulse flow during the Flow Synchronization Period in the Winter Flow Project (TRRP and Reclamation 2022). If the trigger for the geomorphic pulse does not occur, then two biologic pulses with the same pattern as designed in Scenario 2 are released later in the spring—one on March 15 and one on April 15.

The daily flow record at Trinity River above North Fork was developed using the method described in Scenario 2. Constraints and checks were added to the geomorphic pulse release so that the flow would not exceed 18,000 cfs at North Fork, following Reclamation guidelines and the release constraint for the Winter Flow Project (TRRP and Reclamation 2022). The gage at North Fork has a flow forecast window of 5 days, so the pulse release would not occur if the flow at Trinity River exceeded 12,000 cfs in the subsequent 5 days. An additional check was added to reduce the geomorphic pulse flow release if it would cause Trinity River flow at North Fork to exceed 18,000 cfs—this occurred only once during the simulated period, resulting in a loss of 27 cfs on the last release day.

This geomorphic pulse release was designed with a 17-day duration, which assumed the baseflow release at Lewiston was 300 cfs during the fall periods. It is identical to the geomorphic pulse pattern release designed for the Draft Humboldt County Contract Water Study (Naman 2018; USFWS and NOAA 2018). On day 1, the total flow at Lewiston is increased to 1,000 cfs, then peaks at 6,000 cfs on day 2. The ramp down rate is defined by Equation 1, where $k = -0.194$. The ramp up rate (2,850 cfs/day; $k = 1.498$), peak, and ramp down rate are all within acceptable criteria for ramping rates and safety of dams as defined in the Trinity River Mainstem Fishery Restoration Final EIS/EIR (USDOI 2000) and the TRRP Flow Workgroup recommendations (Buxton 2018). The total Contract Water volume required for the geomorphic release pattern is 56,228 acre-feet. The daily release pattern is shown in Figure 4-3 for a Dry water year and the 17-day daily flows are listed in Table 4-4.

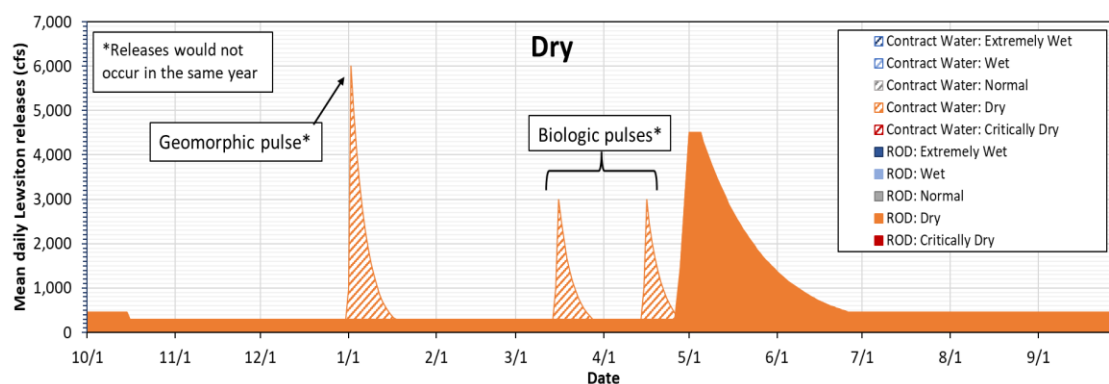


Figure 4-3. Example Combined ROD and Contract Water Releases at Lewiston in a Dry Year for Scenario 3.

Table 4-4. Geomorphic Pulse 17-Day Release Pattern at Lewiston.

Day of Pulse	Mean Daily ROD Release (cfs)	Mean Daily Contract Water Release (cfs)	Mean Daily Combined Release at Lewiston (cfs)
1	300	700	1,000
2	300	5,700	6,000
3	300	4,642	4,942
4	300	3,770	4,070
5	300	3,053	3,353
6	300	2,461	2,761
7	300	1,974	2,274
8	300	1,573	1,873
9	300	1,243	1,543
10	300	971	1,271
11	300	747	1,047
12	300	562	862
13	300	410	710
14	300	285	585
15	300	182	482
16	300	97	397
17	300	27	327

Flows at Trinity River at North Fork were not modeled prior to 1980, so to extend the release series for the geomorphic pulse releases to 1922-1979 for modeling in HEC-5Q and CalSim-II, the probability of the daily flow exceeding 4,500 cfs at Trinity River above North Fork was analyzed by month and water year type for the modeled 1980-2003 period. In an Extremely Wet year, the trigger was met 38.7% of the time between February 1 – 15, which was a greater probability than the trigger being met in December or January, so in the extended series, the geomorphic pulse was released on February 1 in Extremely Wet years. Similarly, in Wet years, December had the greatest probability of having the trigger criteria met, 32.1% of the time, so in Wet years, the pulse was released December 15. In Normal years, the trigger was only met in January, so the pulse was released January 1. In Dry years the probability of the trigger being met was highest in January, but only occurred 1% of the time and did not occur in any Critically Dry years, so for both of those year types, the geomorphic pulse flow was not released, and the two spring biologic pulses were released on March 15 and April 15.

4.1.4 Scenario 4

Scenario 4 was designed to combine Scenarios 1 – 3, while only releasing the geomorphic pulse if the flow at Trinity River above North Fork reached at least 4,500 cfs. It was designed as an upper bookend of potential benefits if an annual Contract Water request was made of between 150 TAF to 200 TAF, consistent with Proviso 2 of the 1955 Act that specifies releases of not less than 50 TAF should be made annually to Humboldt County. An example daily release pattern is shown in Figure 4-4.

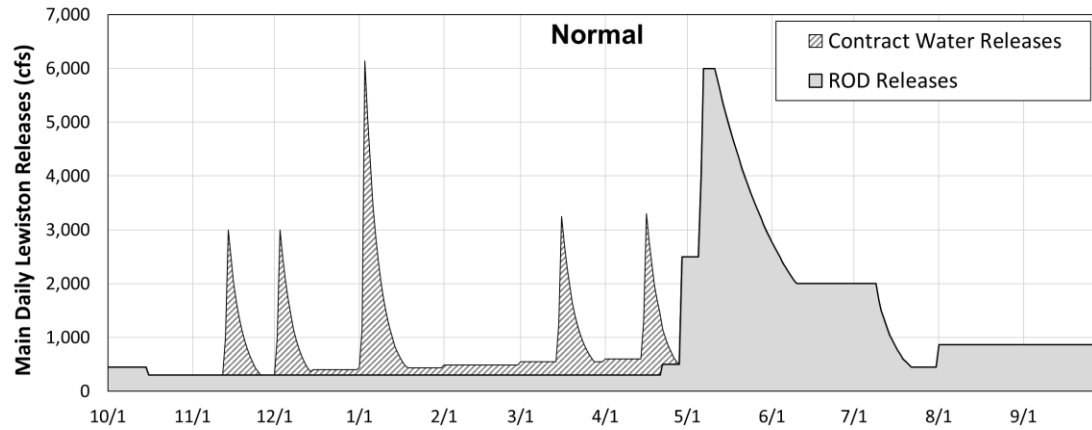


Figure 4-4. Example Combined ROD and Contract Water Releases at Lewiston in a Normal Year for Scenario 4.

4.2 Refined Release Scenario Development

Scenarios 1 – 4 were implemented in the modeling tools, and a summary of results was provided to interested parties during Workshop 4 (see Section 5 for results). Based on a review of results, revised release recommendations included the following:

- Due to the approval and impending implementation of the Winter Flow Project for the 2023 water year, with elevated baseflow being released on February 15, there was strong consensus to focus only on flow releases for the fall period, and to not duplicate Winter Flow Project releases.
- Scenario 1, or any similar building baseflows scenario in the spring, should be revised to concentrate flows in March and April, across a shorter duration once fry have emerged. This would allow the 50 TAF to be released at a higher magnitude, which would increase habitat area and likely result in modeled increases in fish population benefits.
- Scenario 2 should include a constraint where the fall pulse is not released if storage in Trinity Reservoir is less than 750 TAF, as warmer release temperatures below this storage level are known to be inhospitable for Coho Salmon.

Based on these considerations, Scenario 5 was defined fully in the workshop as a modification to Scenario 2 using end of month storage in Trinity Reservoir as a new trigger. As shown in Section 5, Scenario 2 also produced favorable fisheries model outputs, which led the group to prefer minor revisions to this scenario. Based on feedback from participants, the modeling team developed two additional refined scenarios. Scenario 6 was developed to simulate the maximum potential benefit of Contract Water on spawning habitat. Under this scenario, baseflows would be increased in the fall to increase redd habitat area and improve egg survival. Scenario 7 was developed to simulate the potential effects if Contract Water were held as carryover in Trinity Reservoir and not released into Trinity River. Under this scenario, the beneficial use of Contract Water would be to increase the volume of the cold-water pool in Trinity Reservoir, leading to cooler releases during summer and fall months. This scenario would demonstrate whether or not summer water temperatures are a limiting factor to fish production. These three refined scenarios are summarized in Table 4-5 and described in more detail in the following subsections.

Table 4-5. Refined Scenario Recommendations

Scenario #	Scenario Name	Release	Timing	Trigger	Objectives
5	Two fall pulses with storage-based delay	Two 3,000 cfs pulses	Period 1: Oct 15 – Nov 15 Period 2: Nov 16 – Dec 15 Period 3: Dec 16 - Jan 15 Period 4: Jan 16 - Feb 15	1.5-year recurrence interval of Trinity River above North Fork for each period. If Trinity storage < 750 TAF in Period 1 or Period 2, delay pulse release until next period.	Same as Scenario 2 and 3B.
6	Modified fall baseflow	Increase fall baseflows	Oct 15 – Dec 31	Oct 15	<ul style="list-style-type: none"> • Increase spawning and rearing habitat area and quality for Chinook Salmon^M • Improve Chinook Salmon egg survival^M • Increase spawning and rearing habitat for Coho Salmon^{NM}
7	Carryover	No Contract Water release – accumulate 50 TAF each year and only release during spills	No annual Contract Water Release	When Trinity Reservoir safety-of-dams release occurs (earlier than would otherwise), assume Contract Water is spilled first	<ul style="list-style-type: none"> • Reduce water temperature of releases during Dry and Critically Dry years to reduce fish mortality in summer and fall^M

Notes: M = modeled factor; NM = non-modeled factor

4.2.1 Scenario 5

Scenario 5 was the same as the Scenario 2 pattern – two 3,000 cfs pulses over a 13-day duration – with the added constraint that if storage in Trinity Reservoir was less than 750 TAF, the release would not occur until storage exceeded 750 TAF or after December 15. December 15 was selected based on water temperature modeling of Trinity Reservoir (see Section 5.1) as a date when turnover of the reservoir is likely to occur, i.e., cooler surface water mixes with warmer, deeper water, creating a general cooling effect on the reservoir. If the biologic pulses were not made through Periods 1 and 2, then the pulses would occur during the winter period, triggered by the 1.5-year recurrence flow during the period of December 16 – January 15 (Period 3) and January 16 – February 15 (Period 4). If the flow trigger was not met during either period, the pulse was released on the last day of the period.

The flow at Trinity River above North Fork and exceedance intervals were developed using the method described in Scenario 2. The 1.5-year recurrence interval flow at Trinity River above North Fork was 1,907 cfs for Period 3 and 2,401 cfs for Period 4. Only two of the modeled years 1980-2003 changed as a result of this constraint—in Dry water year 1992 the releases were delayed to the end of Periods 3 and 4 and in the following Wet water year 1993 the releases were at the end of Period 3 and with a flow trigger on February 9 in Period 4.

For the extended 1922-1979 period, the daily simulated storage in Trinity Reservoir which was produced through the original modeling of Scenario 2 in CalSim II and HEC-5Q was used to set a constraint on the releases. In 10 of the 58 water years in this period (1925, 1930-1937, and 1979), the releases were delayed until the end of Period 3 and 4 due to low storage in Trinity Reservoir.

4.2.2 Scenario 6

Scenario 6, fall baseflow, was designed to release Contract Water in an incrementally increasing stair-step pattern, between October 16 and December 31 to target spawning, with an extended release of 90 cfs from January 1 to February 15 to avoid redd dewatering as described below. The ascending baseflow pattern and timing was designed to mimic a lower magnitude release analogous to the hydrograph designed by Goodman, et al. (2018) to optimize increased spawning habitat. The Scenario 6 release pattern would require 50,569 acre-feet of Contract Water distributed across 122 flow days. The daily release pattern is shown in Figure 4-5 for a Critically Dry water year and mean monthly releases are listed in Table 4-6.

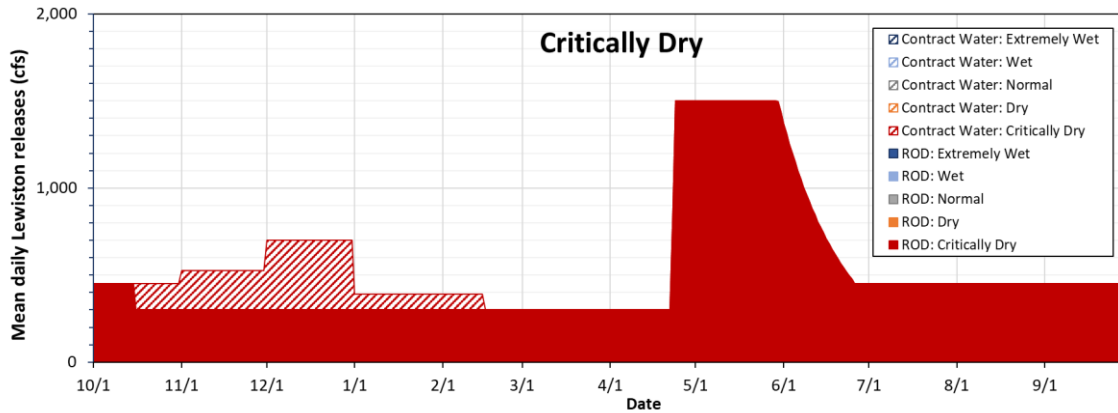


Figure 4-5. Example Combined ROD and Contract Water Releases at Lewiston in a Critically Dry Year for Scenario 6.

Table 4-6. Average Monthly ROD and Contract Water Releases at Lewiston for Scenario 6, Years 1980-2003.

Month	Monthly Average ROD Release (cfs)	Monthly Average Contract Water Release (cfs)	Monthly Average Combined Release (cfs)
October ¹	373	77	450
November	300	225	525
December	300	400	700
January	300	90	390
February ²	300	48	348
March	300	0	300
April	501	0	501
May	3,578	0	3,578
June	2,168	0	2,168
July	841	0	841
August	450	0	450
September	450	0	450

Notes:

1. The October monthly average ROD release reflects a release of 450 cfs from October 1 through October 15 and a release of 300 cfs from October 16 through October 31. The October monthly average Contract Water release reflects a release of 0 cfs from October 1 through October 15 and a release of 150 cfs from October 16 through October 31.

1. The February monthly average Contract Water release reflects a release of 90 cfs from February 1 through February 15 and a release of 0 cfs from February 16 through February 28. The February monthly average combined release reflects a release of 390 cfs from February 1 through February 15 and a release of 300 cfs from February 16 through February 28.

Scenario 6 was developed to minimize the risk of redd dewatering. Chinook Salmon incubation and fry emergence life stages occur within the gravel interstitial spaces of redds. A reduction in

flow during these life stages, which can extend from January through mid-March, could result in reduction of redd submergence, and potentially mortality if the redd is fully dewatered. To minimize the potential for redd dewatering, the reduction in flows on January 1 was limited to 310 cfs, or a drop from 700 cfs to 390 cfs, based on the following logic:

- Redd surveys from 2007, 2012, 2014 indicated the majority of redds in the Restoration Reach are formed in the upper reach directly below Lewiston and above Rush Creek (Figure 3-8; Gaeuman et al. 2023). Lewiston releases are the primary flow contribution that maintains water depth at this location (i.e., additional tributary inflows are not present), and all flow changes at Lewiston reflect flow changes in this reach.
- An analysis of the stage-discharge relationship at U.S. Geological Survey (USGS) gage 11525500 Trinity River at Lewiston indicated a drop in flow from 700 cfs to 390 cfs corresponds to a drop in water surface elevation of 0.5 feet (6 inches) (USGS 2022).
- Spring-run and fall-run Chinook Salmon spawning depth suitability is 0 at depths less than 0.8 feet and 0.5 feet, respectively, and preferred spawning habitat is at depths of 1 to 3 feet (USFWS 2007, CalTrout 2017). Chinook Salmon spawning observations for the Trinity Flow Evaluation Study on the Trinity River confirmed the majority of Chinook Salmon redds were located at depths between 0.8 and 2.5 feet (USFWS and HVT 1999). Steelhead spawning depth suitability is 0 at depths of less than 0.4 feet and the majority of Coho salmon observed spawning in the Trinity Flow Evaluation Study constructed redds at depths between 0.5 and 2.2 feet (USFWS and HVT 1999, USFWS 2007).
- California Department of Fish and Wildlife (CDFW) developed criteria for identifying flow depths that support physical movement of salmonids through critical riffle sites (CDFW 2017). A minimum depth of 0.9 ft is required for adult Chinook Salmon and 0.7 ft for adult steelhead and Coho Salmon. At flows less than the minimum depth, critical life history tactics of salmon are impeded, including passage to and from spawning areas.
- It is unlikely redds would be established at depths of less than 0.5 ft since these depths do not provide unimpeded passage and are not suitable for spawning. For scenario 6, when the water surface elevation drops 0.5 ft following a flow reduction of 700 cfs to 390 cfs in January, it is unlikely that any redds would be completely dewatered.

4.2.3 Scenario 7

Scenario 7 was designed to use carryover storage in Trinity Reservoir as a beneficial use of Contract Water and as a bookend to determine if water temperature during summer and fall months was a limiting factor in fish production. Increasing storage is expected to increase thermal buffering capacity of the reservoir and increase the cold-water pool volume. By increasing carryover storage cumulatively each year by 50 TAF, particularly during drought years, Contract Water would have the effect of reducing water temperature of releases to Trinity River, particularly during the months of July through October when the North Coast Regional Water Quality Control Board Basin Plan (NCRWQCB 2011) temperature targets are specified and generally exceeded under existing condition (Humboldt County 2022).

Development of this release scenario occurred within the CalSim II model and was described in Section 3.1.2. In general, 50 TAF of Contract Water was accumulated in a separate storage account in Trinity Reservoir every year. When a safety-of-dams release was made, Contract Water in the carryover storage account was spilled first.

5 MODEL RESULTS

This section summarizes results from all models. Results in Sections 5.1 through 5.5 are summarized by the five water year types of the Trinity River system as established in the ROD: Extremely Wet, Wet, Normal, Dry, and Critically Dry. Results in Section 5.6 are summarized by the five water year types of the Sacramento Valley Index: Wet, Above Normal, Below Normal, Dry, and Critical.

5.1 Trinity Reservoir and Lewiston Reservoir

Following development of a daily time series of ROD water and Contract Water releases, CalSim II was modified to release a monthly volume of Contract Water consistent with the daily release pattern of each scenario. Monthly release volumes from Trinity Reservoir and Lewiston Reservoir were input to the HEC-5Q model, which repatterned releases into a daily flow based on ROD water obligations, Contract Water release assumptions, and required safety-of-dams releases that CalSim II forces out of Trinity Reservoir to maintain water surface elevations below flood pool elevation requirements. This section summarizes results from all scenarios for the simulation period of 1922 – 2003.

5.1.1 Trinity Reservoir Storage

Trinity Reservoir storage was modeled in CalSim II based on a water balance of inflows and outflows. Outflows from Trinity Reservoir were higher under all scenarios due to the release of at least 50 TAF of Contract Water every year. TRD exports were also reduced under all scenarios, but not enough to offset the full release of Contract Water. As shown in Figure 5-1 and Table 5-1, mean annual Trinity Reservoir storage was 30 – 50 TAF less than the baseline under Scenarios 1 – 6, and 100 TAF greater than the baseline for Scenario 7 due to the consistent accumulation of carryover water. The annual timeseries of Trinity Reservoir storage for all scenarios (Figure 5-2) shows that most scenarios maintain similar storage to the baseline in wetter periods, while storage drops relative to the baseline in drier years, and more so in extended dry periods (e.g., 1988 – 1994). Mean monthly Trinity Reservoir storage by water year type is shown in Figure 5-3. Scenarios 1 – 6 show similar storage to the baseline in Extremely Wet years, while dropping to 100 TAF less relative to the baseline in Critically Dry years, with consistent difference across months in all water year types. Scenario 7 shows similar storage to the baseline, increasing to 150 TAF greater storage in Critically Dry years, which generally occur after periods of prolonged drought when there were no safety-of-dams releases.

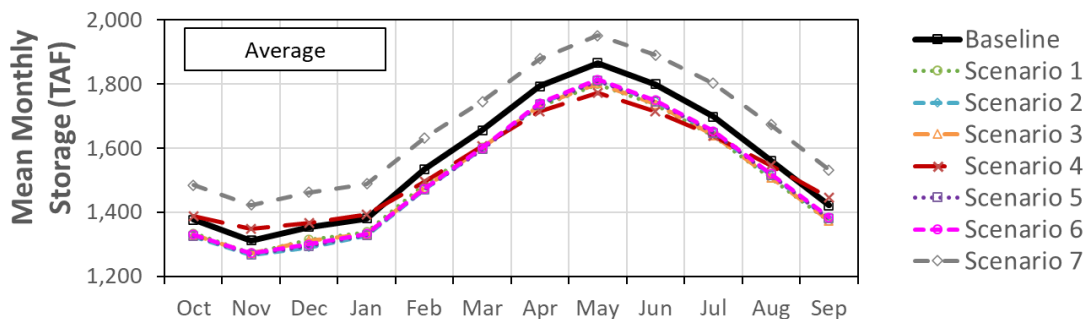


Figure 5-1. Trinity Reservoir Mean Monthly Storage in Thousand Acre-Feet (TAF) for All Scenarios.

Table 5-1. Trinity Reservoir Mean Monthly Storage in Thousand Acre-Foot (TAF) for All Scenarios.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Baseline	1,377	1,311	1,353	1,380	1,534	1,656	1,793	1,866	1,800	1,699	1,561	1,421	1,563
Scenario 1	1,334	1,272	1,314	1,337	1,487	1,603	1,731	1,800	1,736	1,639	1,507	1,372	1,511
Diff (TAF)	-42	-40	-40	-43	-47	-53	-63	-65	-64	-60	-54	-48	-52
Diff (%)	-3	-3	-3	-3	-3	-3	-3	-4	-4	-4	-3	-3	-3
Scenario 2	1,325	1,267	1,290	1,328	1,471	1,598	1,738	1,812	1,747	1,650	1,517	1,381	1,510
Diff (TAF)	-52	-44	-63	-53	-63	-58	-55	-54	-53	-49	-44	-40	-52
Diff (%)	-4	-3	-5	-4	-4	-4	-3	-3	-3	-3	-3	-3	-3
Scenario 3	1,329	1,272	1,312	1,332	1,477	1,600	1,734	1,802	1,738	1,640	1,509	1,374	1,510
Diff (TAF)	-48	-39	-41	-48	-57	-56	-60	-63	-62	-58	-52	-47	-53
Diff (%)	-3	-3	-3	-3	-4	-3	-3	-3	-3	-3	-3	-3	-3
Scenario 4	1,388	1,347	1,367	1,393	1,496	1,606	1,715	1,773	1,715	1,639	1,545	1,446	1,536
Diff (TAF)	11	35	13	12	-38	-50	-79	-93	-85	-60	-15	26	-27
Diff (%)	1	3	1	1	-2	-3	-4	-5	-5	-4	-1	2	-2
Scenario 5	1,326	1,268	1,294	1,329	1,472	1,596	1,737	1,810	1,746	1,648	1,515	1,380	1,510
Diff (TAF)	-50	-44	-59	-51	-62	-60	-56	-55	-54	-50	-45	-41	-52
Diff (%)	-4	-3	-4	-4	-4	-4	-3	-3	-3	-3	-3	-3	-3
Scenario 6	1,330	1,272	1,300	1,333	1,474	1,600	1,740	1,814	1,750	1,653	1,520	1,384	1,514
Diff (TAF)	-47	-39	-53	-47	-60	-56	-53	-51	-50	-46	-41	-37	-48
Diff (%)	-3	-3	-4	-3	-4	-3	-3	-3	-3	-3	-3	-3	-3
Scenario 7	1,485	1,423	1,462	1,488	1,633	1,746	1,880	1,952	1,891	1,803	1,673	1,532	1,664
Diff (TAF)	108	111	109	108	99	90	86	86	91	104	112	111	101
Diff (%)	8	9	8	8	6	5	5	5	5	6	7	8	6

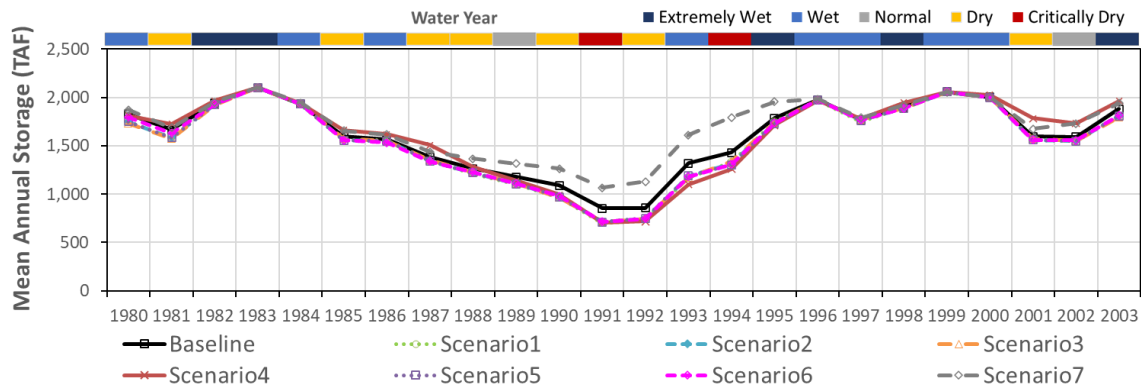


Figure 5-2. Trinity Reservoir Mean Annual Storage in Thousand Acre-Foot (TAF) for All Scenarios.

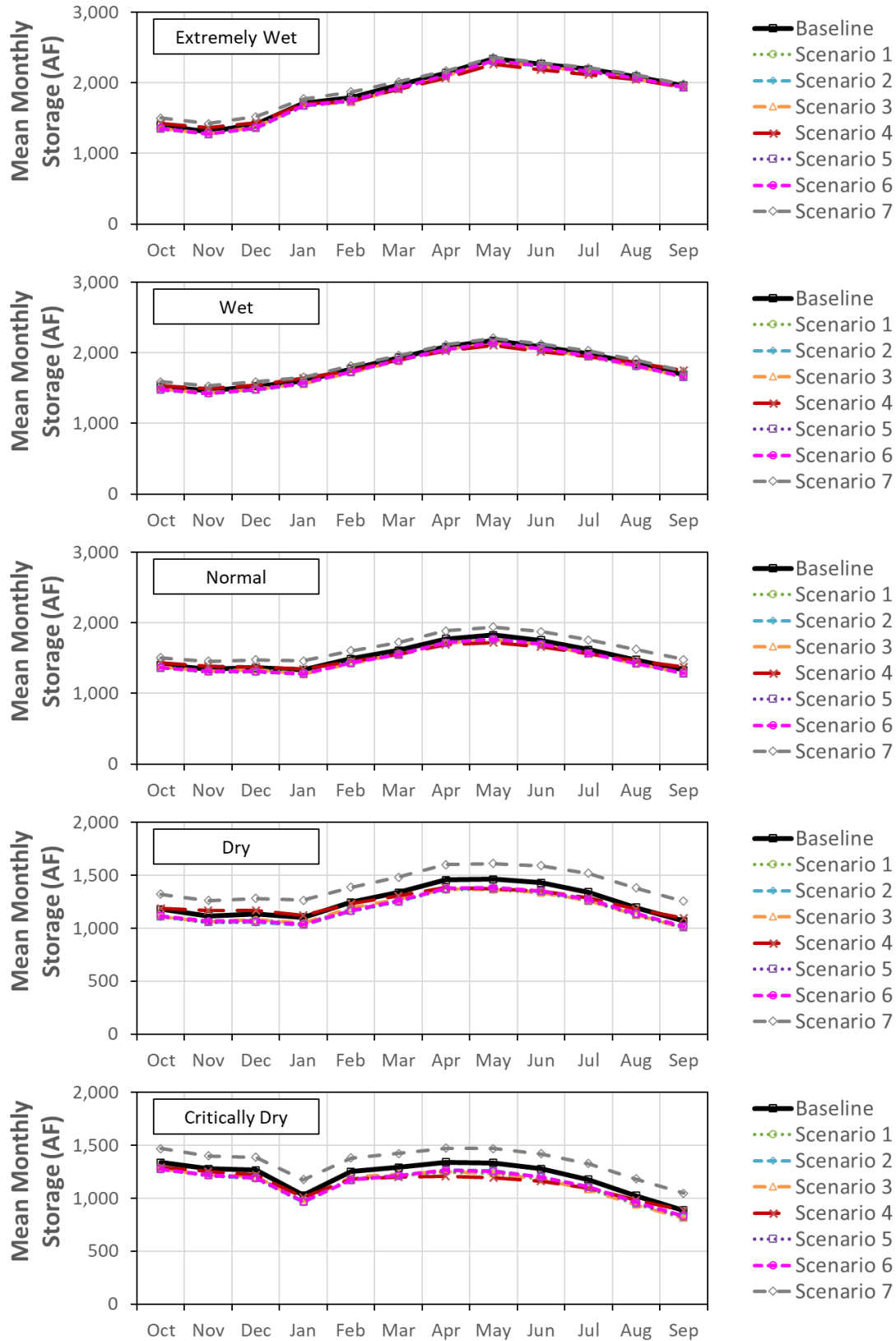


Figure 5-3. Trinity Reservoir Mean Monthly Storage in Thousand Acre-Foot (TAF) for All Scenarios by Water Year Type.

5.1.2 Trinity Reservoir Releases

Trinity Reservoir releases were modeled in HEC-5Q based on monthly releases modeled in CalSim II. Monthly releases were repatterned to a daily timeseries in HEC-5Q to reflect ROD flows, safety-of-dams releases, late-summer and fall releases consistent with the LTP, TRD exports, and Contract Water releases.

Mean monthly Trinity Reservoir releases are shown in Figure 5-4 and Table 5-2. In general, all but Scenario 4 showed releases relatively consistent to the baseline from May through September. Scenario 4 released 150 to 200 TAF annually down the Trinity River, which required additional TRD export cuts. Since TRD exports are highest in July through August (see section 5.6.2), a reduction in exports resulted in a reduction in releases from Trinity Reservoir. All scenarios required higher release magnitudes from October through April depending on the timing of the specific scenario. Mean monthly Trinity Reservoir releases by water year type are shown in Figure 5-5. The trends across water year types generally follow the same trends as the mean annual releases, with Scenario 4 showing larger magnitude reductions relative to the baseline for longer durations in drier years.

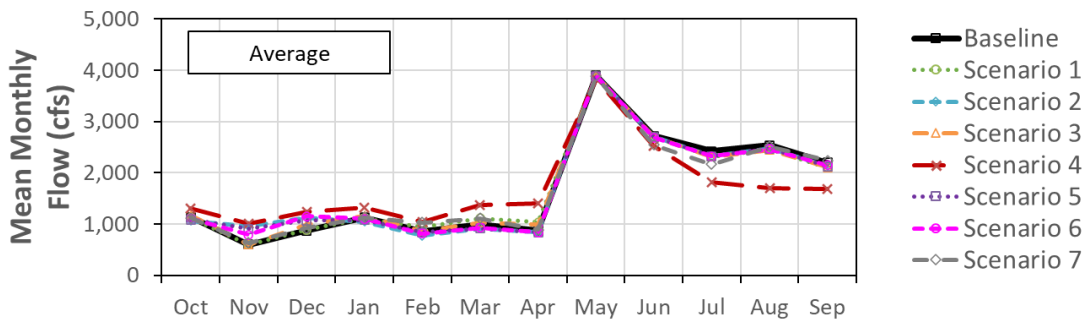


Figure 5-4. Trinity Reservoir Mean Monthly Releases in Cubic Feet per Second (cfs) for All Scenarios.

Table 5-2. Trinity Reservoir Mean Monthly Releases in Cubic Feet Per Second for All Scenarios.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Baseline	1,132	602	866	1,122	852	995	874	3,896	2,721	2,419	2,532	2,194	1,684
Scenario 1	1,122	594	890	1,113	934	1,110	1,038	3,889	2,697	2,311	2,453	2,100	1,688
Diff (cfs)	-10	-8	24	-9	82	116	164	-7	-24	-108	-79	-95	4
Diff (%)	0	-1%	3%	-1%	10%	12%	19%	0%	-1%	-4%	-3%	-4%	0%
Scenario 2	1,057	960	1,127	1,047	769	914	841	3,890	2,703	2,326	2,473	2,129	1,686
Diff (cfs)	-76	359	261	-75	-83	-81	-32	-6	-19	-93	-59	-66	2
Diff (%)	-7%	60%	30%	-7%	-10%	-8%	-4%	0%	-1%	-4%	-2%	-3%	0%
Scenario 3	1,170	600	986	1,159	861	1,023	982	3,888	2,703	2,314	2,449	2,110	1,687
Diff (cfs)	38	-2	120	37	9	29	109	-8	-18	-104	-83	-84	3
Diff (%)	3%	0%	14%	3%	1%	3%	12%	0%	-1%	-4%	-3%	-4%	0%
Scenario 4	1,304	1,004	1,234	1,316	1,032	1,370	1,401	3,835	2,530	1,821	1,697	1,674	1,685
Diff (cfs)	171	402	368	194	180	375	527	-61	-191	-598	-835	-520	1
Diff (%)	15%	67%	42%	17%	21%	38%	60%	-2%	-7%	-25%	-33%	-24%	0%
Scenario 5	1,087	903	1,069	1,077	834	914	841	3,890	2,702	2,325	2,470	2,126	1,687
Diff (cfs)	-45	301	202	-44	-18	-81	-32	-6	-19	-94	-62	-69	3
Diff (%)	-4%	50%	23%	-4%	-2%	-8%	-4%	0%	-1%	-4%	-2%	-3%	0%
Scenario 6	1,111	785	1,152	1,102	810	926	836	3,889	2,687	2,326	2,461	2,145	1,686
Diff (cfs)	-21	184	286	-20	-42	-68	-38	-7	-35	-93	-72	-49	2
Diff (%)	-2%	31%	33%	-2%	-5%	-7%	-4%	0%	-1%	-4%	-3%	-2%	0%
Scenario 7	1,120	630	924	1,130	1,024	1,111	887	3,882	2,547	2,165	2,509	2,241	1,681
Diff (cfs)	-13	29	57	8	172	117	14	-14	-174	-253	-24	46	-3
Diff (%)	-1%	5%	7%	1%	20%	12%	2%	0%	-6%	-10%	-1%	2%	0%

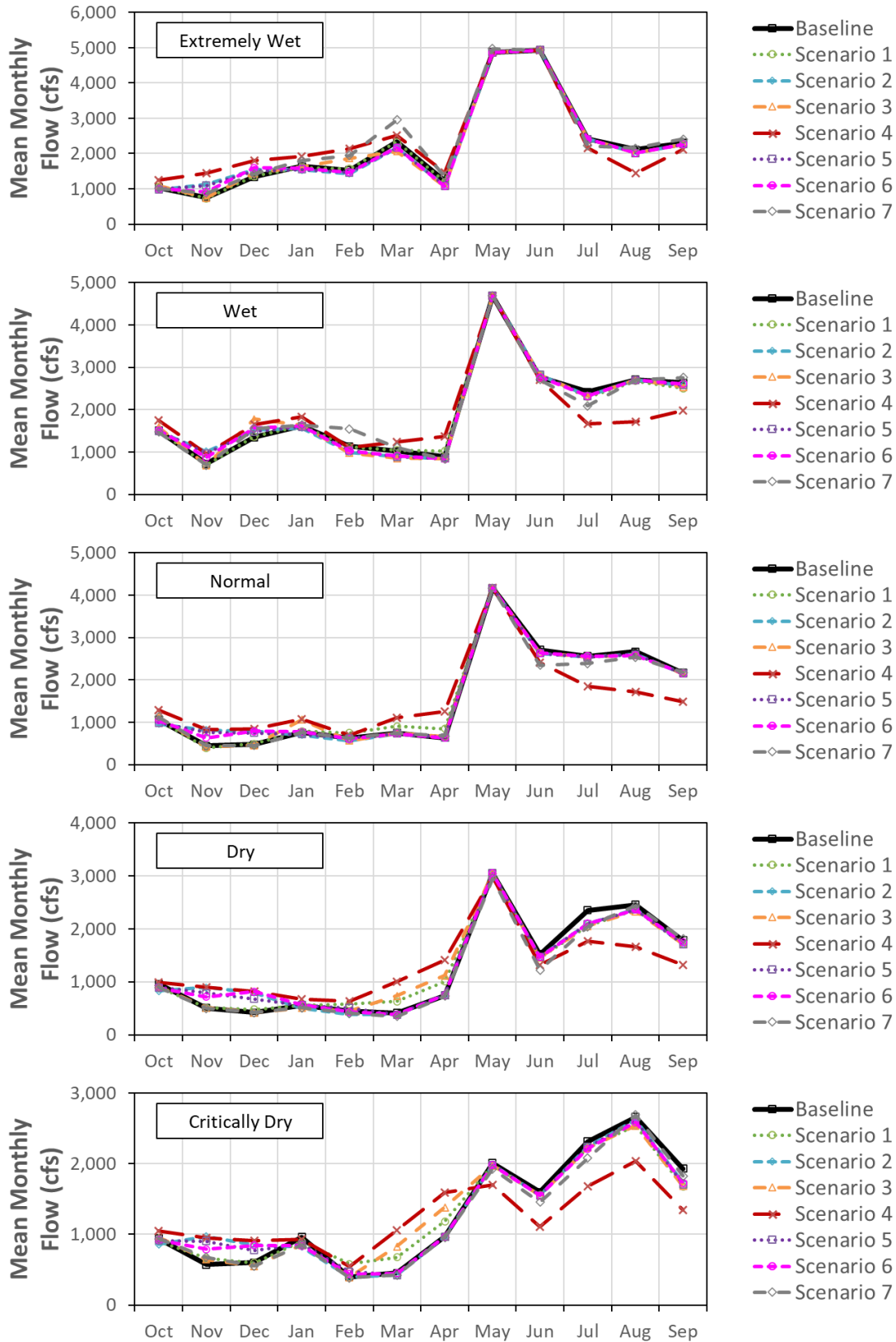


Figure 5-5. Trinity Reservoir Mean Monthly Releases in Cubic Feet per Second (cfs) for All Scenarios, by Water Year Type.

5.1.3 Trinity Reservoir Release Temperature

Trinity Reservoir release temperatures were modeled in HEC-5Q based on modeled water temperature profiles in Trinity Reservoir and model logic that selects release elevation.

Mean monthly Trinity Reservoir release temperatures are shown in Figure 5-6 and Table 5-3. Results across scenarios were generally similar, with notable changes for Scenario 4 and Scenario 7. From June through August, Scenario 4 produced slightly lower Trinity Reservoir storage levels relative to the baseline, but reduced releases relative to the baseline the most of any scenarios due to the higher volume Contract Water releases. The result of lower storage and a release reduction was a slight increase in release water temperature. From July through January, Trinity Reservoir storage in the baseline is relatively low for the year (see Section 5.1.1), but Scenario 7 increases storage due to carryover. The result of increased storage during this period is a slight reduction in release temperatures (0.3 – 0.5 degrees F) relative to the baseline. Mean monthly Trinity Reservoir release temperatures by water year type are shown in Figure 5-7. The trends across water year types generally follow the same trends as the mean annual releases, with all Scenarios 1 – 6 showing greater differences from the baseline predominantly in Normal, Dry, and Critically Dry years.

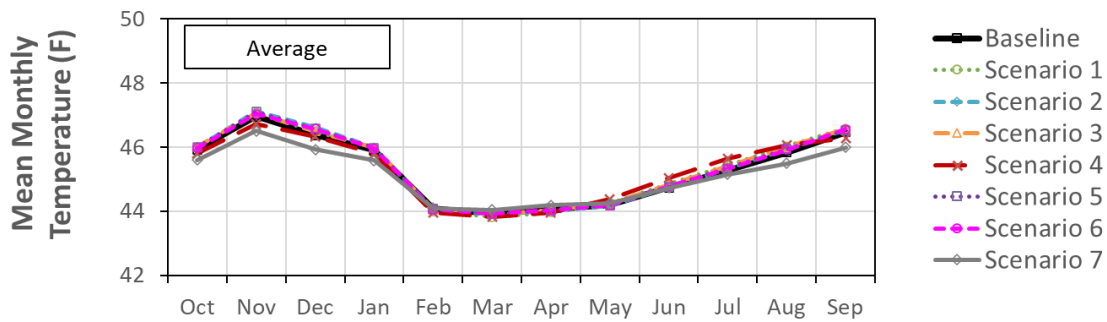


Figure 5-6. Mean Monthly Release Temperature in Degrees Fahrenheit (F) from Trinity Reservoir for All Scenarios.

Table 5-3. Mean Monthly Trinity Reservoir Release Temperature in Degrees Fahrenheit for All Scenarios.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Baseline	46	47	46	46	44	44	44	44	45	45	46	46	45
Scenario 1	46	47	46	46	44	44	44	44	45	45	46	47	45
Diff (°F)	0.1	0.1	0.1	0.1	-0.1	-0.1	-0.1	0.0	0.1	0.1	0.2	0.1	0.1
Diff (%)	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenario 2	46	47	47	46	44	44	44	44	45	45	46	47	45
Diff (°F)	0.1	0.2	0.2	0.1	0.0	0.0	-0.1	0.0	0.0	0.0	0.1	0.1	0.1
Diff (%)	0	0	1	0	0	0	0	0	0	0	0	0	0
Scenario 3	46	47	46	46	44	44	44	44	45	45	46	47	45
Diff (°F)	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.1
Diff (%)	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenario 4	46	47	46	46	44	44	44	44	45	46	46	46	45
Diff (°F)	-0.1	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	0.2	0.3	0.4	0.2	-0.2	0.0
Diff (%)	0	0	0	0	0	0	0	0	1	1	0	0	0
Scenario 5	46	47	47	46	44	44	44	44	45	45	46	47	45
Diff (°F)	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Diff (%)	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenario 6	46	47	47	46	44	44	44	44	45	45	46	47	45
Diff (°F)	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Diff (%)	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenario 7	46	47	46	46	44	44	44	44	45	45	45	46	45
Diff (°F)	-0.3	-0.5	-0.5	-0.3	0.0	0.1	0.1	0.0	0.0	-0.1	-0.3	-0.5	-0.2
Diff (%)	-1	-1	-1	-1	0	0	0	0	0	0	-1	-1	0

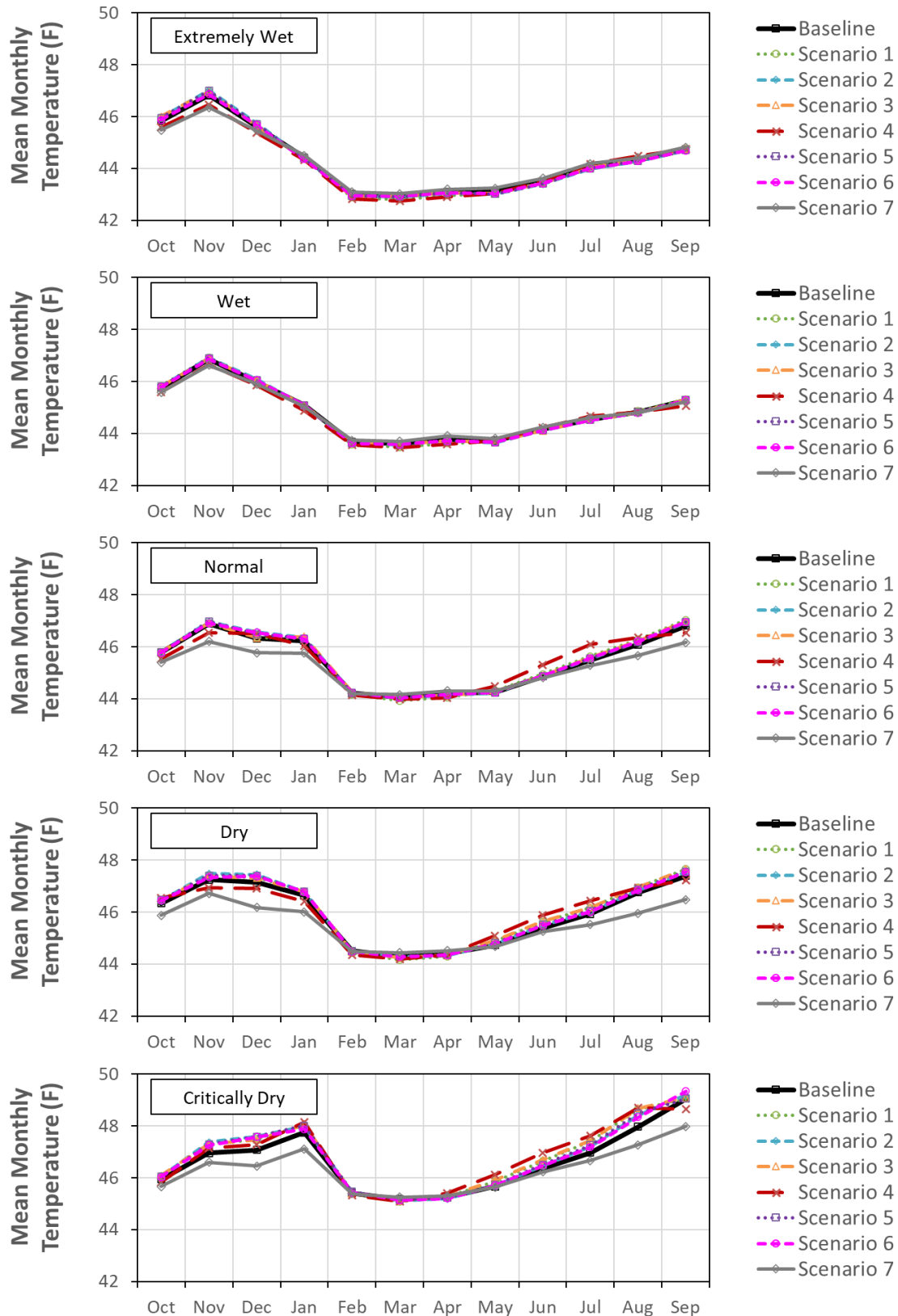


Figure 5-7. Mean Monthly Release Temperature in Degrees Fahrenheit (F) from Trinity Reservoir for All Scenarios by Water Year Type.

5.1.4 Lewiston Reservoir Releases

Lewiston Reservoir releases were modeled in HEC-5Q based on monthly releases modeled in CalSim II. Monthly releases were repatterned to a daily timeseries in HEC-5Q to reflect ROD flows, safety-of-dams releases, late-summer and fall releases consistent with the LTP, TRD exports, and Contract Water releases.

Mean monthly releases throughout the entire simulation period are shown in Figure 5-8 and Table 5-4, and mean monthly releases by water year type throughout the entire simulation period are shown in Figure 5-9. Key takeaways include the following:

- Releases are generally increased from the baseline only from October through April based on the timing of the individual scenario.
- There are no relative increases from May through September on average or in any water year type for any scenario.
- The magnitude of relative release increases over the baseline is greater in Dry and Critically Dry years. This is because there are few safety-of-dams releases in these water year types.

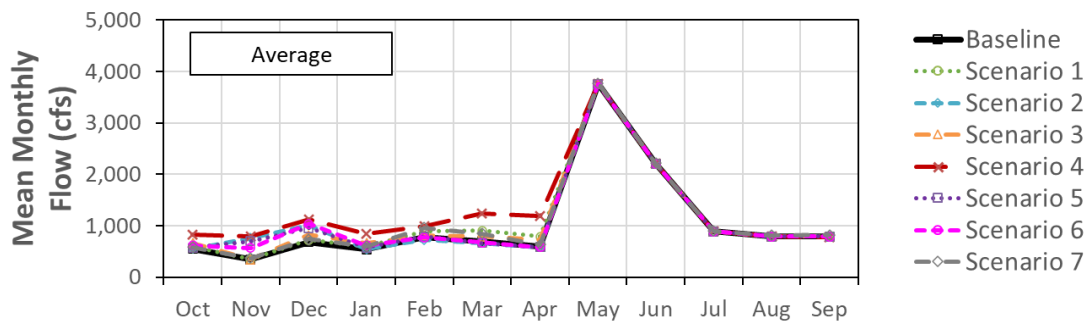


Figure 5-8. Lewiston Reservoir Mean Monthly Releases in Cubic Feet per Second (cfs) for All Scenarios.

Table 5-4. Lewiston Reservoir Mean Monthly Releases in Cubic Feet per Second (cfs) for All Scenarios.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Baseline	546	346	680	543	781	697	587	3,753	2,210	890	788	788	1,051
Scenario 1	602	342	723	600	889	902	792	3,753	2,210	890	788	788	1,107
Diff (cfs)	56	-3	43	57	107	205	205	0	0	0	0	0	56
Diff (%)	0	-1	6	10	14	29	35	0	0	0	0	0	5
Scenario 2	545	763	1,011	542	724	668	580	3,753	2,210	890	788	788	1,105
Diff (cfs)	-2	417	331	-2	-57	-29	-7	0	0	0	0	0	54
Diff (%)	0	121	49	0	-7	-4	-1	0	0	0	0	0	5
Scenario 3	666	344	825	662	817	785	723	3,753	2,210	890	788	788	1,104
Diff (cfs)	120	-2	145	118	35	88	136	0	0	0	0	0	53
Diff (%)	22	-1	21	22	4	13	23	0	0	0	0	0	5
Scenario 4	819	788	1,124	837	993	1,236	1,190	3,753	2,210	890	788	777	1,284
Diff (cfs)	273	442	443	294	211	539	603	0	0	0	0	-11	233
Diff (%)	50	128	65	54	27	77	103	0	0	0	0	-1	22
Scenario 5	575	701	951	571	789	668	580	3,753	2,210	890	788	788	1,105
Diff (cfs)	28	355	271	28	8	-29	-7	0	0	0	0	0	54
Diff (%)	5	103	40	5	1	-4	-1	0	0	0	0	0	5
Scenario 6	614	566	1,032	612	768	668	580	3,753	2,210	890	788	788	1,106
Diff (cfs)	68	220	352	68	-13	-29	-7	0	0	0	0	0	55
Diff (%)	12	64	52	13	-2	-4	-1	0	0	0	0	0	5
Scenario 7	578	370	740	595	963	849	627	3,774	2,211	897	810	823	1,103
Diff (cfs)	32	24	60	51	182	152	40	20	1	7	22	36	52
Diff (%)	6	7	9	9	23	22	7	1	0	1	3	5	5

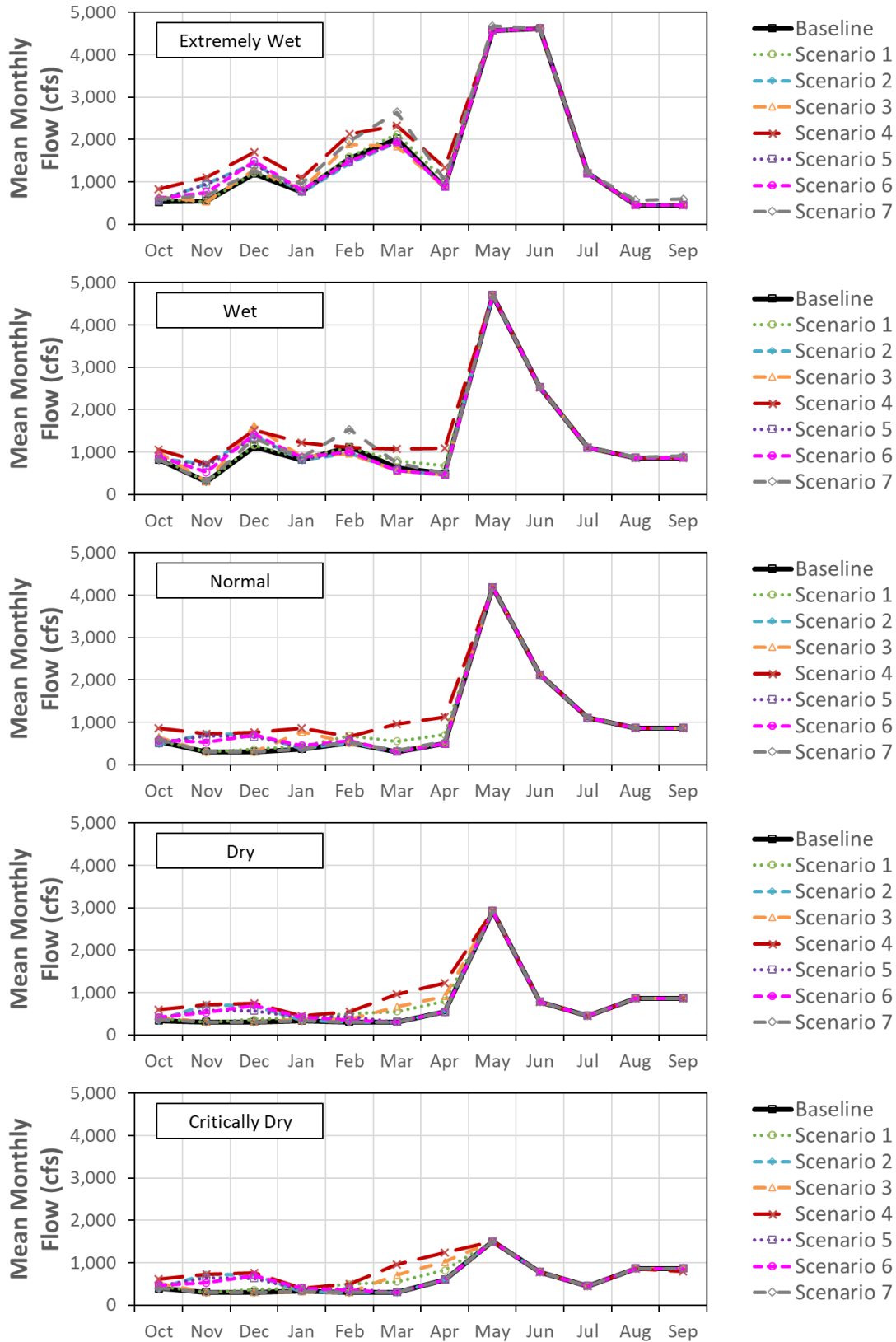


Figure 5-9. Lewiston Reservoir Mean Monthly Flow in Cubic Feet per Second (cfs) for All Scenarios by Water Year Type.

5.1.5 Lewiston Reservoir Release Temperature

Lewiston Reservoir release temperatures were modeled in HEC-5Q based on modeled water temperature profiles in Lewiston Reservoir and model logic that selects release elevation.

Mean monthly Lewiston Reservoir release temperatures are shown in Figure 5-10 and Table 5-5, and by water year type in Figure 5-11. Key takeaways include the following:

- Scenarios that put more water down in the spring months of March and April (Scenarios 1, 3, and 4) on average showed reduced release temperatures of 1 – 1.5 F relative to the baseline, particularly in drier water year types. In these months, the higher volume of cold-water releases resulted in lower travel times of releases through Lewiston and less warming of flows.
- Scenarios that put more water down in the fall months of October through December (Scenarios 2, 5, 6) on average or across water year type did not show a notable release temperature change during those months relative to the baseline.
- Scenario 4 resulted in warmer monthly release temperatures July through September, especially in drier years, due to the combination of lower Trinity Reservoir storage and reduced Trinity Reservoir releases (i.e., fewer TRD exports). For all other scenarios except Scenario 7, release temperatures in the summer are consistent with the baseline, except in Critically Dry years, when release temperatures are consistently elevated between 0.5 F and 1 F above the baseline.
- Scenario 7 resulted in slightly lower (0.5 – 1 F) release temperatures relative to the baseline from August through January of drier water year types, a result of higher Trinity Reservoir storage producing cooler Trinity Reservoir releases (see Section 5.1.3).

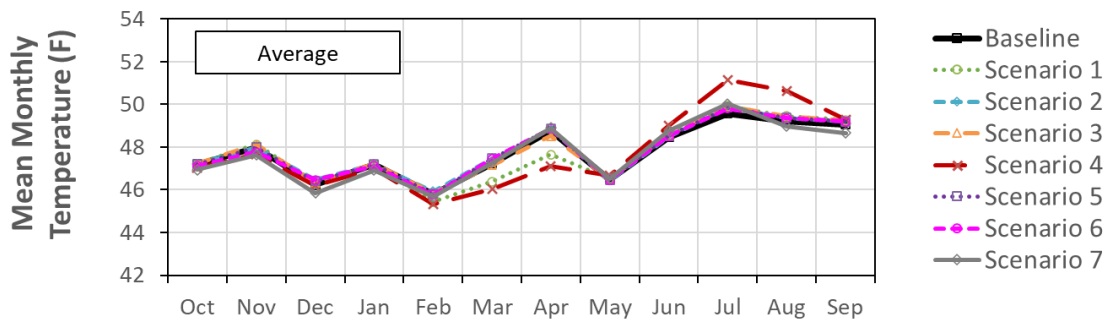


Figure 5-10. Lewiston Reservoir Mean Monthly Release Temperature in Degrees Fahrenheit (F) for All Scenarios.

Table 5-5. Lewiston Reservoir Mean Monthly Release Temperature in Degrees Fahrenheit (F) for All Scenarios.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Baseline	47	48	46	47	46	47	49	46	48	50	49	49	48
Scenario 1	47	48	46	47	45	46	48	47	49	50	49	49	48
Diff (°F)	0.0	0.2	0.1	0.0	-0.4	-0.8	-1.1	0.0	0.1	0.4	0.3	0.2	-0.1
Diff (%)	0	0	0	0	-1	-2	-2	0	0	1	1	0	0
Scenario 2	47	48	46	47	46	47	49	46	49	50	49	49	48
Diff (°F)	0.0	0.0	0.2	0.0	0.1	0.2	0.1	0.0	0.0	0.3	0.2	0.1	0.1
Diff (%)	0	0	0	0	0	1	0	0	0	1	0	0	0
Scenario 3	47	48	46	47	46	47	49	47	49	50	49	49	48
Diff (°F)	0.0	0.1	0.1	0.0	0.0	-0.1	-0.2	0.0	0.1	0.3	0.3	0.2	0.1
Diff (%)	0	0	0	0	0	0	0	0	0	1	1	0	0
Scenario 4	47	48	46	47	45	46	47	47	49	51	51	49	48
Diff (°F)	-0.2	-0.3	0.0	-0.2	-0.5	-1.2	-1.7	0.2	0.6	1.6	1.4	0.2	0.0
Diff (%)	0	-1	0	0	-1	-3	-3	0	1	3	3	0	0
Scenario 5	47	48	46	47	46	47	49	46	49	50	49	49	48
Diff (°F)	0.0	0.0	0.2	0.0	0.0	0.2	0.1	0.0	0.1	0.3	0.2	0.1	0.1
Diff (%)	0	0	0	0	0	1	0	0	0	1	0	0	0
Scenario 6	47	48	46	47	46	47	49	46	49	50	49	49	48
Diff (°F)	-0.1	-0.2	0.2	-0.1	0.0	0.2	0.1	0.0	0.1	0.3	0.2	0.1	0.1
Diff (%)	0	0	1	0	0	0	0	0	0	1	0	0	0
Scenario 7	47	48	46	47	46	47	49	47	49	50	49	49	48
Diff (°F)	-0.2	-0.3	-0.4	-0.3	-0.1	0.1	0.2	0.1	0.3	0.5	-0.2	-0.4	-0.1
Diff (%)	-1	-1	-1	-1	0	0	0	0	1	1	0	-1	0

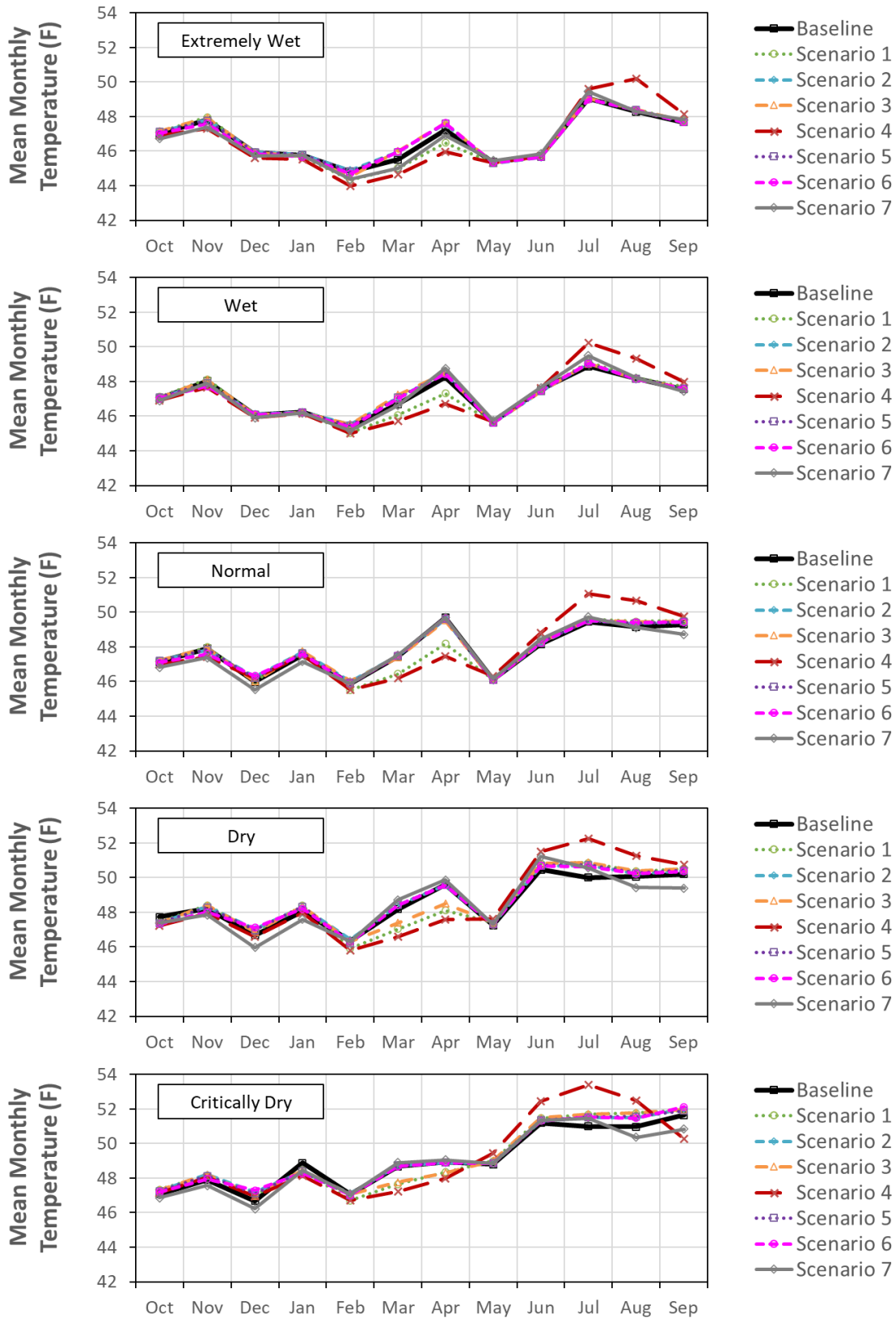


Figure 5-11. Lewiston Reservoir Mean Monthly Release Temperature in Degrees Fahrenheit (F) for All Scenarios by Water Year Type.

5.2 Trinity River Discharge and Water Temperature

A daily discharge time series at Pear Tree Creek, located just upstream of the North Fork Trinity River confluence (Figure 2-3), is shown in Figure 5-12 for the 23-year simulation period. River flows at Pear Tree reflect inputs from tributaries downstream of Lewiston Dam. Because tributary inputs are held constant between scenarios, differences in flow at Pear Tree are due to differences in Lewiston Dam releases among scenarios.

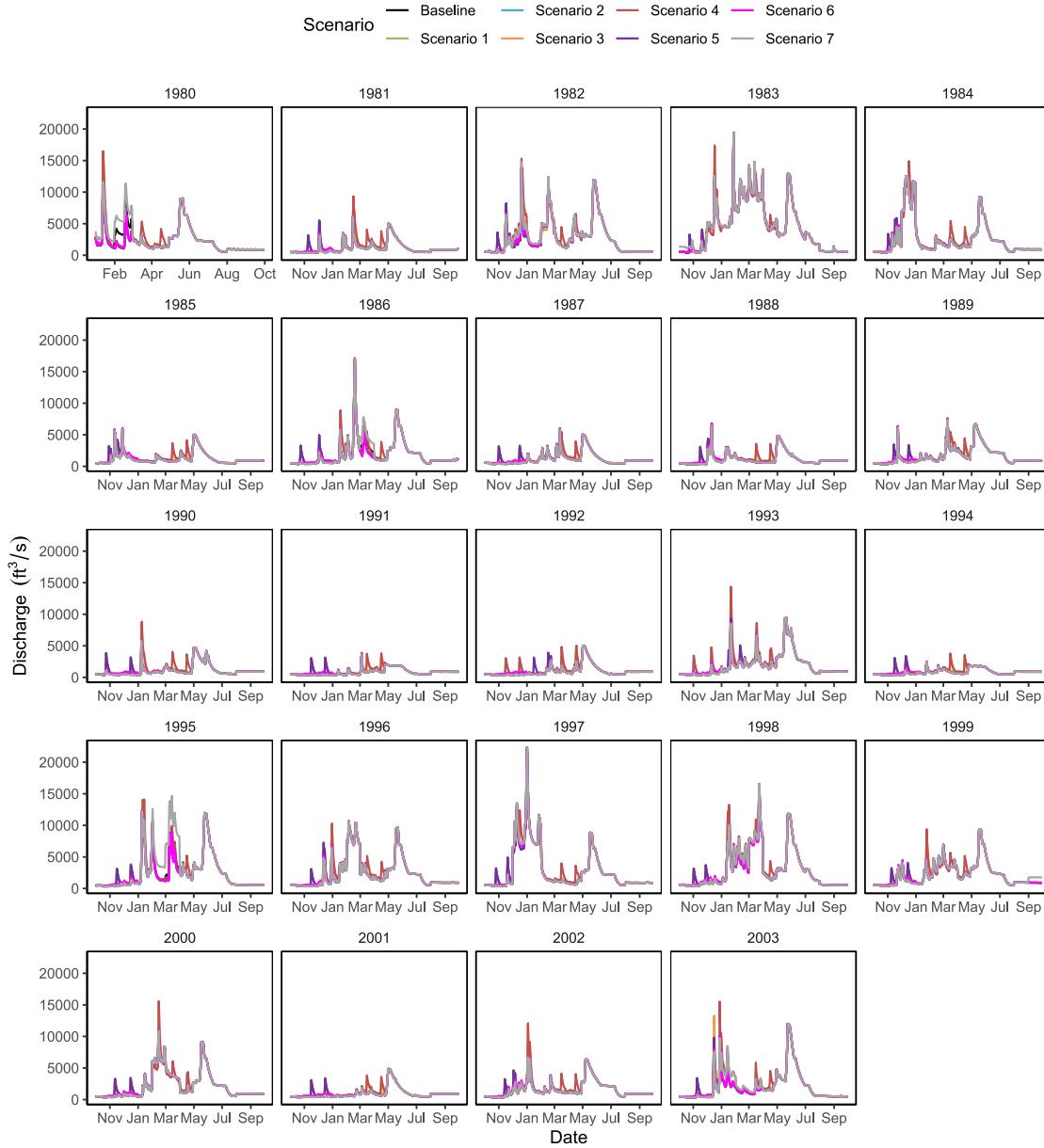


Figure 5-12. Daily Discharge of the Trinity River at Pear Tree Creek (River Kilometer 119) as Simulated by RBM10 for All Scenarios.

A daily water temperature time series at Pear Tree Creek is shown in Figure 5-13 for the 23-year simulation period. Although tributary discharge and water temperatures were the same among scenarios, water temperature at Pear Tree reflects both differences in temperature of water released from Lewiston Dam and changes in water temperature owing to heat exchange at the air-water interface. Daily water temperature differences relative to the baseline tended to be less than 4°F (2°C), with some larger differences for shorter durations in some years (Figure 5-14). As shown in Section 5.1.5, mean monthly Lewiston release temperature changes relative to the baseline were on average less than 1°F, but daily fluctuations due to pulse releases, safety-of-dams releases, and the relationship between Trinity Reservoir releases and TRD exports from Lewiston resulted in greater range of daily temperature differences.

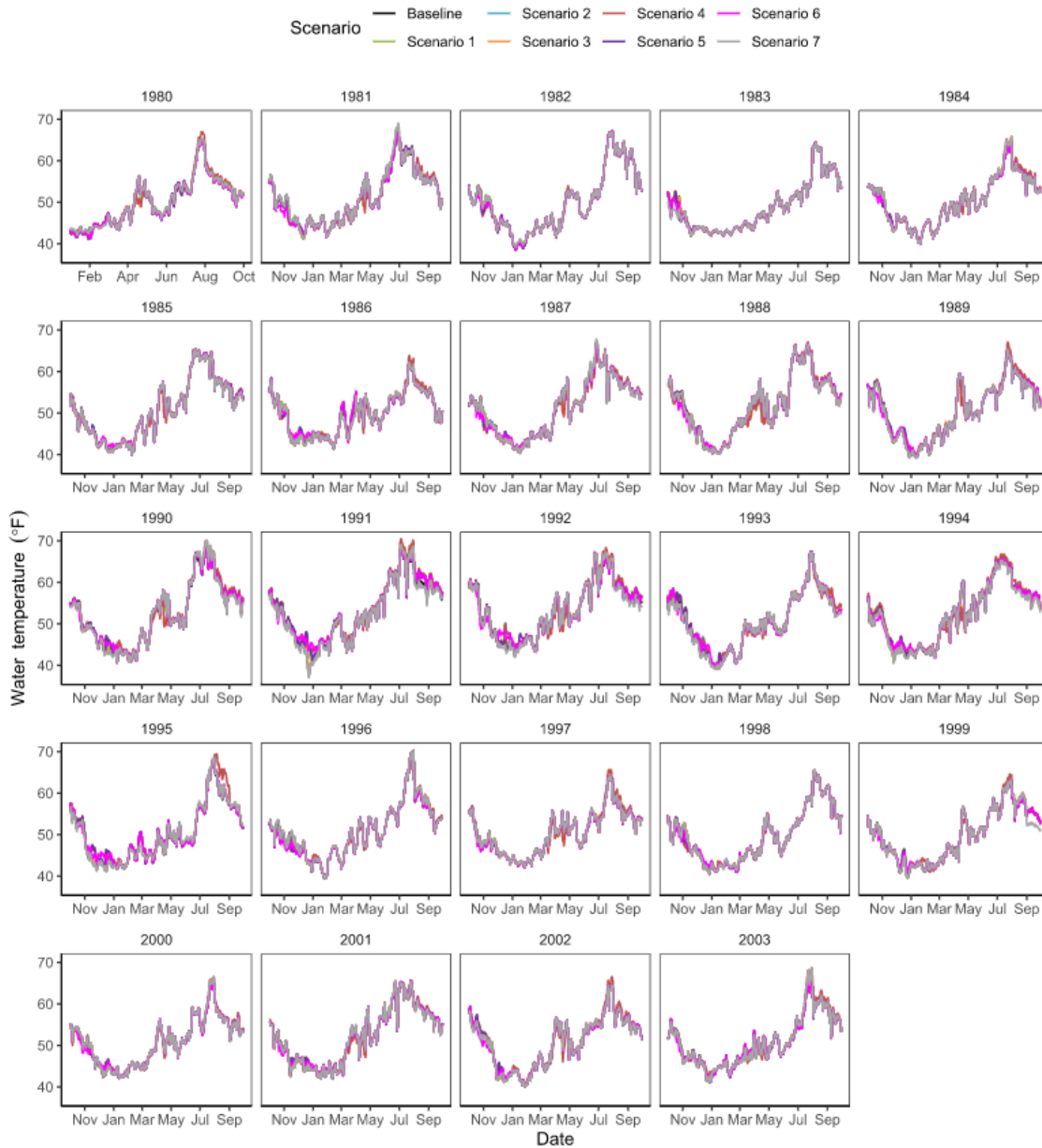


Figure 5-13. Daily Water Temperature of the Trinity River at Pear Tree Creek (River Kilometer 119) as Simulated by RBM10 for All Scenarios.

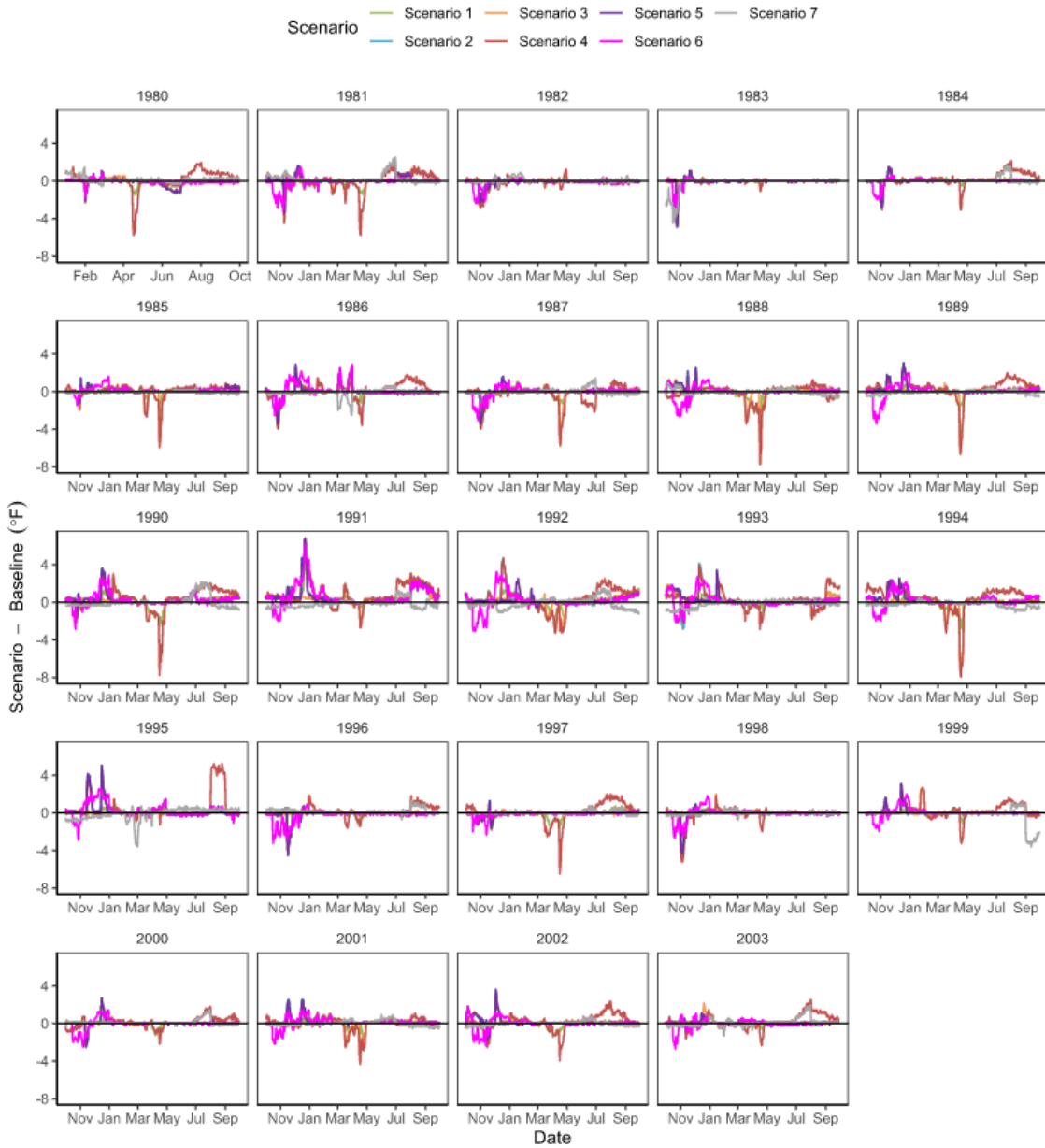


Figure 5-14. Difference Between the Baseline and each Contract Water Release Scenario in Mean Daily Water Temperature of the Trinity River at Pear Tree Creek (River Kilometer 119) as Simulated by RBM10.

5.3 Habitat

The Chinook Salmon habitat models revealed that the scenarios differed in the amount of habitat for different life stages. For spawning habitat, Scenario 6 led to an increase in spawning habitat that was maintained for the duration of spawning season relative to the baseline (October – January; Figure 5-15 and Figure 5-16). In contrast, scenarios with fall pulse flows tended to either decrease (during the peak) or increase (during ascending and descending limbs) spawning habitat for relatively brief periods (i.e., days). For juvenile capacity, there was a large difference in capacity among water years, with wetter years (e.g., 1983) increasing capacity for a longer period of time relative to drier years (e.g., 1994, Figure 5-17 and Figure 5-19). Relative to the baseline, fry and parr capacity increased in response to both fall and spring flow increases, but such increases tended to be of short duration (Figure 5-18 and Figure 5-20). Scenarios with a fall release produced lower winter Trinity Reservoir storage, which resulted in lower magnitude safety-of-dams releases in the spring, reducing spring fry and parr capacity in some years.

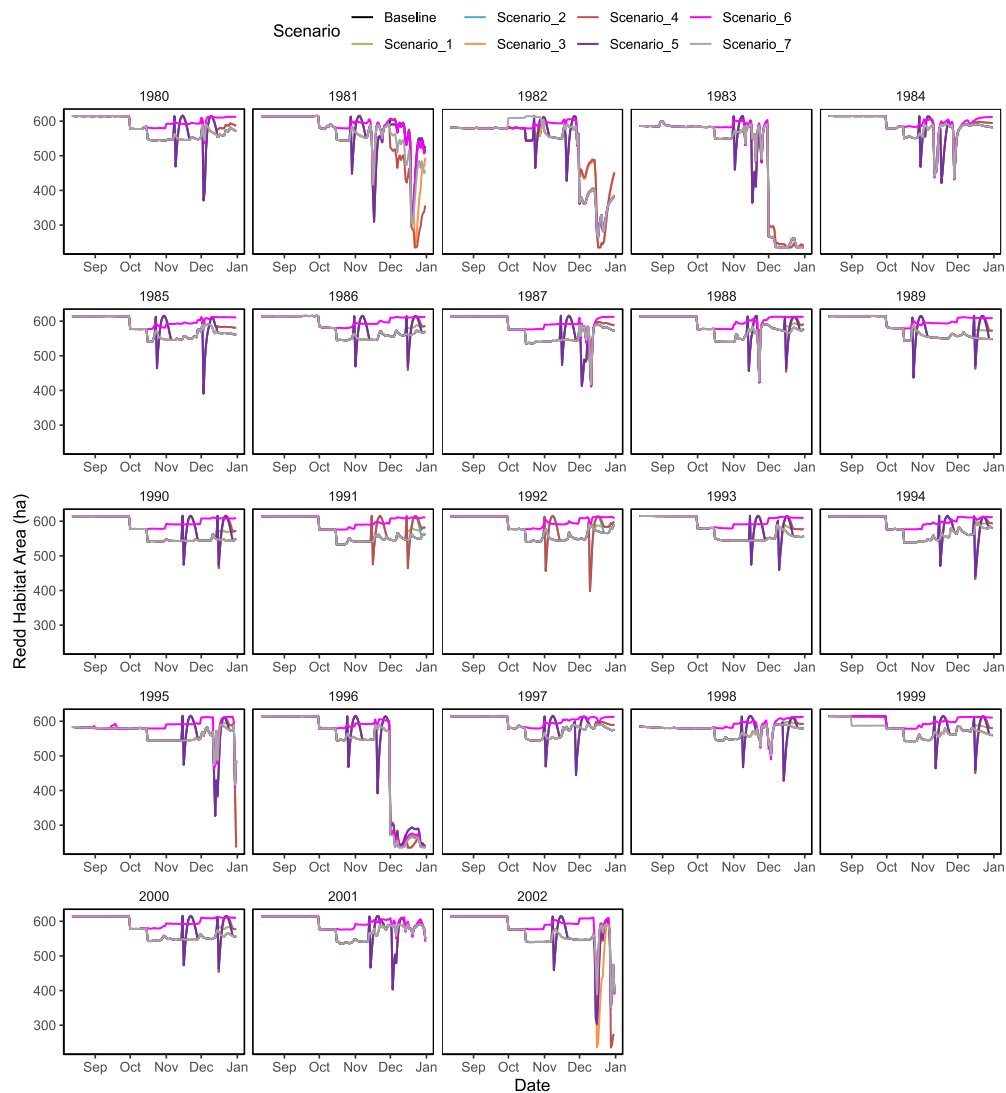


Figure 5-15. Daily Time Series of Total Spawning Habitat Area in the Restoration Reach for All Scenarios.

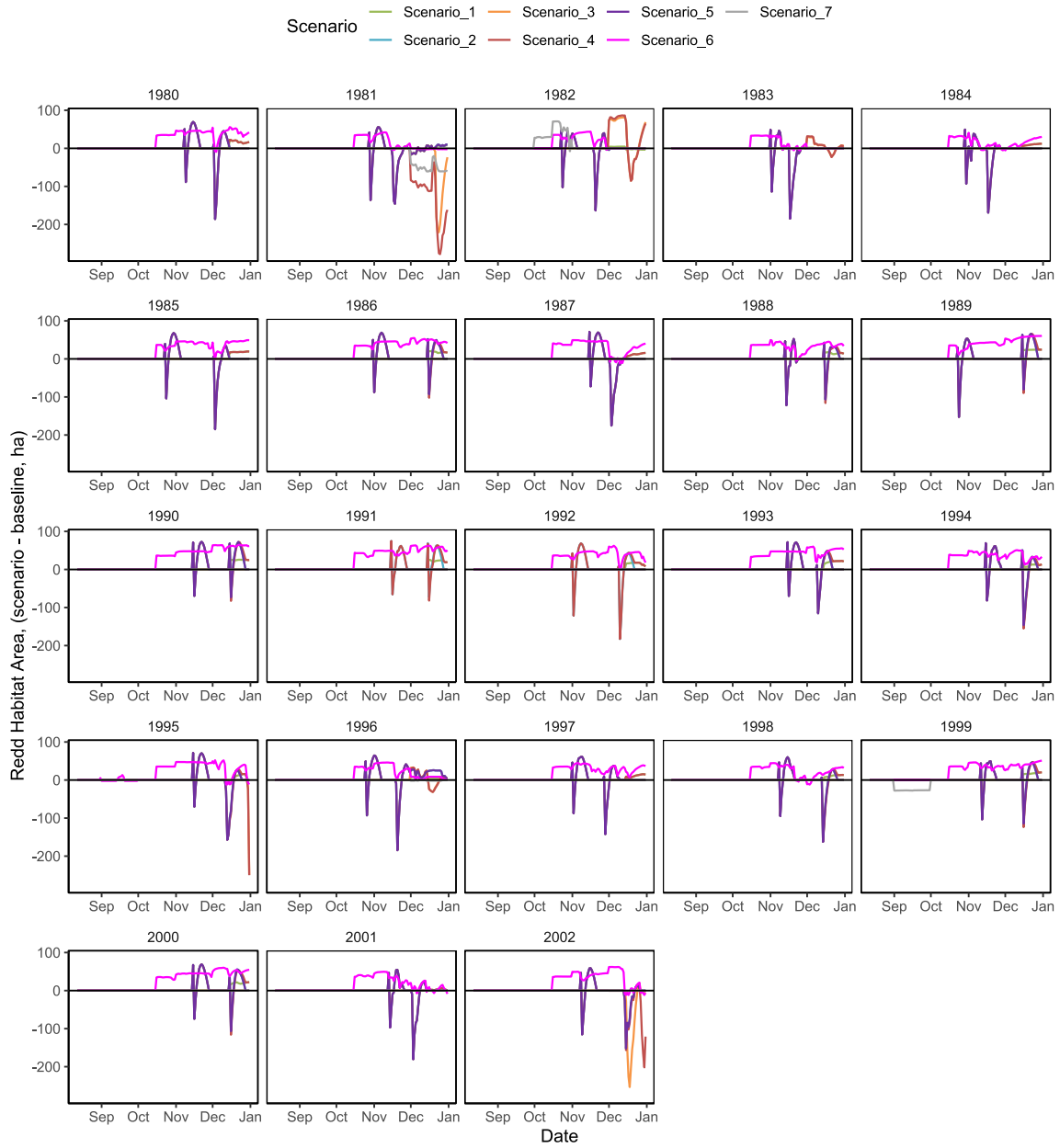


Figure 5-16. Daily Time Series of the Difference in Total Spawning Habitat Area in the Restoration Reach Relative to the Baseline for All Scenarios.

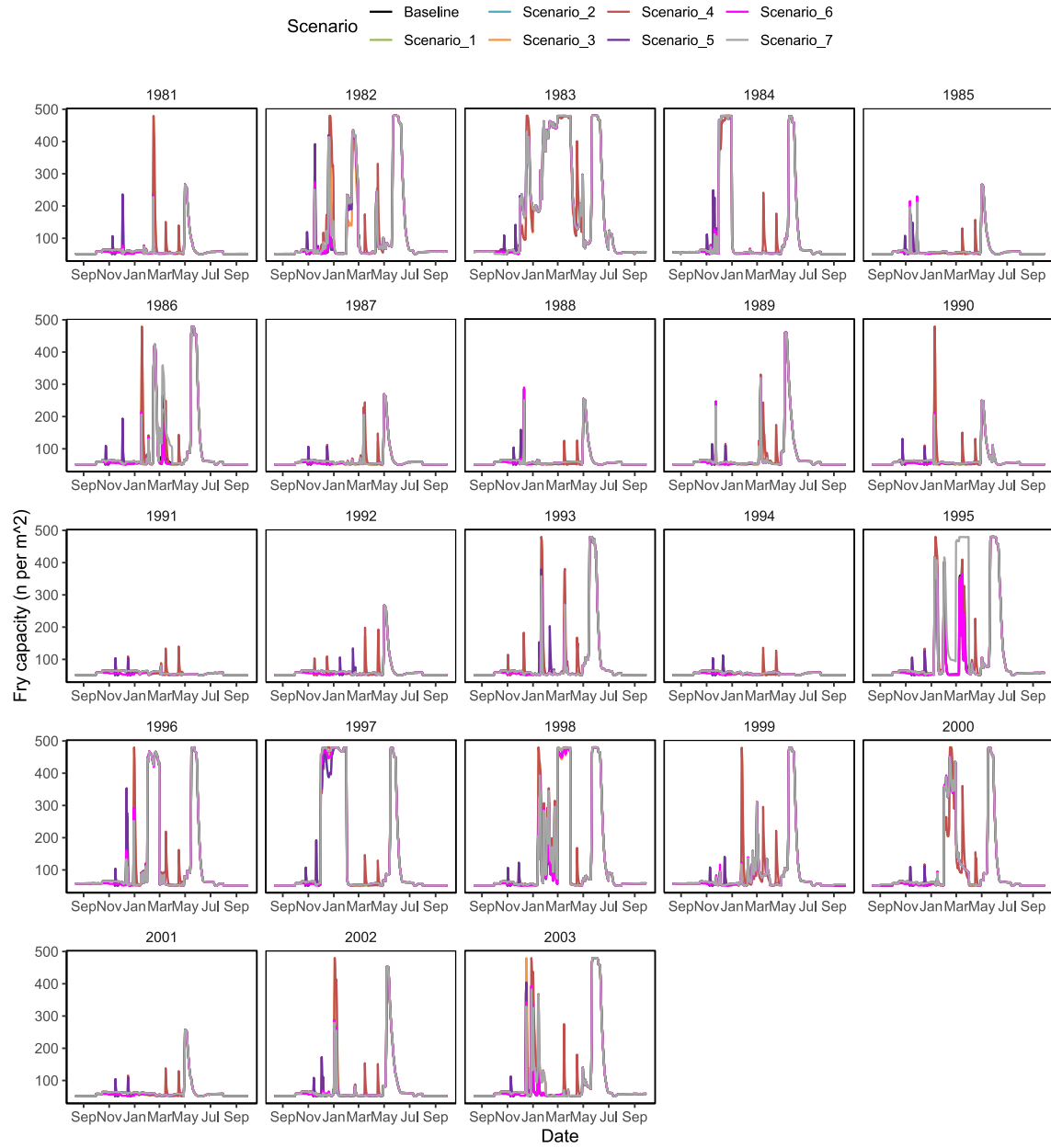


Figure 5-17. Daily Time Series of Mean Fry Capacity in the Restoration Reach for All Scenarios.

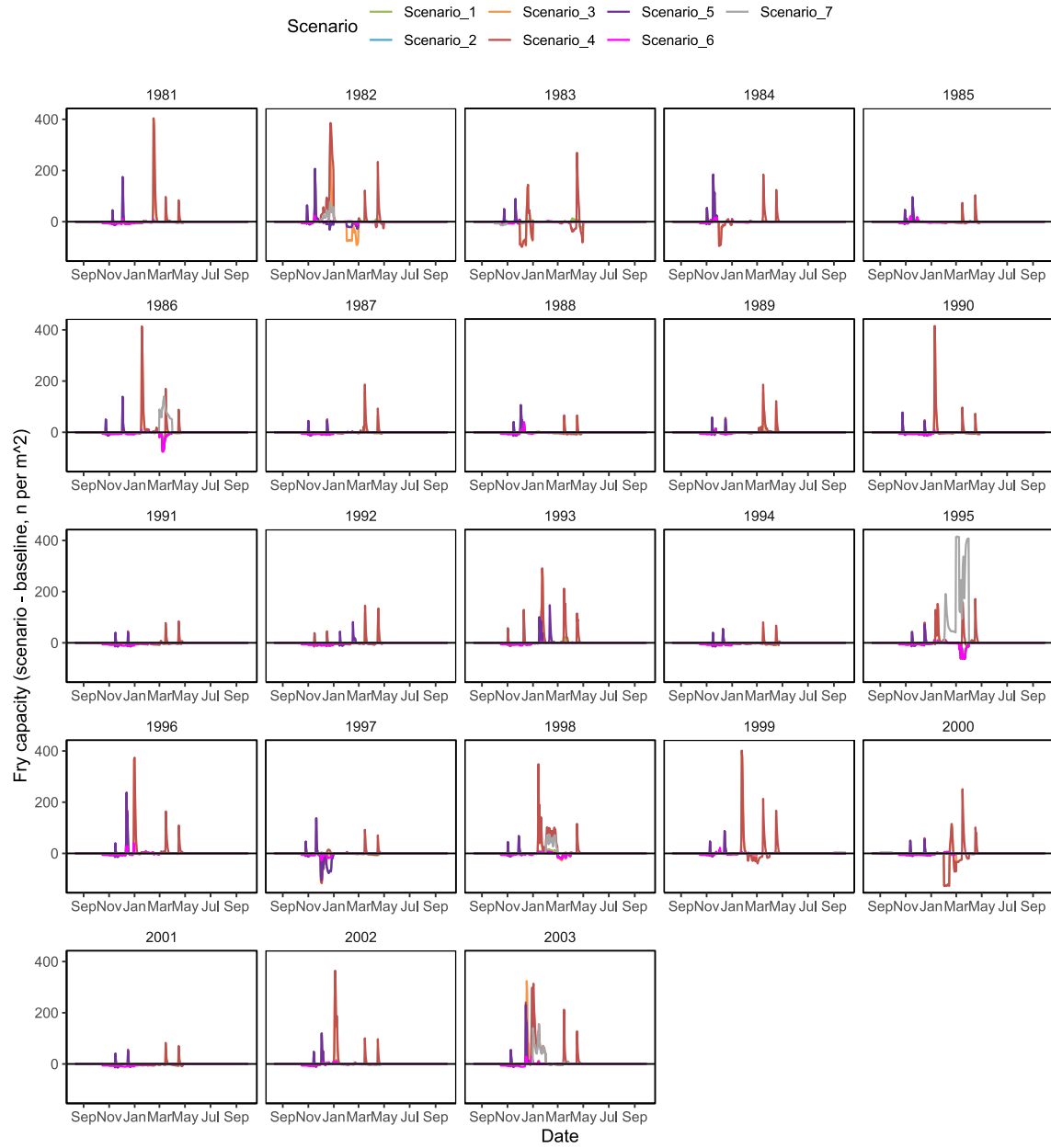


Figure 5-18. Daily Time Series of the Difference in Mean Fry Capacity in the Restoration Reach Relative to the Baseline for All Scenarios.

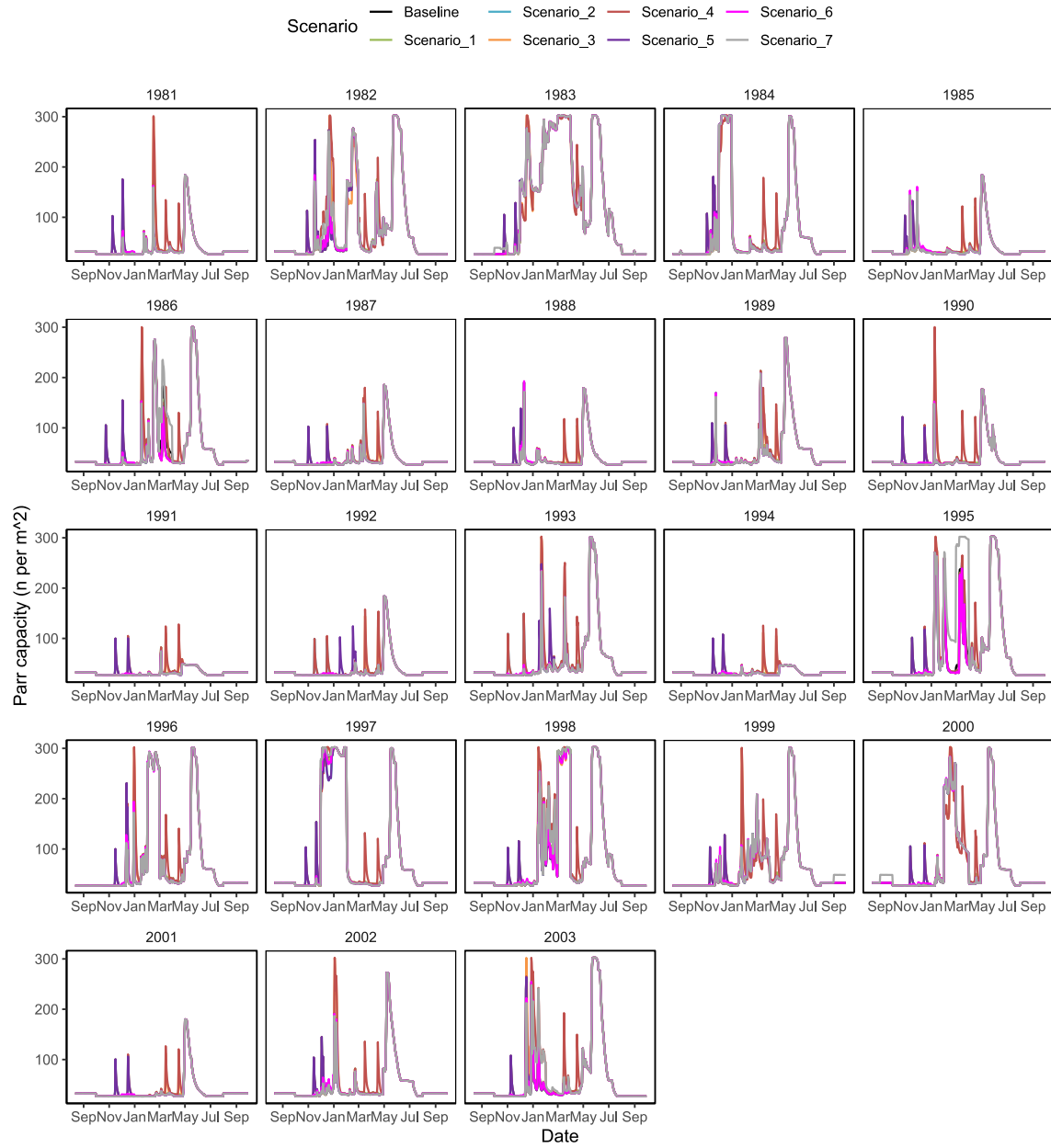


Figure 5-19. Daily Time Series of Mean Parr Capacity in the Restoration Reach for All Scenarios.

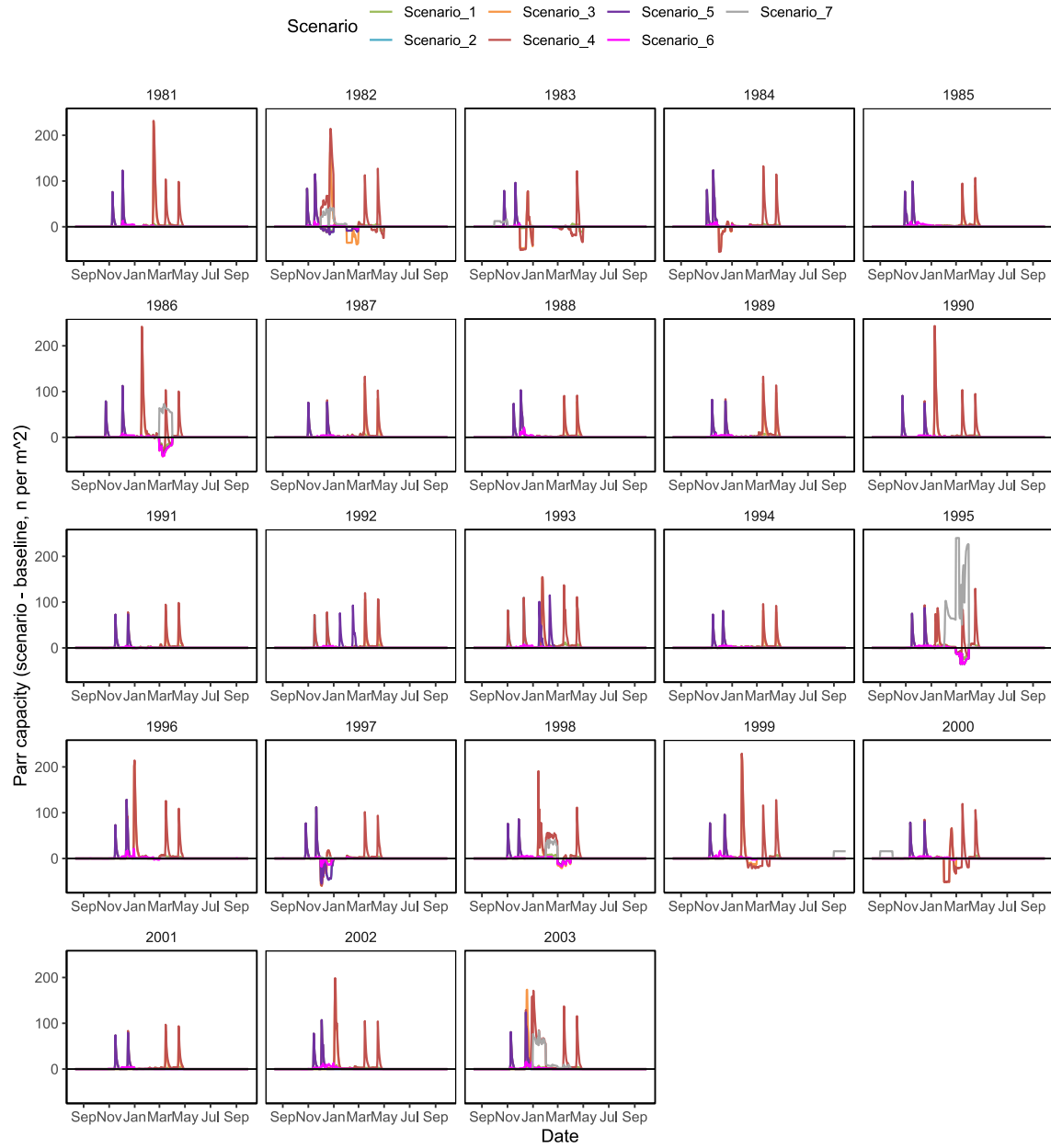


Figure 5-20. Daily Time Series of the Difference in Mean Parr Capacity in the Restoration Reach Relative to the Baseline for All Scenarios.

5.4 Fisheries

Output from an annual S3 model simulation can be summarized on a daily, weekly, monthly, or annual time scale. Because the seven Contract Water release scenarios were run over 23 water years, the S3 model output was summarized on an annual basis with emphasis on evaluating the effect of Contract Water release scenarios relative to baseline conditions.

5.4.1 Mean Annual and Water Year Metrics

The annual S3 output is summarized by calculating (1) egg survival (percentage) from spawning to emergence, (2) juvenile fish survival (percentage) from emergence to the Pear Tree fish trap, (3) the annual abundance of fish (number of fish) that passed Pear Tree, (4) the mean annual mass (grams) of individual fish that passed Pear Tree, and (5) the mean annual biomass (metric tons) of fish that passed Pear Tree (i.e., mean annual mass times annual abundance). For each of these metrics, the annual difference is calculated relative to the corresponding metric in the baseline as $(Scenario - Baseline)/Baseline$. The annual time series of the metrics across scenarios and water year types is tabulated. Summary tables of all five metrics across scenarios are shown in Table 5-6 for mean annual metrics, in Table 5-7 for mean annual metrics averaged by water year type, in Table 5-8 for the magnitude difference between each scenario and the baseline for mean annual metrics averaged by water year type, and Table 5-9 for the percentage difference between each scenario and the baseline for mean annual metrics averaged by water year type. Details about simulated egg survival and emergence, and simulated juvenile survival, abundance, and biomass are described in the following two sections. Key observations from the mean annual summary statistics relative to the baseline include the following:

- Egg survival increased for Scenarios 2, 4, 5, and 6 that release water in the fall, and decreased (less than 0.5% reduction and within the range of normal annual variation) for the Scenarios 1, 3, and 7. Increases ranged from 1% to 2.6%, with the largest increase due to fall baseflow releases (Scenario 6).
- Juvenile fish survival increased for scenarios that have higher magnitude releases in March and April (Scenarios 1 and 4) and for Scenario 6, but decreased for Scenarios 2, 3, 5, and 7 (less than 0.2% reduction and within the range of normal annual variation). The largest increase of 1.6% was for Scenario 4, which released a spring baseflow and fall and spring pulses in all years.
- Annual juvenile abundance increased for most scenarios and decreased by less than 1% for Scenarios 3 and 7, within the range of normal annual variation. The largest increases in abundance were 2.9% for Scenario 4, which released the largest volume of Contract Water, and 2.7% for Scenario 6, which had the highest egg survival increase.
- Mean annual fish mass increased for Scenarios 2, 5, and 7, and decreased for all other scenarios from 0% to 5%. The largest decreases in fish mass occurred for scenarios releasing water in the spring that was generally 1°F to 2°F cooler than the baseline (Scenarios 1 and 4).
- Mean annual juvenile biomass changes reflect differences in both abundance and fish size. Juvenile biomass increased for Scenarios 2, 5, 6, and 7, and decreased for Scenarios 1, 3, and 4. The increase in juvenile biomass for Scenario 6 was three times greater than for any other scenario, primarily due to an increase in abundance.

Table 5-6. Mean Annual Metrics of Stream Salmonid Stimulator (S3) Output for Juvenile Life Stages of Chinook Salmon in the Restoration Reach of the Trinity River.

Scenario	Egg survival (percent)	Juvenile survival (percent)	Juvenile abundance (number of fish)	Juvenile size (grams)	Juvenile biomass (metric tons)
Baseline	67.3	21.2	2,138,140	1.335	2.845
Scenario 1	67.0	21.3	2,142,655	1.277	2.731
Scenario 2	68.2	21.0	2,147,696	1.34	2.872
Scenario 3	67.1	21.1	2,123,236	1.309	2.774
Scenario 4	67.9	21.5	2,194,435	1.257	2.755
Scenario 5	68.1	21.0	2,144,826	1.34	2.868
Scenario 6	69.0	21.2	2,197,813	1.333	2.923
Scenario 7	67.2	21.1	2,136,551	1.34	2.845
Percent difference from the baseline					
Scenario 1	-0.3	0.6	0.2	-4.1	-3.9
Scenario 2	1.4	-0.9	0.5	0.5	0.9
Scenario 3	-0.3	-0.4	-0.7	-1.7	-2.4
Scenario 4	1	1.6	2.7	-5.4	-2.8
Scenario 5	1.2	-0.9	0.3	0.6	0.8
Scenario 6	2.6	0.2	2.9	-0.1	2.8
Scenario 7	0	-0.1	-0.1	0.4	0.3
Difference from the baseline					
Scenario 1	-0.3	0.1	4,515	-0.06	-0.11
Scenario 2	0.9	-0.2	9,556	0.01	0.03
Scenario 3	-0.2	-0.1	-14,904	-0.03	-0.07
Scenario 4	0.6	0.3	56,295	-0.08	-0.09
Scenario 5	0.8	-0.2	6,686	0.01	0.02
Scenario 6	1.7	0.0	59,673	0	0.08
Scenario 7	-0.1	-0.1	-1,589	0.01	0.01
Percent of water years with annual metric values exceeding the baseline					
Scenario 1	18.2	68.2	59.1	4.5	13.6
Scenario 2	95.5	22.7	72.7	54.5	77.3
Scenario 3	18.2	36.4	31.8	13.6	31.8
Scenario 4	90.9	59.1	72.7	13.6	36.4
Scenario 5	90.9	22.7	68.2	54.5	77.3
Scenario 6	95.5	54.5	86.4	18.2	77.3
Scenario 7	27.3	22.7	45.5	50	54.5

Note: Metrics were calculated annually and averaged over the 23 simulated water years for the baseline and each Contract Water release scenario. The percent difference from the baseline was calculated as the mean of all individual year differences, not as the difference of the mean of the simulation period.

Table 5-7. Means of Annual Population Statistics by Water Year Type for Juvenile Chinook Salmon Life Stages as Simulated by the Stream Salmonid Simulator (S3) Model Applied to Contract Water Release Scenarios in the Restoration Reach of the Trinity River.

Scenario	Water year type	Mean of annual values				
		Egg survival (percent)	Juvenile survival to Pear Tree (percent)	Abundance at Pear Tree (number of fish)	Mean fish size at Pear Tree (grams)	Biomass at Pear Tree (metric tons)
Baseline	Critically Dry	69.0	21.0	2,177,751	1.405	3.053
Baseline	Dry	67.2	20.4	2,060,907	1.446	2.98
Baseline	Normal	66.4	20.7	2,063,537	1.491	3.078
Baseline	Wet	67.6	21.0	2,128,796	1.287	2.739
Baseline	Extremely Wet	66.5	22.7	2,273,343	1.156	2.629
1	Critically Dry	68.9	20.9	2,166,033	1.342	2.905
1	Dry	67.0	20.6	2,079,631	1.352	2.812
1	Normal	66.2	20.3	2,020,749	1.356	2.741
1	Wet	67.2	21.2	2,138,427	1.247	2.669
1	Extremely Wet	66.4	22.8	2,276,217	1.155	2.63
2	Critically Dry	70.5	20.8	2,204,614	1.4	3.083
2	Dry	67.9	20.4	2,077,843	1.442	2.997
2	Normal	67.5	20.6	2,088,052	1.486	3.103
2	Wet	68.5	20.7	2,135,410	1.299	2.774
2	Extremely Wet	67.4	22.4	2,263,783	1.173	2.656
3	Critically Dry	68.8	20.7	2,143,681	1.332	2.855
3	Dry	67.0	20.6	2,077,268	1.389	2.885
3	Normal	66.2	20.2	2,013,023	1.401	2.82
3	Wet	67.3	20.8	2,108,359	1.296	2.733
3	Extremely Wet	66.5	22.5	2,244,327	1.169	2.624
4	Critically Dry	69.7	21.2	2,222,044	1.311	2.914
4	Dry	67.6	21.0	2,135,371	1.326	2.832
4	Normal	67.1	20.1	2,031,312	1.311	2.662
4	Wet	68.6	21.6	2,222,954	1.226	2.728
4	Extremely Wet	67.0	22.8	2,291,406	1.161	2.659
5	Critically Dry	70.5	20.8	2,205,458	1.399	3.082
5	Dry	67.8	20.4	2,073,876	1.442	2.991
5	Normal	67.5	20.6	2,087,852	1.486	3.103
5	Wet	68.4	20.7	2,130,372	1.299	2.768
5	Extremely Wet	67.4	22.3	2,262,927	1.173	2.655
6	Critically Dry	70.4	21.0	2,221,660	1.395	3.092
6	Dry	69.0	20.6	2,138,966	1.434	3.067
6	Normal	69.0	20.9	2,168,180	1.482	3.214
6	Wet	69.1	21.0	2,175,494	1.294	2.812
6	Extremely Wet	68.2	22.6	2,313,760	1.163	2.691
7	Critically Dry	68.9	21.0	2,177,239	1.415	3.072
7	Dry	67.0	20.3	2,042,985	1.458	2.978
7	Normal	66.2	20.6	2,046,315	1.506	3.082
7	Wet	67.8	21.1	2,153,758	1.286	2.768
7	Extremely Wet	66.5	22.6	2,263,272	1.155	2.613

Table 5-8. Mean Percent Changes from the Baseline for Population Statistics on Juvenile Chinook Salmon Life Stages as Simulated by the Stream Salmonid Simulator (S3) Model Applied to Contract Water Release Scenarios in the Restoration Reach of the Trinity River.

Scenario	Water year type	Mean percent difference in annual values from Baseline				
		Egg survival	Juvenile survival to Pear Tree	Abundance at Pear Tree	Mean fish size at Pear Tree	Biomass at Pear Tree
1	Critically Dry	-0.2	-0.2	-0.5	-4.3	-4.7
1	Dry	-0.2	1.2	0.9	-6.6	-5.6
1	Normal	-0.3	-1.7	-2	-9.1	-10.9
1	Wet	-0.5	1	0.4	-3	-2.6
1	Extremely Wet	-0.2	0.4	0.1	-0.1	0
2	Critically Dry	2.1	-0.9	1.2	-0.2	1
2	Dry	1.1	-0.4	0.8	-0.2	0.5
2	Normal	1.7	-0.5	1.2	-0.4	0.9
2	Wet	1.4	-1.1	0.3	1	1.2
2	Extremely Wet	1.3	-1.8	-0.4	1.5	1.1
3	Critically Dry	-0.4	-1.4	-1.6	-5	-6.3
3	Dry	-0.2	1	0.8	-4	-3.2
3	Normal	-0.3	-2.2	-2.4	-5.9	-8.1
3	Wet	-0.4	-0.5	-0.9	0.7	-0.3
3	Extremely Wet	-0.1	-1.1	-1.2	1	-0.2
4	Critically Dry	1	1	2.1	-6.2	-4.3
4	Dry	0.7	2.8	3.6	-8.2	-4.7
4	Normal	1	-2.7	-1.5	-12.3	-13.4
4	Wet	1.5	3	4.5	-4.5	-0.3
4	Extremely Wet	0.7	0.1	0.8	0.4	1.3
5	Critically Dry	2.1	-0.9	1.3	-0.2	1
5	Dry	0.9	-0.3	0.6	-0.2	0.4
5	Normal	1.7	-0.5	1.2	-0.4	0.8
5	Wet	1.2	-1.1	0.1	1.1	1
5	Extremely Wet	1.3	-1.8	-0.4	1.7	1.1
6	Critically Dry	2	0	2	-0.7	1.4
6	Dry	2.7	1	3.8	-0.9	2.9
6	Normal	4	1.2	5	-0.7	4.4
6	Wet	2.3	0	2.3	0.6	2.7
6	Extremely Wet	2.6	-0.7	1.9	0.5	2.5
7	Critically Dry	-0.1	0	0	0.8	0.7
7	Dry	-0.3	-0.6	-0.9	0.8	-0.1
7	Normal	-0.2	-0.5	-0.8	1	0.1
7	Wet	0.4	0.8	1.1	0	1.1
7	Extremely Wet	0	-0.4	-0.4	0.2	-0.5

Note: The mean percent differences were calculated by averaging the differences from each individual year and are not representative of the difference in mean values presented in Table 5-7. Results representing equal to or greater than a positive or negative 2% Change (+ or -) from the baseline are presented in bold and highlighted gray and orange, respectively.

Table 5-9. Mean Annual Differences in Summary Statistics Relative to the Baseline for Juvenile Chinook Salmon Life Stages as Simulated by the Stream Salmonid Simulator (S3) Model Applied to Contract Water Release Scenarios in the Restoration Reach of the Trinity River.

Scenario	Water year type	Mean annual difference in values from Baseline				
		Egg survival	Juvenile survival to Pear Tree	Abundance at Pear Tree (number of fish)	Mean fish size at Pear Tree (grams)	Biomass at Pear Tree (metric tons)
1	Critically Dry	-0.2	0.0	-11,718	-0.065	-0.148
1	Dry	-0.2	0.2	18,724	-0.096	-0.169
1	Normal	-0.2	-0.4	-42,789	-0.135	-0.336
1	Wet	-0.4	0.2	9,631	-0.04	-0.07
1	Extremely Wet	-0.1	0.1	2,874	-0.002	0.001
2	Critically Dry	1.4	-0.2	26,864	-0.005	0.03
2	Dry	0.7	-0.1	16,936	-0.003	0.017
2	Normal	1.1	-0.1	24,514	-0.005	0.026
2	Wet	1.0	-0.2	6,614	0.013	0.035
2	Extremely Wet	0.9	-0.4	-9,560	0.018	0.028
3	Critically Dry	-0.2	-0.3	-34,070	-0.075	-0.198
3	Dry	-0.2	0.2	16,361	-0.059	-0.095
3	Normal	-0.2	-0.5	-50,514	-0.09	-0.258
3	Wet	-0.3	-0.1	-20,437	0.009	-0.007
3	Extremely Wet	-0.1	-0.2	-29,016	-0.005	-0.001
4	Critically Dry	0.7	0.2	44,293	-0.14	0.007
4	Dry	0.4	0.6	74,464	-0.12	-0.149
4	Normal	0.7	-0.5	-32,226	-0.185	-0.416
4	Wet	1.0	0.6	94,158	-0.06	-0.012
4	Extremely Wet	0.4	0.0	18,063	0.004	0.03
5	Critically Dry	1.5	-0.2	27,708	-0.005	0.029
5	Dry	0.6	-0.1	12,969	-0.003	0.011
5	Normal	1.1	-0.1	24,314	-0.005	0.026
5	Wet	0.8	-0.2	1,576	0.014	0.029
5	Extremely Wet	0.9	-0.4	-10,416	0.02	0.027
6	Critically Dry	1.4	0.0	43,908	-0.01	0.039
6	Dry	1.8	0.2	78,060	-0.013	0.086
6	Normal	2.6	0.2	104,642	-0.01	0.136
6	Wet	1.5	0.0	46,699	0.007	0.073
6	Extremely Wet	1.7	-0.2	40,417	0.006	0.062
7	Critically Dry	-0.1	0.0	-512	0.01	0.02
7	Dry	-0.2	-0.1	-17,922	0.011	-0.002
7	Normal	-0.2	-0.1	-17,222	0.015	0.005
7	Wet	0.2	0.2	24,962	0	0.029
7	Extremely Wet	0.0	-0.1	-10,071	0.002	-0.016

Note: The mean annual differences in values were calculated by averaging the differences from each individual year and are not representative of the difference in mean values presented in Table 5-7.

5.4.2 Simulated Egg Survival and Emergence Timing

Annual egg survival estimates include the period from spawning to fry emergence. Simulated egg mortality can result from redd superimposition during spawning or naturally during incubation. Given a time-dependent egg mortality rate of 0.25 percent per day during incubation, cumulative egg survival would be 86% after 60 days and 79% after 90 days of simulated incubation time. Given the difference in time between spawning and emergence distributions (Figure 3-8), incubation time contributed to a large fraction of the egg mortality. Given an incubation time of 90 days, cumulative egg survival would be 79%, and any additional mortality in S3 would be due to superimposition mortality and changes in spawning habitat availability. Mean egg survival under the baseline was 67%, while mean egg survival by scenario ranged from 67% to 69% (Table 5-6; Figure 5-21, Figure 5-22). The largest average increase in egg survival was measured for Contract Water release Scenario 6, which resulted in a mean annual egg survival rate 2.6% higher than the baseline. Given this difference in egg survival rate, the total number of spawners (4,794 females), and the assumed fecundity (3,135 eggs per female), then Scenario 6 created about 81 more redds than the baseline. Note, as mentioned in Section 4.2.2, Scenario 6 results do not account for the potential effects of redd dewatering, as this is not explicitly incorporated into S3. Contract Water release scenarios 2, 4, 5, and 6 all produced a high frequency (> 90%) of simulated years with higher egg survival than the baseline (Table 5-6).

Emergence timing in S3 simulations is a function of water temperature during egg incubation. Within optimal temperatures for egg incubation, decreases in water temperature decrease egg maturation rates, which in turn, result in later fish emergence and lower egg survival. For example, later and more protracted emergence times and lower egg survival rates were apparent during extremely wet (and cooler) water year types (Figure 5-23; Table 5-7, Table 5-8, Table 5-9). There were no marked differences in emergence time across the Contract Water release scenarios. For example, Scenario 6 had the earliest median day of emergence across the water years at day 81 (March 22nd), whereas Scenarios 1, 3, 4, and the Baseline had the latest median day of emergence at day 83 (March 24th), a difference of only 2 days.

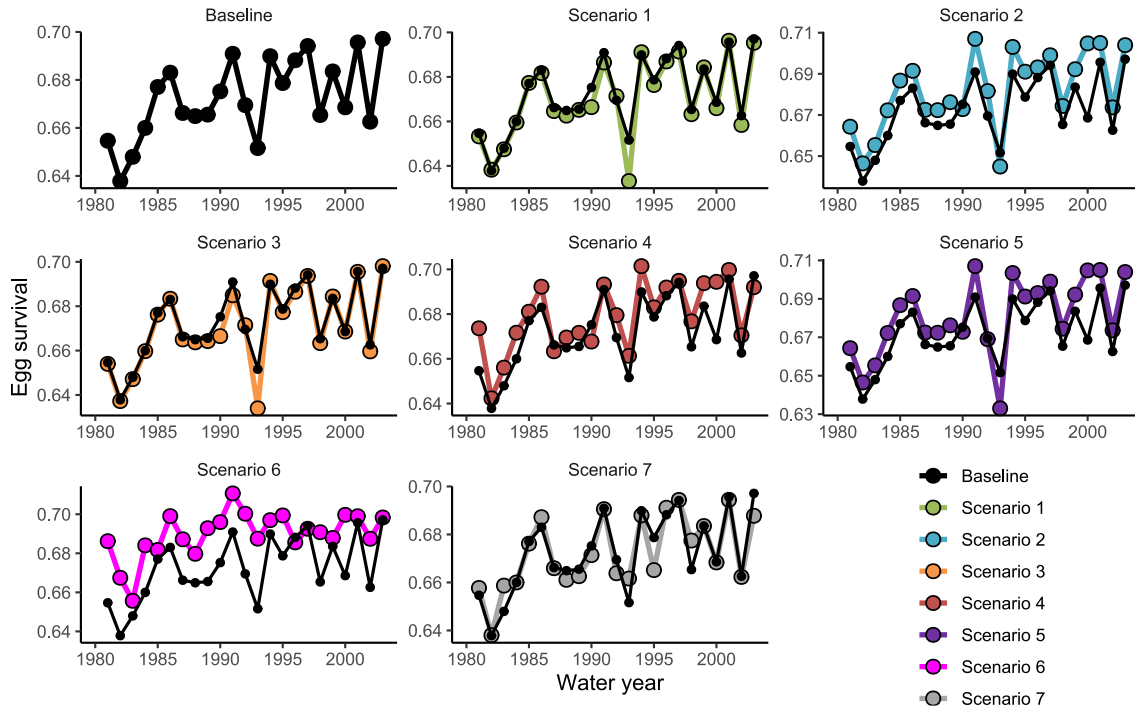


Figure 5-21. Time Series of Annual Egg Survival from Spawning to Emergence Within the Restoration Reach of the Trinity River, CA for All Scenarios.

Note: Annual egg survival is shown for each simulated Contract Water release scenario relative to the baseline.

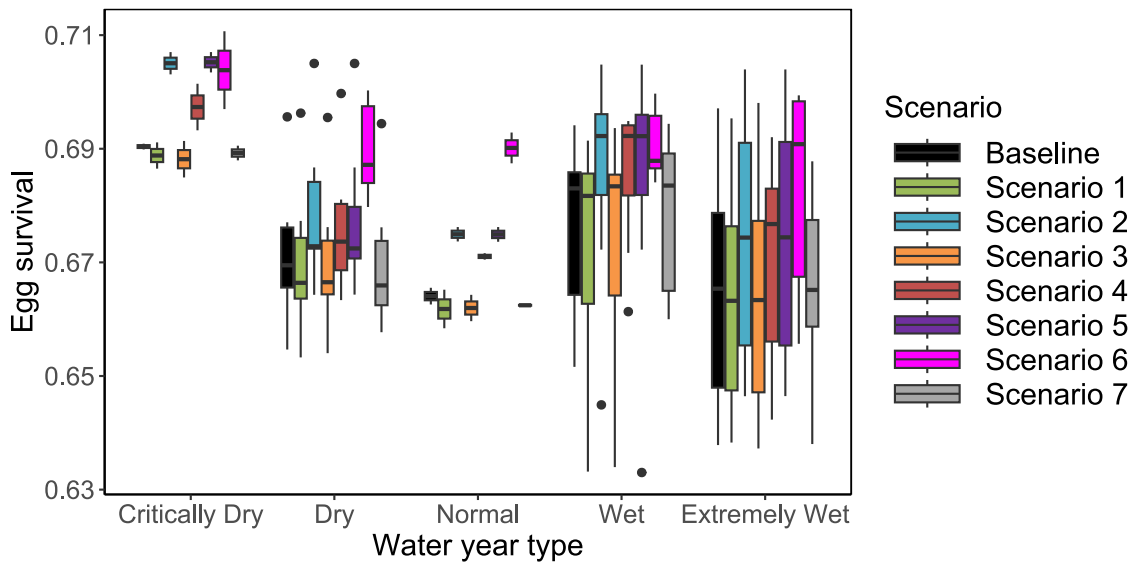


Figure 5-22. Boxplots of Mean Annual Egg Survival from Spawning to Emergence Within the Restoration Reach of the Trinity River, CA for All Scenarios.

Note: Annual egg survival is colored by the simulated Contract Water release scenario and grouped by water year type.

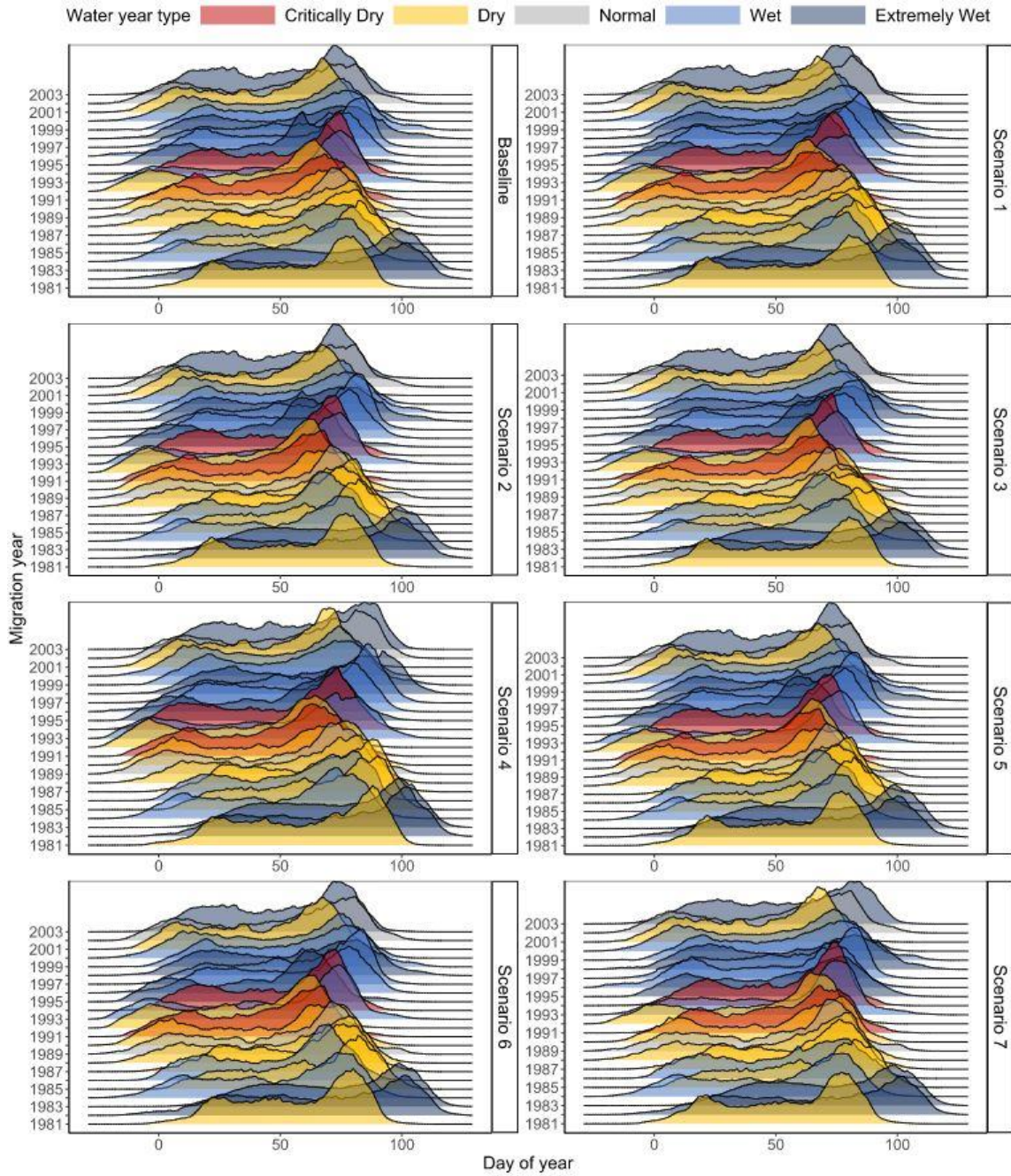


Figure 5-23. Emergence Timing Distributions of Juvenile Chinook Salmon as Simulated by the Stream Salmonid Simulator model (S3) in the Restoration Reach of the Trinity River, CA for All Scenarios.

Note: Plots are ordered by water year and colored by water year type. The origin for day of year is January 1.

5.4.3 Simulated Juvenile Survival, Abundance, and Size

Estimates of juvenile Chinook Salmon survival through the Restoration Reach of the Trinity River encompasses the time from emergence to passage of the Pear Tree reference site. Mean juvenile Chinook Salmon survival was similar across the Contract Water release scenarios ranging from 21.0% to 21.5% (Table 5-7, Figure 5-24). Scenario 4 had the highest water volume released and also had the largest positive effect on juvenile Chinook Salmon survival. Under Scenario 4, juvenile Chinook Salmon survival was, on average, 1.6% higher than juvenile survival under the baseline (Table 5-6). Over the simulated water years, Scenario 1 had the highest frequency (68%) of years with survival greater than the baseline. Scenario 4 had the second highest frequency (59%) of years with juvenile Chinook Salmon survival greater than the baseline.

Comparison of juvenile Chinook Salmon survival across water year types supported the conclusion that higher annual water volumes released from October through April under the proposed release patterns would modestly increase fish survival from emergence to Pear Tree (Table 5-7, Table 5-8, Table 5-9). All simulated scenarios showed slightly higher average survival in Extremely Wet years (range 22.3% to 22.8%) compared to survival in Critically Dry years (range 20.7% to 21.2%; Figure 5-25). The largest percent increase in survival relative to the baseline was in Scenario 4 (2.8%) during Dry water years (Table 5-8). Thus, even though Extremely Wet years were simulated to have higher juvenile Chinook Salmon survival, the increase in survival was relatively small (<2.8%) across the Contract Water release scenarios in comparison to the baseline. Many scenarios and water year types were also associated with modest decreases in survival relative to the baseline. For example, Scenario 2 resulted in lower survival to Pear Tree relative to the baseline in all water year types.

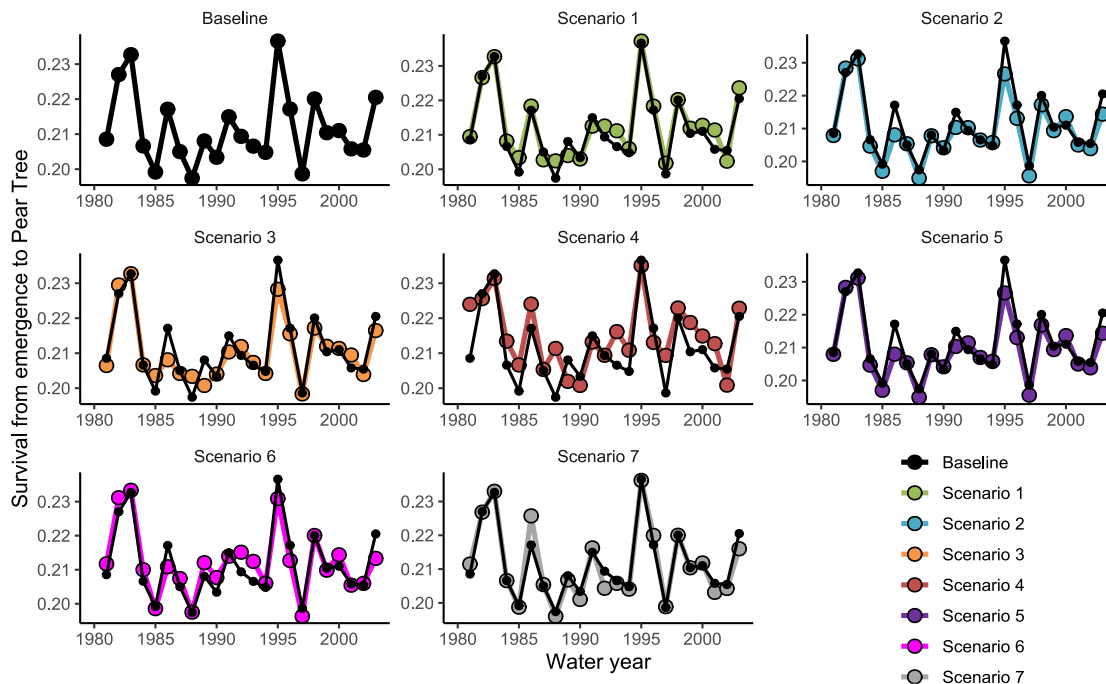


Figure 5-24. Time Series of Annual Juvenile Chinook Salmon Survival from Emergence to Passing Pear Tree at the End of the Restoration Reach of the Trinity River, CA for All Scenarios.

Note: Annual survival is shown by simulated Contract Water release scenario in contrast to the baseline.

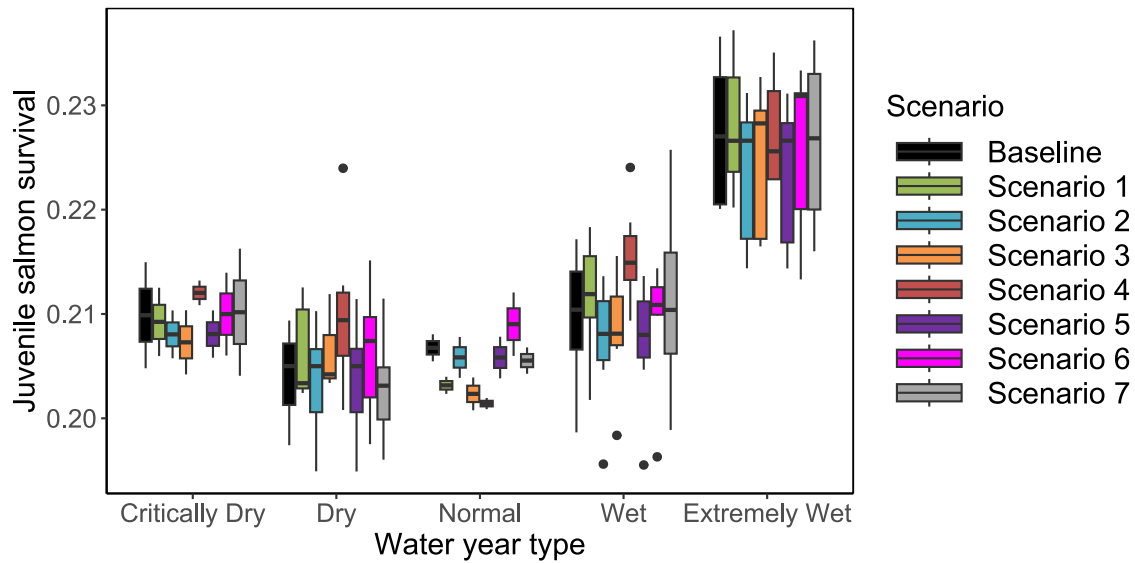


Figure 5-25. Boxplots of Mean Annual Juvenile Chinook Salmon Survival from Emergence to Pear Tree within the Restoration Reach of the Trinity River, CA for All Scenarios.

Note: Annual Survival is colored by the simulated Contract Water release scenario and grouped by water year type.

Variation in the annual abundance of simulated juvenile Chinook Salmon passing the Pear Tree reference site was the result of differences in survival between egg and juvenile life stages. For example, Scenario 6 had the greatest average increase (2.9%) in annual abundance relative to the baseline, which was in association with this scenario's high average egg and juvenile survival (Table 5-6; Figure 5-26, Figure 5-27). On average, Scenario 6 resulted in 59,673 more juvenile Chinook Salmon and Scenario 4 resulted in 56,295 more juvenile Chinook Salmon at Pear Tree than the baseline. Scenario 3 resulted in 14,904 fewer juvenile Chinook Salmon at Pear Tree than the baseline. Higher abundance was simulated during Critically Dry years compared to Dry, Normal, and Wet years due to the higher simulated egg and juvenile Chinook Salmon survival during Critically Dry conditions (Table 5-7, Table 5-8, Table 5-9). Interestingly, Scenario 6 released about one third of the water volume as Scenario 4, yet Scenario 6 was associated with higher estimates of abundance across the water year types, indicating that the timing of water releases with respect to early life stages may be just as influential to fish population dynamics as the total amount of water released.

The abundance of fish arriving at Pear Tree over time reflected fish emergence times, with later emerging fish arriving at Pear Tree later in the year (Figure 5-28). There were no marked differences in arrival at Pear Tree across the Contract Water release scenarios. However, in a similar fashion as emergence timing, Extremely Wet years were associated with a later and more protracted emigration of fish passing Pear Tree. Likewise, there was a tendency for fish to emigrate earlier in Critically Dry and Dry water year types.

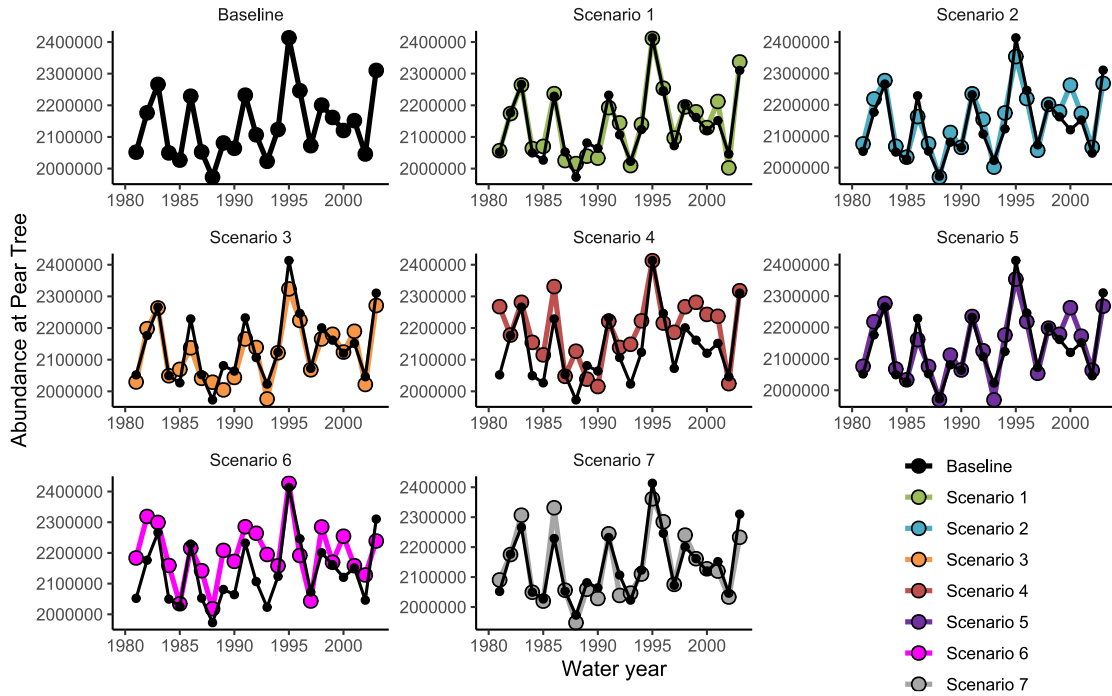


Figure 5-26. Time Series of Annual Juvenile Chinook Salmon Abundance Passing Pear Tree at the End of the Restoration Reach of the Trinity River, CA for All Scenarios.

Note: Annual abundances are shown by simulated Contract Water release scenario in contrast to the baseline.

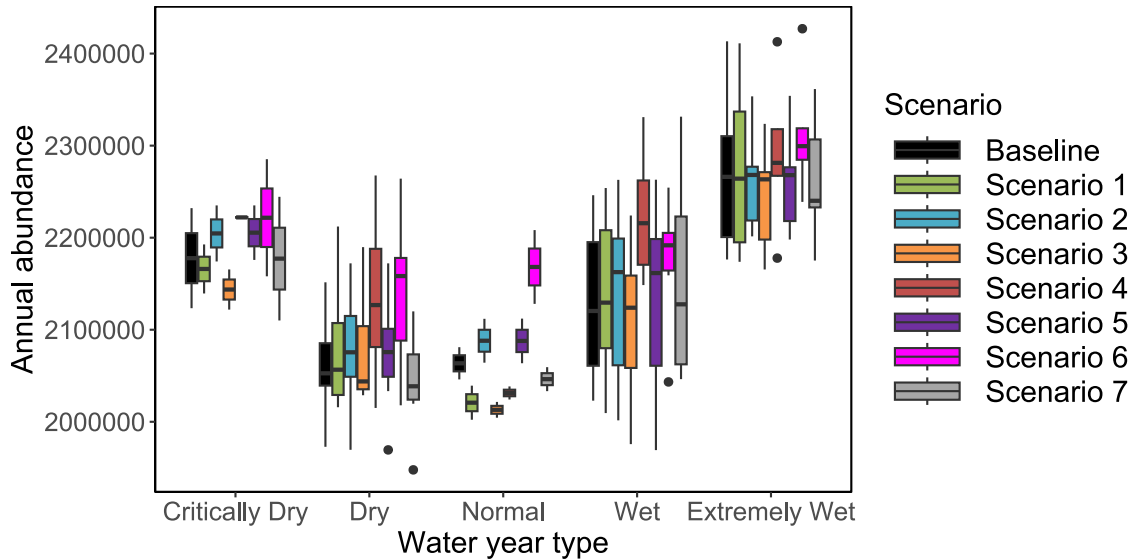


Figure 5-27. Boxplots of Mean Annual Juvenile Chinook Salmon Abundance Passing Pear Tree at the End of the Restoration Reach of the Trinity River, CA for All Scenarios.

Note: Annual Abundance is colored by the simulated Contract Water release scenario and grouped by water year type.

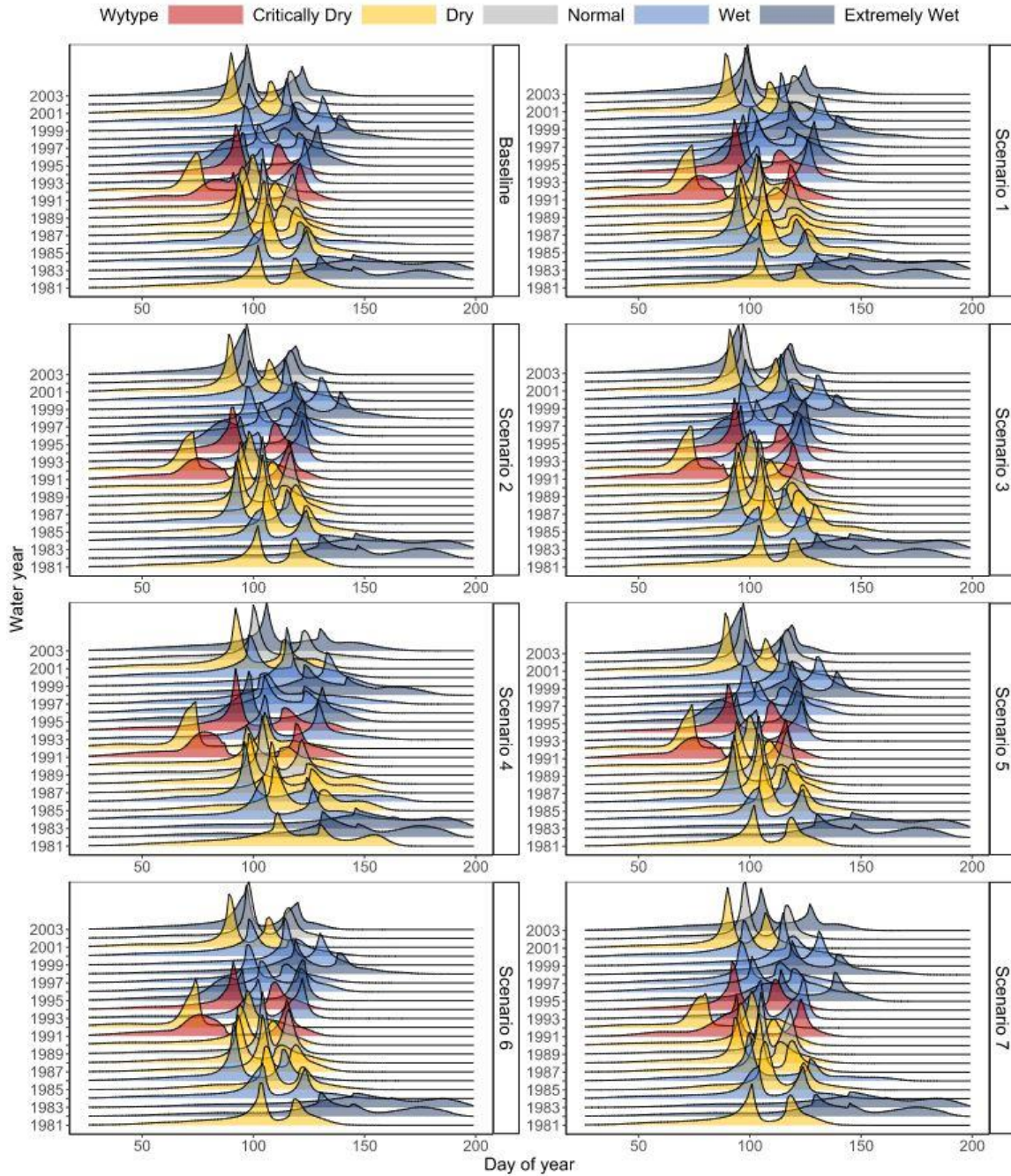


Figure 5-28. Emigration Timing Distributions of Juvenile Chinook Salmon passing Pear Tree as Simulated by the Stream Salmonid Simulator model (S3) in the Restoration Reach of the Trinity River, CA for All Scenarios.

Note: Plots are ordered by water year and colored by water year type. The origin for day of year is January 1.

The size of simulated fish passing the Pear Tree reference site is a consequence of fish travel time and the intervening water temperatures during emigration. Scenario 4 with the largest (and cooler during spring months) volume of Contract Water released was associated with the greatest reduction in fish size at Pear Tree (Figure 5-29, Figure 5-30). On average, Scenario 4 reduced the size of fish passing Pear Tree by about 5.4% relative to the baseline, with just 13% of simulated water years resulting in greater fish size than the baseline (Table 5-6). Scenario 1 also released a large volume of cooler Contract Water in the spring, which resulted in reduced fish size similar to Scenario 4. Scenario 5 had the largest positive effect on fish size, increasing fish size by 0.6% relative to the baseline. Scenario 5 resulted in 54% of water years with greater average fish size than the baseline. Simulations also indicated a clear reduction in average fish sizes in wetter and cooler water year types (Table 5-7, Table 5-8, Table 5-9).

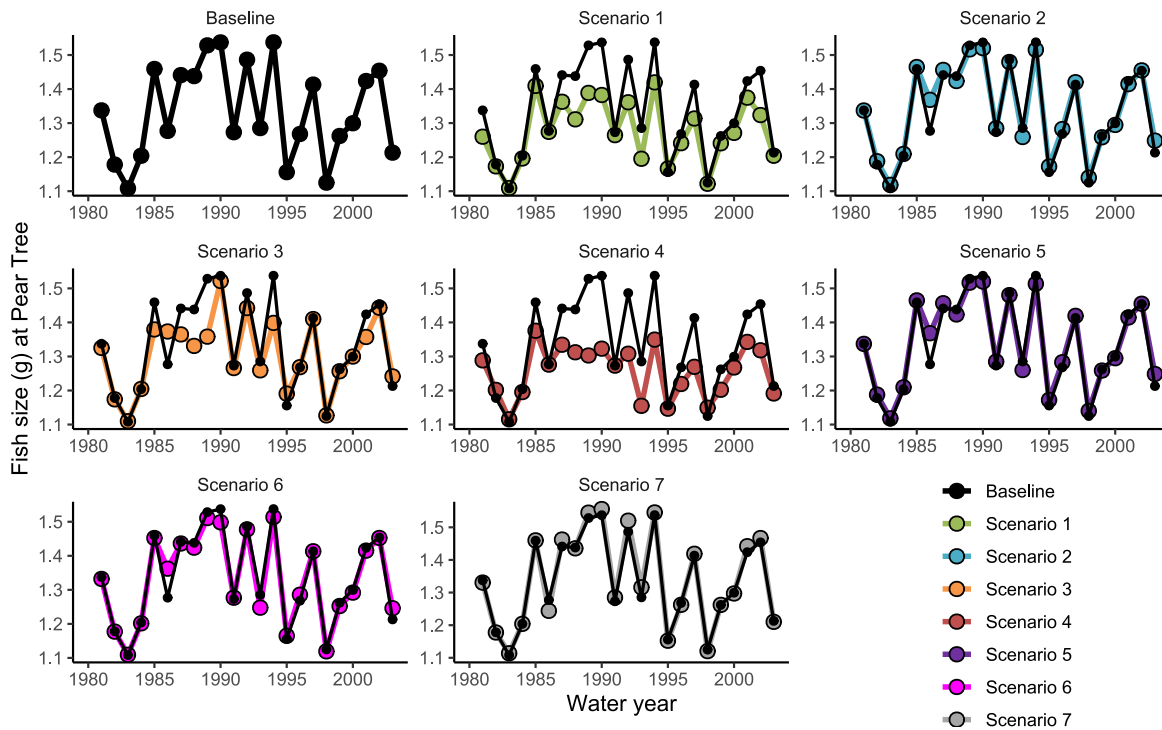


Figure 5-29. Time Series of Annual Size (grams) of Juvenile Chinook Salmon Passing Pear Tree at the End of the Restoration Reach of the Trinity River, CA for All Scenarios.

Note: Annual size is shown by simulated Contract Water release scenario in contrast to the baseline.

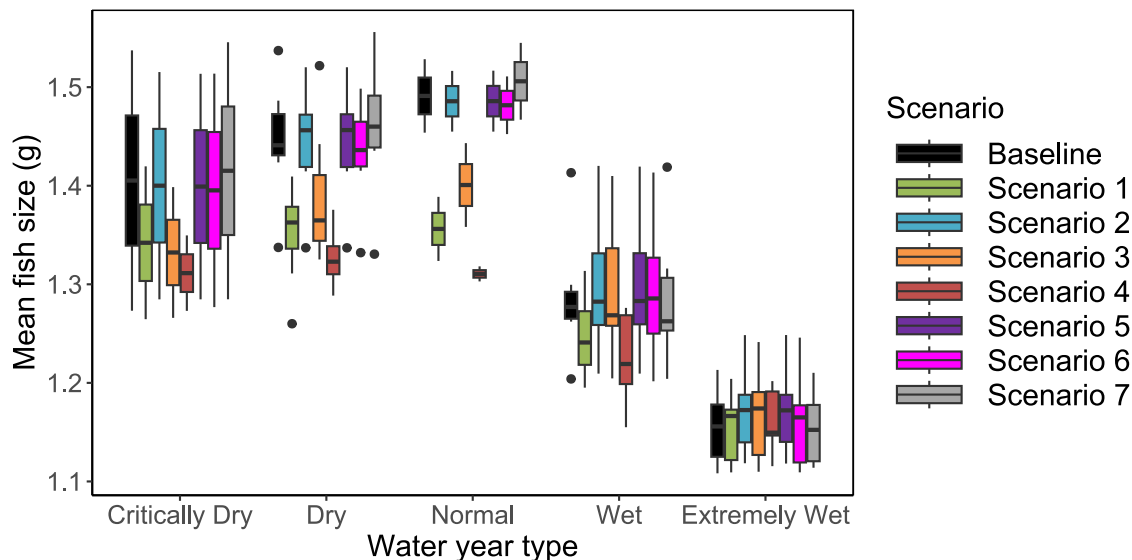


Figure 5-30. Boxplots of Mean Annual Juvenile Chinook Salmon Size at Pear Tree Within the Restoration Reach of the Trinity River, CA for All Scenarios.

Note: Annual size is colored by the simulated Contract Water release scenario and grouped by water year type.

The annual biomass of juvenile Chinook Salmon at Pear Tree is the product of the mean annual fish size and mean annual abundance. As a consequence of the higher abundance, simulations of Scenario 6 resulted in higher average biomass (2.8%) compared to the baseline (Table 5-6; Figure 5-31, Figure 5-32). In accordance with their smaller average fish sizes, Scenarios 1 and 4 resulted in the largest reductions (-2.8% and -3.9%, respectively) in fish biomass at Pear Tree relative to the baseline. The effect of water year type on biomass was apparent across the Contract Water release scenarios (Table 5-7, Table 5-8, Table 5-9). For example, even though Scenario 6 often resulted in higher average biomass, a marked decrease in biomass at Pear Tree was evident during Wet and Extremely Wet water year types. Although S3 simulated generally higher abundances during wetter conditions and years, this reduction in biomass was a consequence of reduced fish size (Figure 5-27).

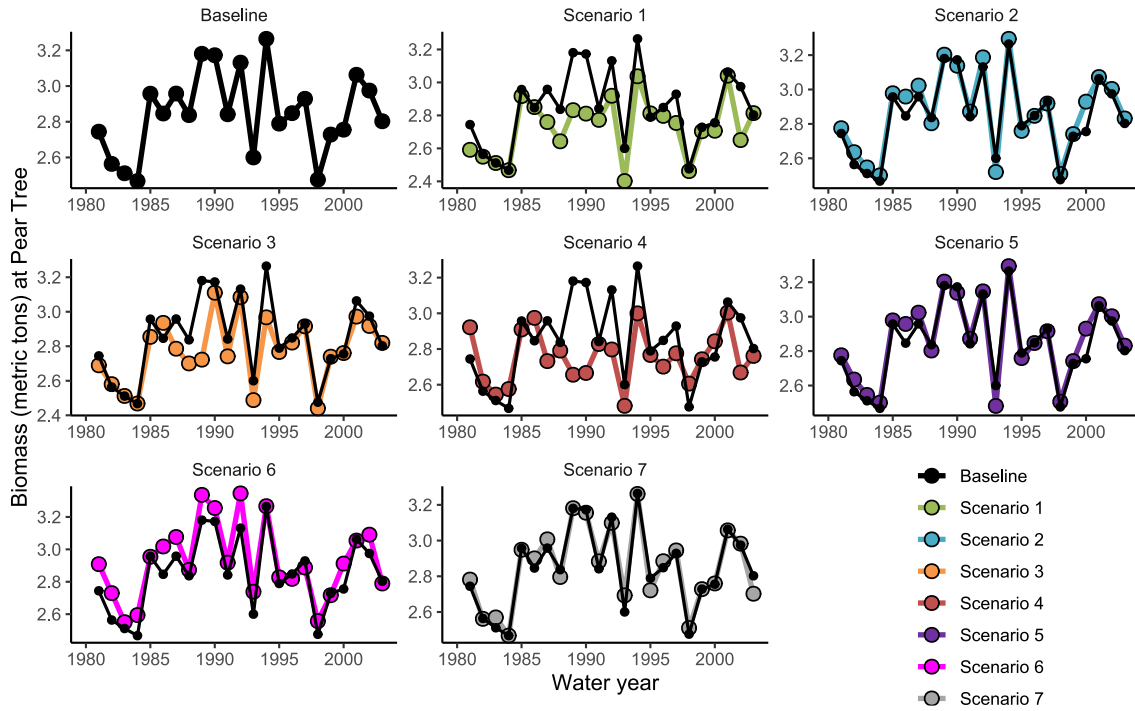


Figure 5-31. Time Series of Annual Biomass (metric tons) of Juvenile Chinook Salmon Passing Pear Tree at the End of the Restoration Reach of the Trinity River, CA for All Scenarios.

Note: Annual biomass is shown by simulated Contract Water release scenario in contrast to the baseline.

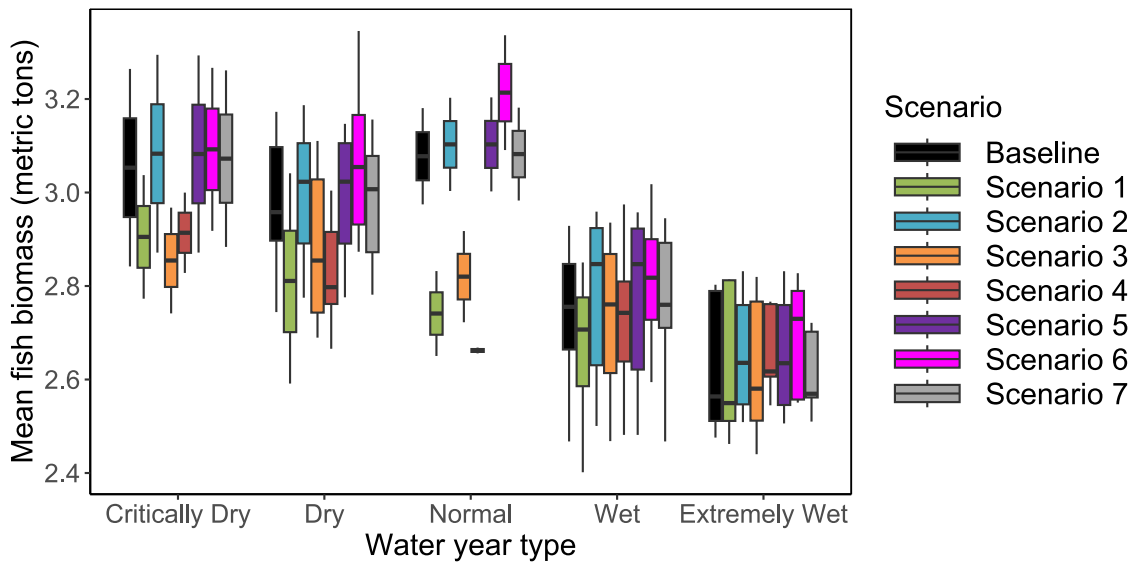


Figure 5-32. Boxplots of Mean Annual Juvenile Chinook Salmon Biomass (metric tons) at Pear Tree within the Restoration Reach of the Trinity River, CA for All Scenarios.

Note: Annual biomass is colored by the simulated Contract Water release scenario and grouped by water year type.

5.5 Sediment

5.5.1 Coarse Bedload Transport

The annual yield of coarse bedload for each scenario was analyzed by summing the daily transport for all six reaches in tons/day to total volume in tons across the total period, divided by 23.75 years. Annual coarse bedload transported throughout Restoration Reach is shown in Figure 5-33. Scenario 4 was the only scenario to explicitly include sediment transport as an objective and produced the largest increase from the baseline of 14% annually. Scenarios 3 and 7 were the only other scenarios to increase the magnitude of high flow events in the spring through pulses and larger magnitude safety-of-dams releases, respectively. Scenario 3 transported about 5,000 tons per year more than the baseline, around a 7% increase, and Scenario 7 transported 8% more bedload than the baseline. Scenario 1 transported the same amount of bedload as the Baseline. Scenarios 2, 5, and 6 all transported slightly less bedload, as the early fall pulses and baseflow releases reduced storage in Trinity Reservoir prior to the winter season, which typically reduced the magnitude of the required safety-of-dams releases during the winter and spring.

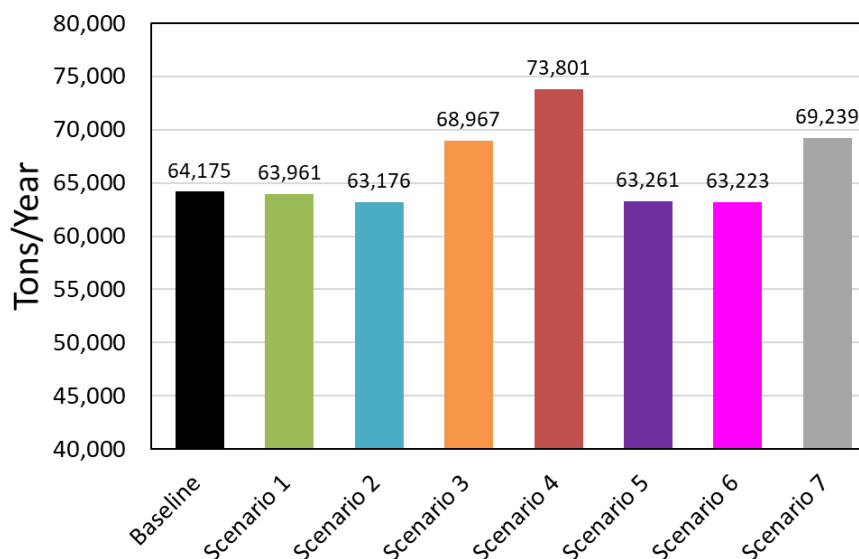


Figure 5-33. Annual Yield of Coarse Bedload in Tons/Year for All Scenarios.

The annual sediment transport for each reach was analyzed by summing the daily transport in tons/day to total volume in tons across the total period, divided by 23.75 years. Figure 5-34 shows the difference in annual average bedload yield in tons per year in each reach for each scenario relative to the Baseline. Sediment transport varies from upstream to downstream, with the three most downstream reaches transporting most of the additional bedload for Scenarios 3, 4, and 7, which emphasizes the influence of additional downstream tributary inflows on sediment transport. Although additional annual sediment yield in scenarios 3 and 4 in the upper three reaches was minimal (+100 to 600 tons/year) relative to the downstream reaches, the majority of redds are established in the reach directly below Lewiston (based on 2007, 2012, and 2014 surveys; Figure 3-8, Gaeuman et al. 2023), so this increase in sediment yield could still have a large impact on spawning habitat. The sediment rating curve for TRDC is more sensitive than at the upstream sites, with the equation suggesting potential transport at flows as low as 1,000 cfs. Presumably this is based on the sediment supplied from tributaries that create a finer, more mobile substrate. Scenario 3 experienced a 7% increase in annual yield relative to the baseline while Scenario 4 experienced a 14% increase in annual yield—double the increase of Scenario 3.

This is because Scenario 4 added on fall and winter biologic pulses every year in addition to the geomorphic pulses, which, even though they are only designed to peak at 3,000 cfs, would be enough to transport sediment in the downstream reaches based on the rating curve.

The annual amount of sediment transported in relation to the year, water year type, and whether a geomorphic pulse occurred (for Scenario 3 and 4) is shown in Figure 5-35. The 14 wetter years, mostly Wet and Extremely Wet (~60% of the modeled years) were responsible for most of the sediment transport which occurred. Notably, this graph shows that 1995 was the year responsible for most of the bedload transport in Scenario 7. This is because a large volume of Contract Water carryover that accumulated during several preceding dry years was evacuated during a safety-of-dams release during the Extremely Wet 1995 water year, which led to a modeled 6,000 cfs release for a month in that year.

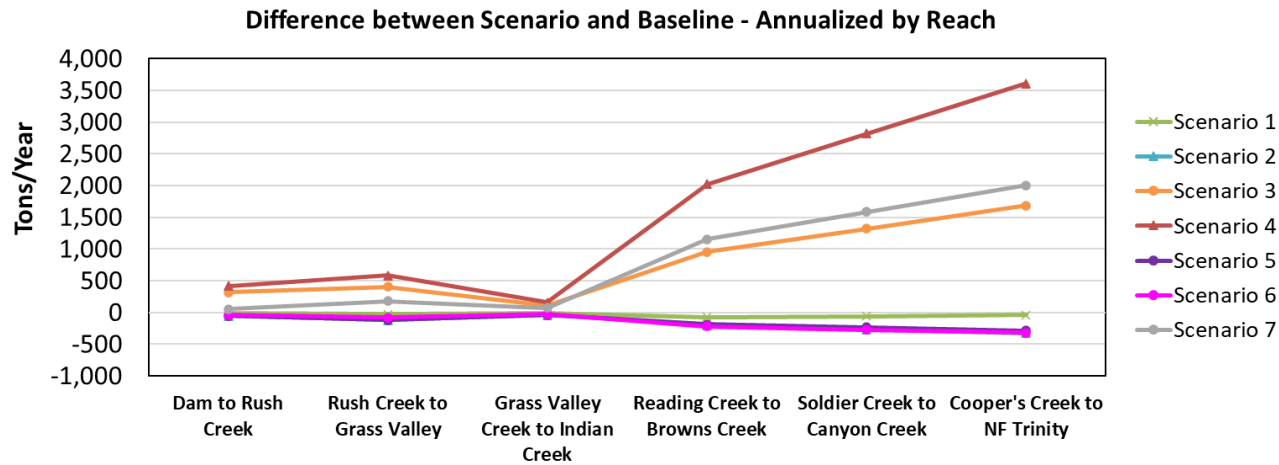


Figure 5-34. Difference Between Scenario and Baseline in the Annual Yield of Coarse Bedload by Reach.

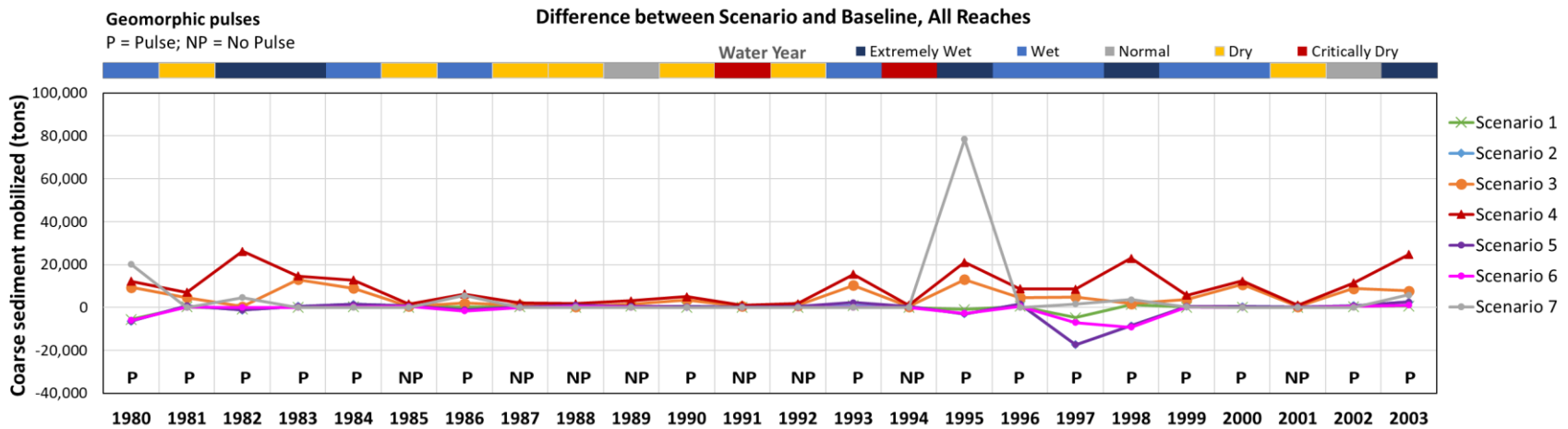


Figure 5-35. Difference Between Scenario and Baseline of the Annual Bedload Yield in Tons Summed Across All Reaches.

Note: Water year type and geomorphic pulse for Scenario 3 and 4 indicated for each year.

5.5.2 Partial Bed Mobilization

Figure 5-36 shows the average percent change in fraction of streambed mobilized in each reach relative to the Baseline across all years. Scenarios 1, 2, 5, 6, and 7 showed almost no difference relative to the Baseline. Scenario 3 and 4 both showed a similar pattern, with increases of 4-10% of the fraction of bed mobilized on average in each reach, but generally greatest in the two downstream reaches between Weaver Creek and Canyon Creek.

The interannual variability is shown in Figure 5-37 as the percent change in the fraction of bed mobilized in each year, averaged across the six reaches, in relation to the year, water year type, and whether a geomorphic pulse occurred for scenario 3 and 4. As expected, a geomorphic pulse (initiated in scenarios 3 and 4) was required to see any increase in percent of bed mobilized, due to the minimum flow of 4,000 cfs required to initiate streambed mobilization. There was less of a trend relative to bedload transport of partial bed mobilization being positively correlated with wet years and years with a geomorphic pulse. Additionally, for Scenario 7, when a large safety-of-dams release was made in 1995 causing a large amount of coarse bedload mobilization (as described in section 5.4.1. above), there was not a proportionally large increase in the fraction of bed mobilized. These trends seen in Scenarios 3, 4, and 7 are due to the fact that, unlike coarse bedload yield which is a function of volume and magnitude of daily flows across the entire hydrograph, the maximum annual fraction of bed mobilized is a function of the maximum flow for the water year, hence why partial bed mobilization does not correlate as strongly with the water year type. There were only five years with a notably significant increase in fraction of bed mobilized (>10%).

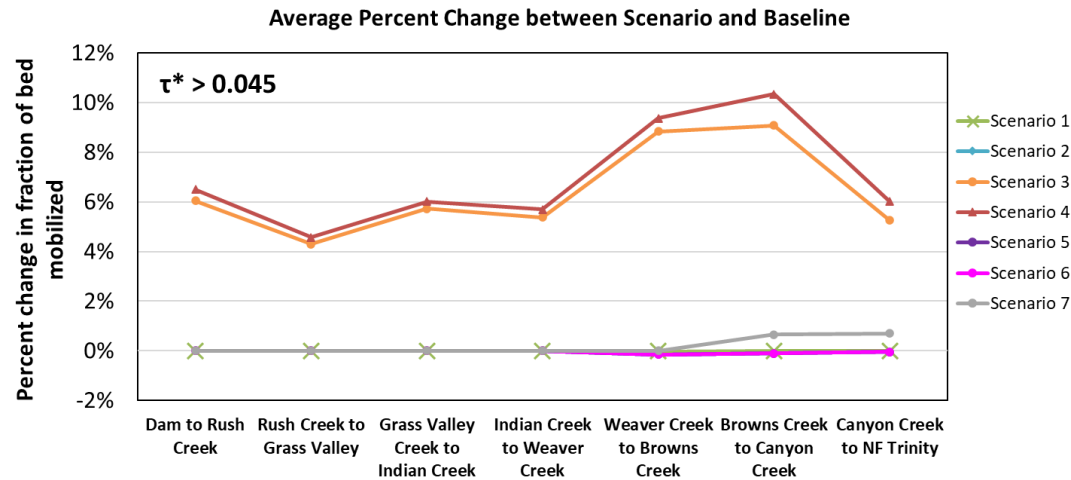


Figure 5-36. Mean Percent Change in Fraction of Bed Mobilized Across All Years Relative to Baseline. τ^* = Shields Stress.

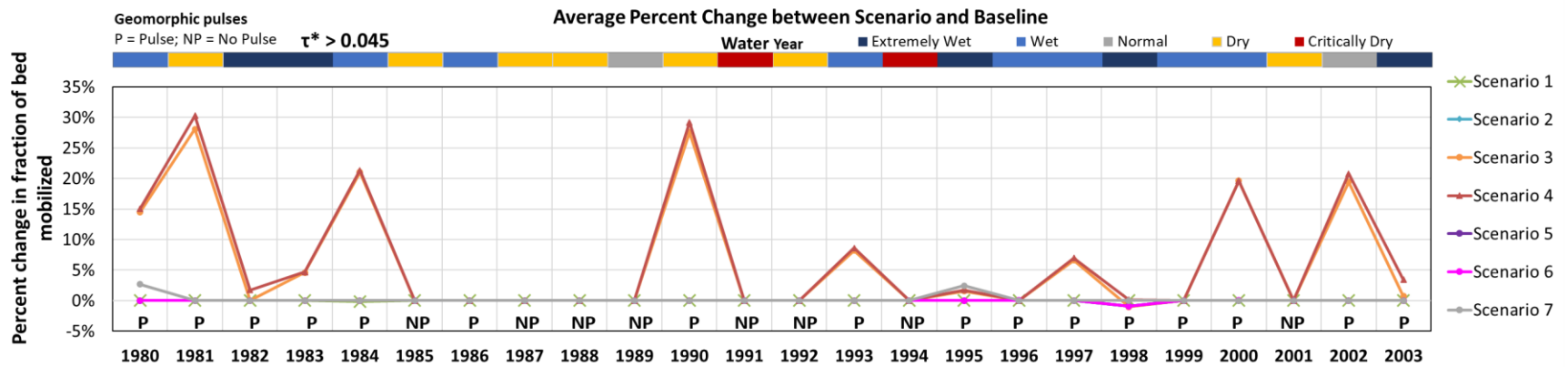


Figure 5-37. Percent Change in Fraction of Bed Mobilized for Each Year Across All Reaches Relative to Baseline.

Note: Water year type and geomorphic pulse for Scenario 3 and 4 indicated for each year. τ^* = shields stress.

5.6 CVP Effects

CalSim II and HEC-5Q were used in combination to model and assess the effects of each scenario on TRD exports to the CVP, total CVP deliveries to NOD and SOD contractors, Shasta Reservoir storage, and water temperatures on the Sacramento River. This section summarizes results from all scenarios for the simulation period of 1922 – 2003.

5.6.1 General Observations

The release of 50 TAF or more of Contract Water down the Trinity River resulted in lower Trinity Reservoir storage levels, which reduced TRD exports to the Sacramento Valley. This resulted in reductions in water supply deliveries to CVP contractors relative to the baseline, as discussed in Section 3.1.2. The operation also resulted in changes to Shasta storage and releases – when TRD exports were reduced, there was less streamflow in the Sacramento River, and Shasta was operated to make up that streamflow to the extent possible to minimize effects on aquatic species. The key takeaways of the effect of Contract Water releases on the CVP system include:

- Most scenarios that release 50 TAF had similar effects on the CVP contract deliveries and Sacramento River water temperatures regardless of the timing of Contract Water releases. That is, fall releases resulted in the same effects as spring releases.
- The reduction of TRD exports did not have a notable effect on Clear Creek water temperatures. Changes to Sacramento River water temperatures were primarily a result of Lake Shasta operations that were modified to offset the effect of reduced TRD exports.

5.6.2 Trinity River Division Exports

Trinity River Division exports to the CVP were modeled in CalSim II on a mean monthly basis. As described in Section 3.1.2, TRD exports were reduced by various amounts to balance the release of Contract Water down the Trinity River.

Mean monthly TRD exports are shown in Figure 5-38 and Table 5-10, and mean monthly releases by water year type throughout the entire simulation period are shown in Figure 5-39. Key takeaways include the following:

- Mean annual reductions in TRD exports are around 40 TAF for scenarios 1 – 3 and 5 – 7. In wetter years, Trinity Reservoir is able to fill with additional water once Contract Water is released, resulting in less than 50 TAF (-8%) reduction in TRD exports relative to the baseline. For Scenario 4, mean annual reductions in TRD exports were 170 TAF (-36%) relative to the baseline to offset the release of Contract Water.
- TRD exports are highest in July through October, and these months have the greatest reductions in exports relative to the baseline. The result in export cuts is a reduction in Trinity Reservoir releases (see Section 5.1.2) and in some cases an increase in Trinity Reservoir release temperature (see Section 5.1.3).

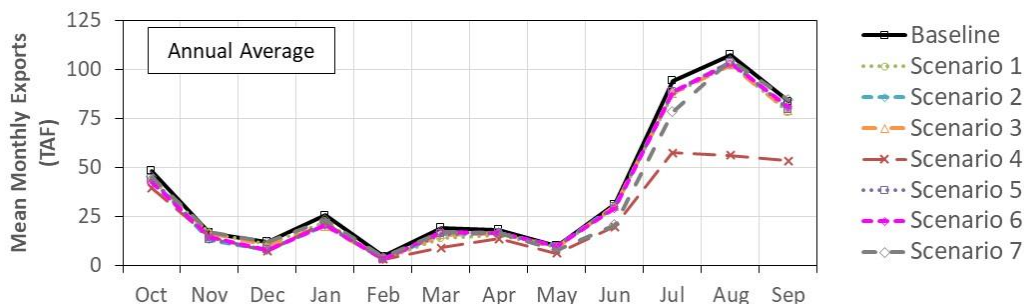


Figure 5-38. Mean Monthly Trinity River Division Exports in Thousand Acre-Feet (TAF) for All Scenarios.

Table 5-10. Mean Monthly Trinity River Division Exports in Thousand Acre-Feet (TAF) for All Scenarios.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Baseline	48	17	12	25	5	19	18	10	31	94	107	84	471
Scenario 1	44	16	11	22	3	14	16	10	30	88	102	78	433
Diff (TAF)	-5	0	-1	-3	-1	-6	-2	0	-1	-7	-5	-6	-38
Diff (%)	-10	-2	-10	-12	-30	-29	-13	-5	-5	-7	-5	-7	-8
Scenario 2	44	13	8	21	3	16	17	10	30	89	104	80	434
Diff (TAF)	-4	-3	-4	-5	-1	-3	-2	0	-1	-6	-4	-4	-38
Diff (%)	-8	-21	-35	-19	-31	-16	-8	-4	-4	-6	-3	-5	-8
Scenario 3	44	17	11	20	3	16	17	10	30	88	102	79	435
Diff (TAF)	-4	0	-2	-6	-1	-4	-2	0	-1	-6	-5	-5	-36
Diff (%)	-9	0	-13	-22	-31	-19	-9	-5	-3	-7	-5	-6	-8
Scenario 4	40	15	7	22	3	9	14	6	20	57	56	53	302
Diff (TAF)	-9	-2	-5	-4	-2	-10	-5	-4	-11	-37	-51	-30	-169
Diff (%)	-18	-13	-39	-15	-36	-53	-25	-37	-37	-39	-48	-36	-36
Scenario 5	44	13	8	21	3	16	17	10	30	88	104	80	434
Diff (TAF)	-4	-3	-4	-5	-1	-3	-2	0	-1	-6	-4	-4	-38
Diff (%)	-8	-19	-34	-19	-31	-16	-8	-4	-4	-6	-4	-5	-8
Scenario 6	42	14	8	21	3	17	16	10	29	89	103	81	433
Diff (TAF)	-6	-2	-4	-5	-2	-2	-2	0	-2	-6	-4	-3	-38
Diff (%)	-13	-13	-33	-19	-34	-13	-10	-4	-7	-6	-4	-3	-8
Scenario 7	45	17	12	23	4	17	17	8	21	78	105	84	431
Diff (TAF)	-3	0	0	-2	-1	-2	-2	-2	-10	-16	-3	1	-40
Diff (%)	-6	2	-1	-9	-13	-11	-9	-21	-34	-17	-3	1	-9

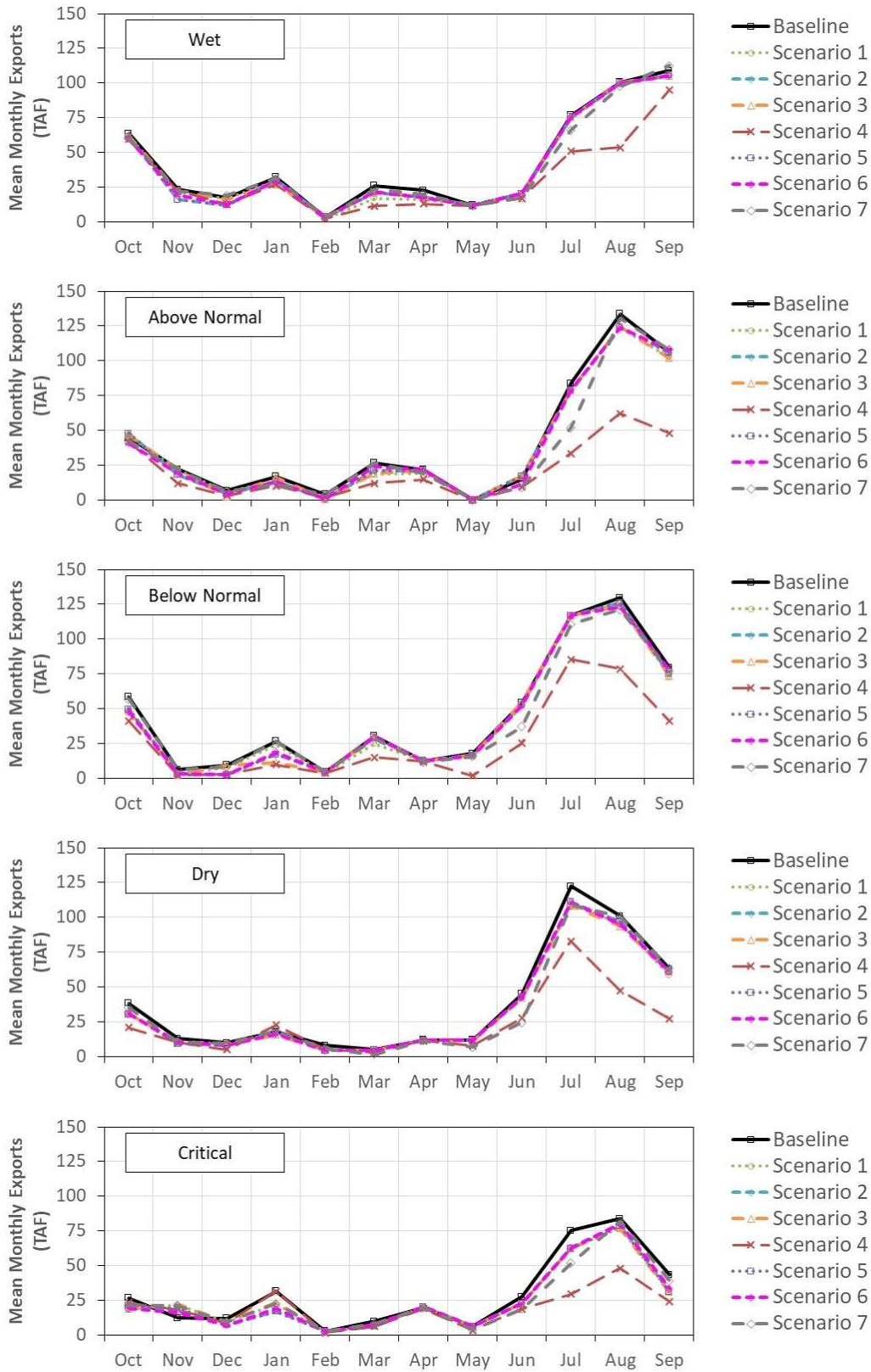


Figure 5-39. Mean Monthly Trinity River Division Exports in Thousand Acre-Feet (TAF) for All Scenarios by Sacramento Valley Water Year Type.

5.6.3 Total CVP Deliveries to NOD and SOD Contractors

Total CVP deliveries to NOD and SOD contractors were modeled in CalSim II on a mean monthly basis. As described in Section 3.1.2, CVP delivery reductions were balanced by Lake Shasta releases in different ways depending on the scenario to balance the release of Contract Water down the Trinity River.

Mean monthly CVP deliveries to NOD and SOD contractors are shown in Figure 5-40 and Table 5-11, and mean monthly CVP deliveries by water year type are shown in Figure 5-41. Key takeaways include the following:

- Mean annual reductions in CVP deliveries are primarily a result of reductions in TRD exports. For scenarios 1 – 3 and 5, Lake Shasta was allowed to release more water and drop storage slightly lower relative to the baseline to make up the difference in CVP delivery cuts. This resulted in mean annual reductions in CVP deliveries of about 10 TAF (-0.2%) relative to the baseline for these scenarios.
- For Scenario 4, to offset the larger reduction in TRD exports due to larger Contract Water release volumes, CVP deliveries were cut and Lake Shasta was allowed to release more water relative to the baseline. This resulted in mean annual reductions in CVP deliveries of 210 TAF (-4.6%) relative to the baseline.
- Scenarios 6 and 7 were operated similar to Scenario 4 – CVP deliveries were cut, but Lake Shasta was operated to maintain storage similar to the baseline. This required greater cuts to CVP deliveries than Scenarios 1 – 3 and 5, resulting in annual CVP delivery reductions of 34 TAF (-0.7%) and 57 TAF (-1.2%) relative to the baseline for Scenario 6 and 7, respectively.
- CVP delivery reduction magnitudes were similar across all years for Scenarios 1 – 3 and 5 – 7. For Scenario 4, CVP delivery reductions were greater in wetter years and less in drier years.

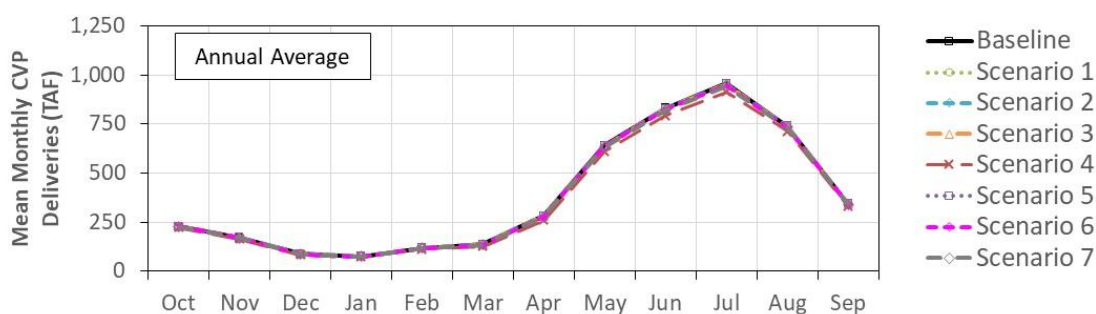


Figure 5-40. Mean Monthly CVP Deliveries to NOD and SOD Contractors in Thousand Acre-Feet (TAF) for All Scenarios.

Table 5-11. Mean Monthly CVP Deliveries to NOD and SOD Contractors in Thousand Acre-Feet (TAF) from the Trinity River Division for All Scenarios.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Baseline	229	170	88	77	120	137	283	640	831	956	740	343	4,614
Scenario 1	228	170	88	77	120	136	282	639	829	954	739	342	4,604
Diff (TAF)	-2	1	0	0	0	0	-1	-2	-2	-2	-1	-1	-11
Diff (%)	-0.7	0.5	-0.3	-0.1	-0.1	-0.3	-0.3	-0.3	-0.2	-0.2	-0.2	-0.3	-0.2
Scenario 2	228	171	88	77	120	136	282	639	829	954	739	343	4,605
Diff (TAF)	-2	1	0	0	0	-1	-1	-2	-2	-2	-1	-1	-10
Diff (%)	-0.7	0.8	-0.3	-0.1	-0.1	-0.4	-0.4	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2
Scenario 3	228	171	88	77	120	136	282	639	829	954	739	342	4,604
Diff (TAF)	-2	1	0	0	0	-1	-1	-2	-2	-2	-1	-1	-10
Diff (%)	-0.7	0.6	-0.3	-0.1	-0.1	-0.4	-0.3	-0.3	-0.2	-0.2	-0.2	-0.3	-0.2
Scenario 4	222	163	83	72	114	125	262	611	793	915	713	331	4,404
Diff (TAF)	-7	-7	-5	-5	-6	-11	-21	-29	-38	-41	-27	-13	-210
Diff (%)	-3.2	-3.9	-5.4	-6.7	-5.1	-8.2	-7.5	-4.6	-4.6	-4.2	-3.7	-3.7	-4.6
Scenario 5	228	171	88	77	120	136	282	639	829	954	739	342	4,604
Diff (TAF)	-2	1	0	0	0	-1	-1	-2	-2	-2	-1	-1	-10
Diff (%)	-0.7	0.8	-0.4	-0.1	-0.1	-0.4	-0.4	-0.3	-0.2	-0.2	-0.2	-0.3	-0.2
Scenario 6	228	170	88	76	119	135	279	635	825	950	735	341	4,580
Diff (TAF)	-2	0	-1	0	0	-2	-4	-6	-6	-6	-5	-2	-34
Diff (%)	-0.7	0.0	-0.7	-0.6	-0.4	-1.6	-1.4	-0.9	-0.7	-0.6	-0.7	-0.6	-0.7
Scenario 7	226	168	87	75	118	134	277	633	820	944	735	340	4,558
Diff (TAF)	-3	-1	-1	-2	-2	-3	-6	-7	-11	-12	-5	-3	-57
Diff (%)	-1.4	-0.7	-1.4	-2.2	-1.7	-2.2	-2.0	-1.2	-1.3	-1.3	-0.7	-0.9	-1.2

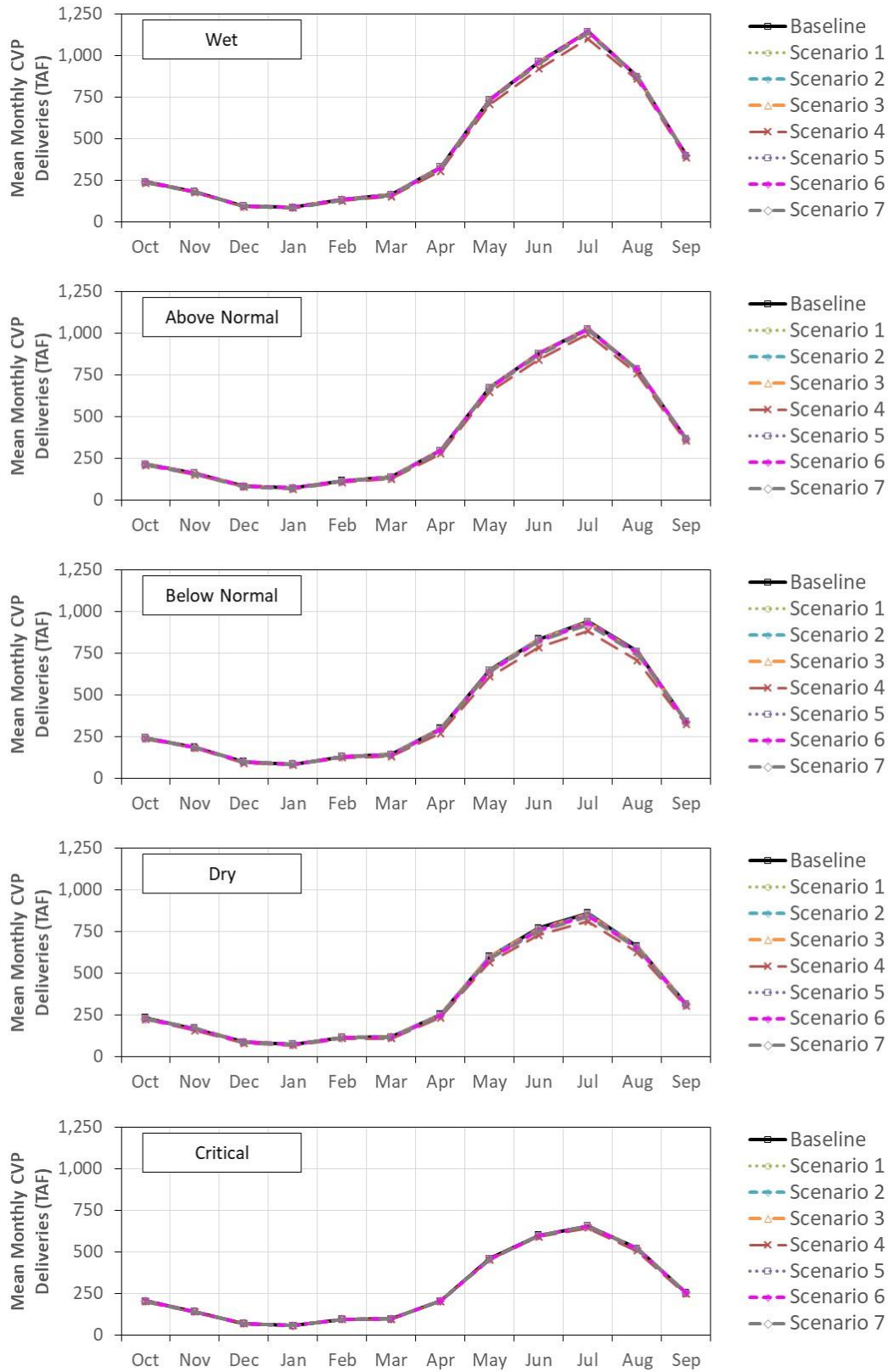


Figure 5-41. Mean Monthly CVP Deliveries to NOD and SOD Contractors in Thousand Acre-Feet (TAF) for All Scenarios by Sacramento Valley Water Year Type.

5.6.4 Lake Shasta Storage

Total Lake Shasta storage was modeled in CalSim II on a mean monthly basis. As described in Section 3.1.2, CVP delivery reductions were balanced by Lake Shasta releases in different ways depending on the scenario to balance the release of Contract Water down the Trinity River.

Mean monthly Lake Shasta storage is shown in Figure 5-42 and Table 5-11, and mean monthly CVP deliveries by water year type are shown in Figure 5-43. Key takeaways include the following:

- Mean annual reductions in Lake Shasta storage are primarily a result of increased releases that offset the reduction in TRD exports. For scenarios 1 – 3 and 5, Lake Shasta was allowed to release more water and drop storage slightly lower relative to the baseline to make up the difference in CVP delivery cuts. This resulted in mean annual Lake Shasta storage reductions of around 20 TAF (-0.5%) relative to the baseline for these scenarios.
- For Scenario 4, to offset the larger reduction in TRD exports due to larger Contract Water release volumes, CVP deliveries were cut, and Lake Shasta was allowed to release only slightly more water relative to the baseline. This resulted in mean annual Lake Shasta storage reductions of around 6 TAF (-0.2%) relative to the baseline.
- Scenarios 6 and 7 were operated similar to Scenario 4 – CVP deliveries were cut, but Lake Shasta was operated to maintain storage similar to the baseline. This required greater cuts to CVP deliveries than Scenarios 1 – 3 and 5, but mean annual Lake Shasta storage reductions were only 6 TAF (-0.2%) less than the baseline.
- CVP delivery reduction magnitudes were similar across all years for Scenarios 1 – 3 and 5 – 7. For Scenario 4, CVP delivery reductions were greater in wetter years and less in drier years.

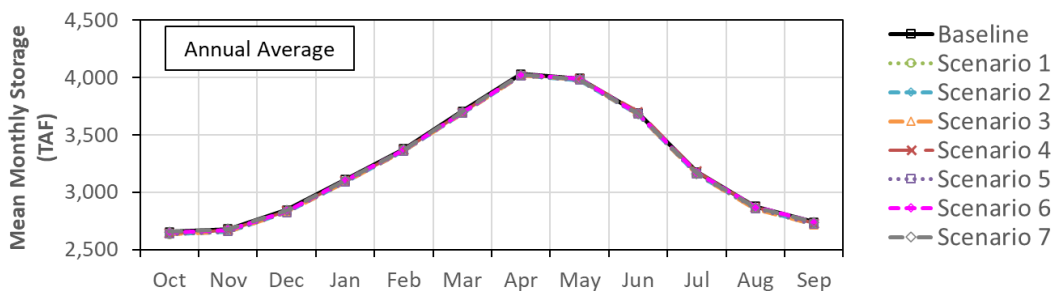


Figure 5-42. Lake Shasta Mean Monthly Storage in Thousand Acre-Feet (TAF) for All Scenarios.

Table 5-12. Lake Shasta Mean Monthly Storage in Thousand Acre-Feet (TAF) for All Scenarios.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Baseline	2,655	2,678	2,843	3,108	3,378	3,705	4,032	3,992	3,693	3,175	2,876	2,740	3,239
Scenario 1	2,634	2,657	2,825	3,090	3,361	3,689	4,016	3,979	3,680	3,158	2,855	2,717	3,222
Diff (TAF)	-21	-21	-18	-18	-16	-16	-16	-14	-13	-18	-21	-22	-18
Diff (%)	-0.8	-0.8	-0.6	-0.6	-0.5	-0.4	-0.4	-0.3	-0.4	-0.6	-0.7	-0.8	-0.5
Scenario 2	2,637	2,658	2,825	3,088	3,360	3,688	4,016	3,978	3,680	3,159	2,857	2,721	3,222
Diff (TAF)	-17	-19	-18	-20	-18	-17	-16	-14	-13	-16	-19	-19	-17
Diff (%)	-0.7	-0.7	-0.6	-0.6	-0.5	-0.5	-0.4	-0.4	-0.4	-0.5	-0.6	-0.7	-0.5
Scenario 3	2,635	2,658	2,826	3,089	3,361	3,689	4,017	3,980	3,681	3,159	2,856	2,719	3,222
Diff (TAF)	-20	-20	-17	-19	-16	-16	-15	-13	-12	-17	-20	-21	-17
Diff (%)	-0.7	-0.7	-0.6	-0.6	-0.5	-0.4	-0.4	-0.3	-0.3	-0.5	-0.7	-0.8	-0.5
Scenario 4	2,645	2,669	2,838	3,099	3,367	3,695	4,021	3,990	3,701	3,184	2,868	2,729	3,234
Diff (TAF)	-10	-8	-5	-9	-10	-10	-10	-2	8	9	-8	-10	-6
Diff (%)	-0.4	-0.3	-0.2	-0.3	-0.3	-0.3	-0.3	-0.1	0.2	0.3	-0.3	-0.4	-0.2
Scenario 5	2,637	2,658	2,825	3,088	3,360	3,688	4,016	3,978	3,680	3,159	2,857	2,720	3,222
Diff (TAF)	-17	-19	-18	-20	-18	-17	-16	-14	-13	-17	-19	-19	-17
Diff (%)	-0.7	-0.7	-0.6	-0.6	-0.5	-0.5	-0.4	-0.3	-0.4	-0.5	-0.7	-0.7	-0.5
Scenario 6	2,650	2,671	2,835	3,098	3,368	3,696	4,024	3,987	3,690	3,173	2,873	2,738	3,233
Diff (TAF)	-5	-7	-8	-10	-10	-9	-8	-6	-3	-3	-3	-2	-6
Diff (%)	-0.2	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2
Scenario 7	2,654	2,677	2,841	3,102	3,372	3,699	4,025	3,986	3,683	3,162	2,867	2,737	3,234
Diff (TAF)	0	0	-3	-6	-6	-6	-7	-6	-10	-14	-9	-2	-6
Diff (%)	0.0	0.0	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.3	-0.4	-0.3	-0.1	-0.2

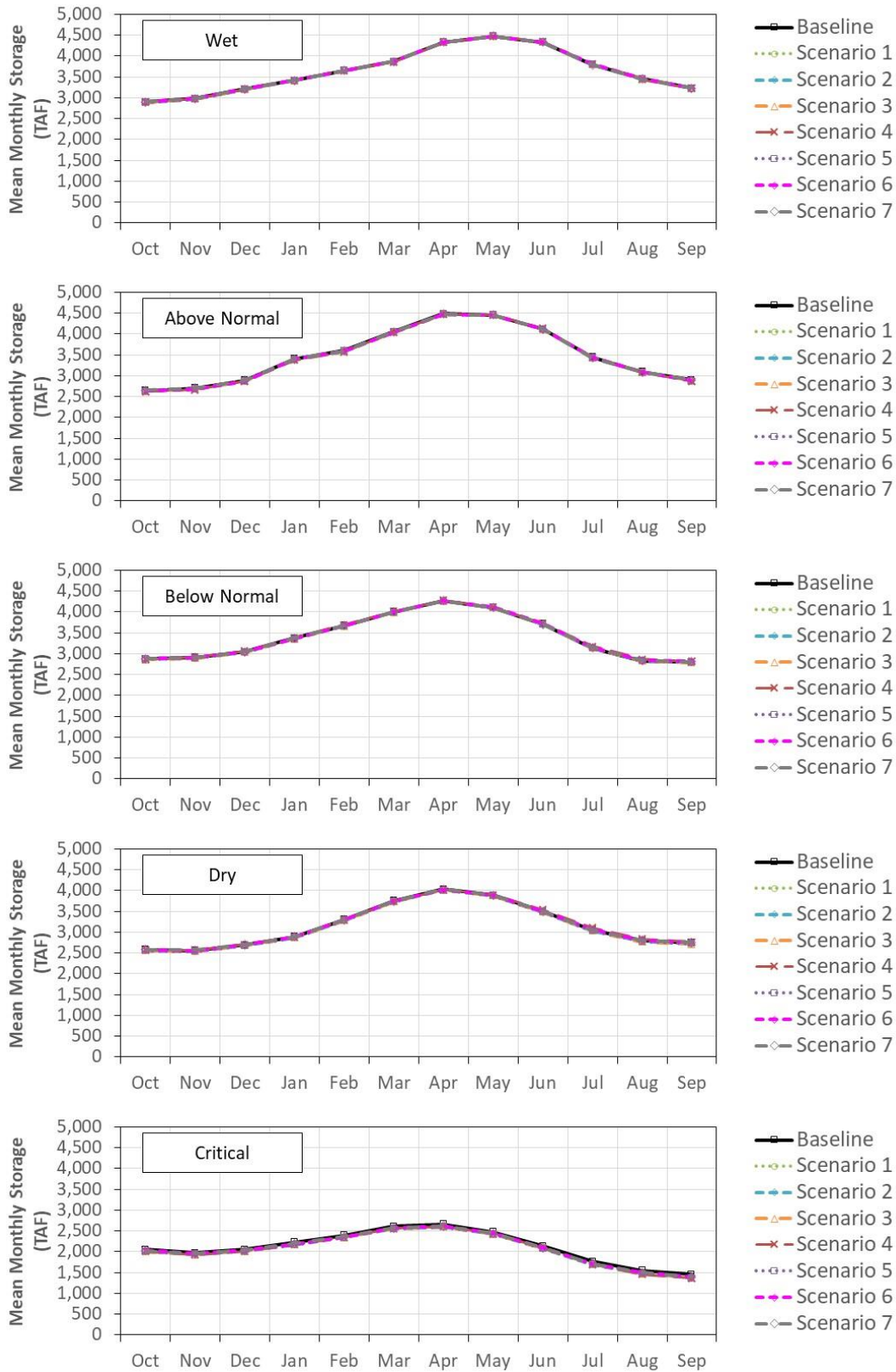


Figure 5-43. Lake Shasta Mean Monthly Storage in Thousand Acre-Feet (TAF) for All Scenarios by Sacramento Valley Water Year Type.

5.6.5 Clear Creek Above Sacramento River Water Temperature

Daily water temperatures in Clear Creek above the Sacramento River were modeled in HEC-5Q. Mean monthly water temperatures are shown in Figure 5-44 and Table 5-13, and mean monthly water temperatures by water year type are shown in Figure 5-45. Key takeaways include the following:

- All scenarios showed a similar mean annual result, with minimal water temperature changes relative to the baseline (between 0 and -0.2 F, or 0 to -0.2% change annually).
- In wetter years, Scenario 4 showed slightly increased water temperatures of 0.5 – 1 F in August and September relative to the baseline, a result of the larger relative decrease in volume of cold-water TRD exports.
- In drier years, Scenario 7 showed slightly decreased water temperatures of 0.5 – 1 F in August through January relative to the baseline, a result of the increase in storage in Trinity Reservoir that decreased the water temperature of Trinity Reservoir releases and TRD exports.

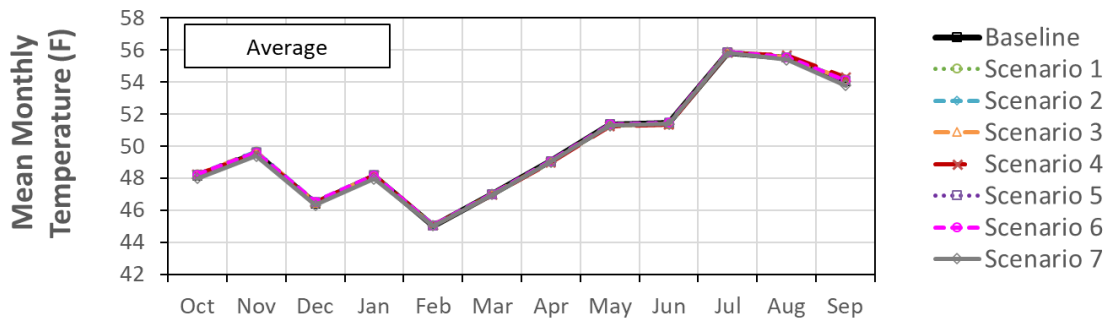


Figure 5-44. Clear Creek Above Sacramento River Mean Monthly Water Temperature in Degrees Fahrenheit (F) for All Scenarios.

Table 5-13. Clear Creek Above Sacramento River Mean Monthly Water Temperature in Degrees Fahrenheit (F) for All Scenarios.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Baseline	48	50	46	48	45	47	49	51	51	56	56	54	50
Scenario 1	48	50	46	48	45	47	49	51	51	56	56	54	50
Diff (°F)	0.1	0.1	0.0	0.1	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.1	0.0
Diff (%)	0.2	0.2	0.1	0.2	0.0	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.2	0.0
Scenario 2	48	50	47	48	45	47	49	51	51	56	56	54	50
Diff (°F)	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diff (%)	0.1	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Scenario 3	48	50	46	48	45	47	49	51	51	56	56	54	50
Diff (°F)	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Diff (%)	0.2	0.2	0.1	0.2	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.2	0.0
Scenario 4	48	50	46	48	45	47	49	51	51	56	56	54	50
Diff (°F)	0.1	0.0	0.1	0.1	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.1	0.2	0.0
Diff (%)	0.2	-0.1	0.1	0.2	0.1	-0.1	-0.2	-0.2	-0.2	0.0	0.2	0.4	0.0
Scenario 5	48	50	47	48	45	47	49	51	51	56	56	54	50
Diff (°F)	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diff (%)	0.1	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Scenario 6	48	50	47	48	45	47	49	51	51	56	56	54	50
Diff (°F)	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diff (%)	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1
Scenario 7	48	49	46	48	45	47	49	51	51	56	55	54	50
Diff (°F)	-0.2	-0.2	-0.1	-0.2	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.2	-0.3	-0.1
Diff (%)	-0.4	-0.3	-0.2	-0.4	0.0	-0.1	-0.1	-0.2	-0.1	0.0	-0.3	-0.5	-0.2

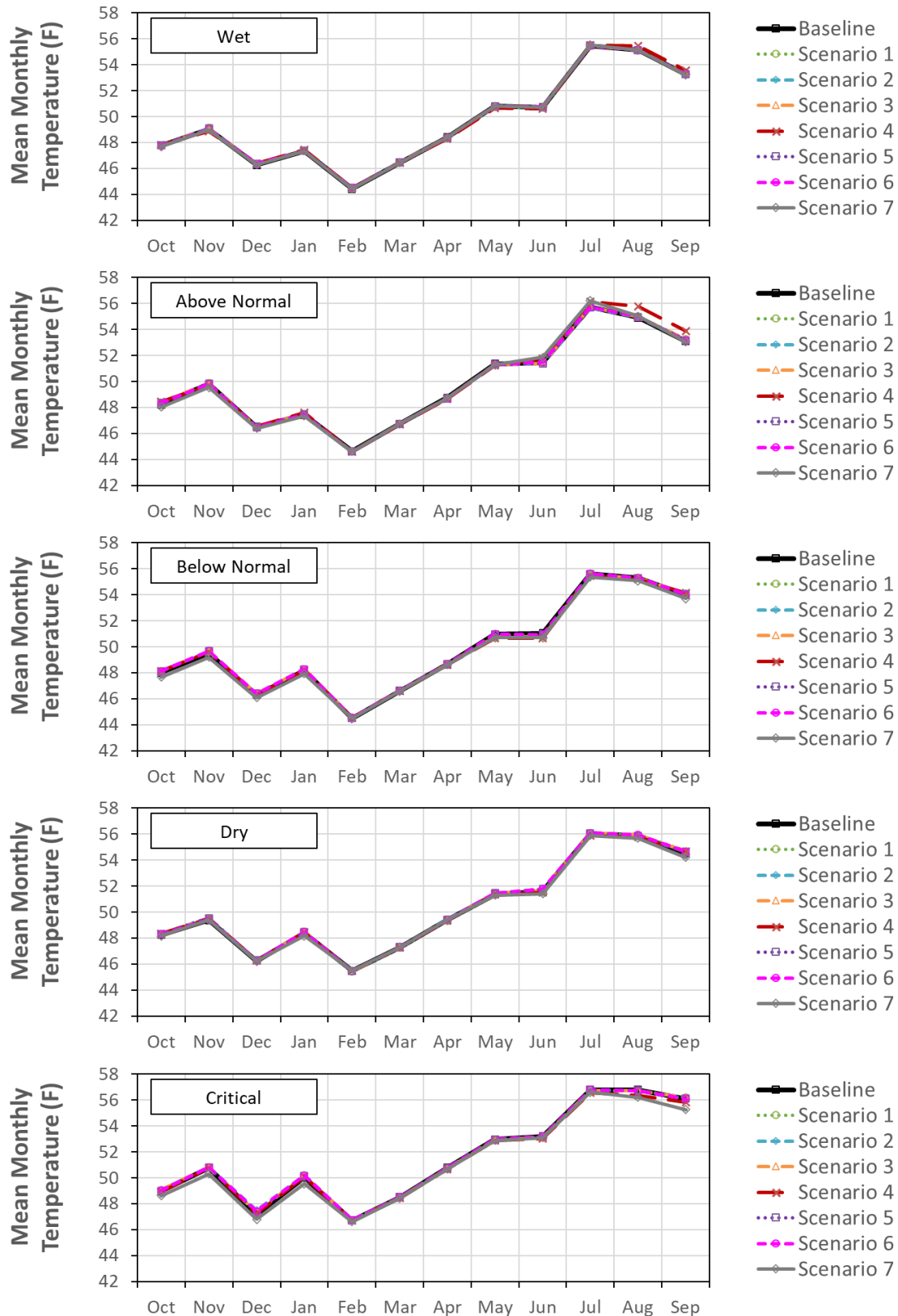


Figure 5-45. Clear Creek Above Sacramento River Mean Monthly Water Temperature in Degrees Fahrenheit for All Scenarios by Sacramento Valley Water Year Type.

5.6.6 Sacramento River Below Clear Creek Water Temperature

Water temperatures in Sacramento River below Clear Creek were modeled in HEC-5Q. Daily water temperatures in the Sacramento River below Clear Creek reflects the weighted flow and temperature contributions of the flow in Clear Creek and the flow in the Sacramento River that was released from Lake Shasta. By separately comparing the water temperatures in Clear Creek above the Sacramento River and the Sacramento River below Clear Creek, the relative influences of TRD export reductions and Lake Shasta release reductions can be evaluated.

Mean monthly Sacramento River water temperatures are shown in Figure 5-46, Figure 5-44 and Table 5-14, and mean monthly Sacramento River water temperatures by water year type are shown in Figure 5-47. Key takeaways include the following:

- All scenarios showed a similar mean annual result, with minimal water temperature changes relative to the baseline in most months, and a slight increase in water temperatures (between 0 and 0.5 F, or 0 to 0.8% change annually) in July and August. Because water temperatures in Clear Creek did not generally show an increase relative to baseline for the scenarios, the slight increase in Sacramento River water temperatures is attributed to changes in Lake Shasta storage and releases.
- July water temperature increases were consistent across water year types, while August and September water temperature increases were greater in drier years relative to the baseline.
- Contract Water releases targeting the fall or spring had the same effect on Sacramento River water temperature, indicating the effects of each scenario on Sacramento River water temperature were independent of release timing.
- Despite the relatively larger cut to TRD exports, Scenario 4 did not have significantly greater effects on Sacramento River water temperatures than any other scenario.

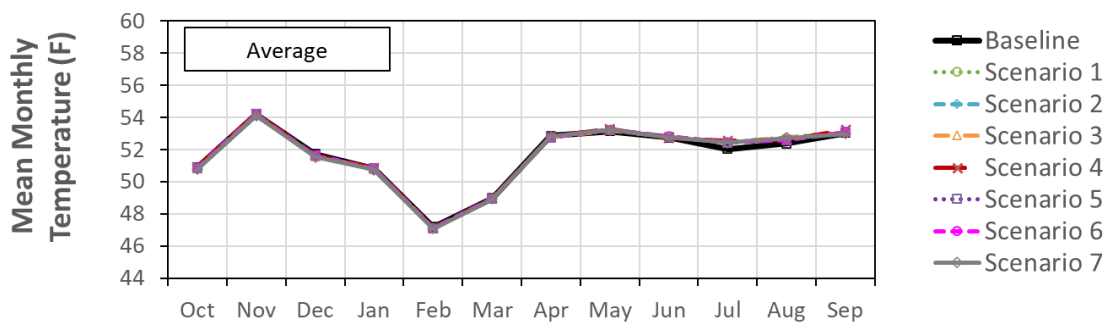


Figure 5-46. Sacramento River below Clear Creek Mean Monthly Water Temperature in Degrees Fahrenheit (F) for All Scenarios.

Table 5-14. Sacramento River below Clear Creek Mean Monthly Water Temperature in Degrees Fahrenheit (F) for All Scenarios.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Baseline	51	54	52	51	47	49	53	53	53	52	52	53	52
Scenario 1	51	54	52	51	47	49	53	53	53	52	53	53	52
Diff (°F)	0.0	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	0.0	0.4	0.4	0.0	0.0
Diff (%)	0.0	-0.1	-0.3	0.0	-0.2	-0.1	-0.2	0.1	0.1	0.8	0.7	0.1	0.1
Scenario 2	51	54	52	51	47	49	53	53	53	52	53	53	52
Diff (°F)	0.0	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	0.1	0.4	0.2	0.0	0.0
Diff (%)	0.0	0.0	-0.1	0.0	-0.1	-0.1	-0.2	0.1	0.1	0.8	0.4	0.1	0.1
Scenario 3	51	54	52	51	47	49	53	53	53	52	53	53	52
Diff (°F)	0.0	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	0.0	0.4	0.4	0.0	0.0
Diff (%)	0.0	-0.1	-0.2	0.0	-0.2	-0.1	-0.2	0.1	0.1	0.8	0.8	0.1	0.1
Scenario 4	51	54	52	51	47	49	53	53	53	53	53	53	52
Diff (°F)	0.0	0.0	-0.1	0.0	-0.1	0.0	0.0	0.1	0.0	0.5	0.3	0.2	0.1
Diff (%)	0.1	0.1	-0.1	0.1	-0.1	0.0	-0.1	0.2	-0.1	1.0	0.5	0.3	0.2
Scenario 5	51	54	52	51	47	49	53	53	53	52	53	53	52
Diff (°F)	0.0	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	0.1	0.4	0.2	0.1	0.0
Diff (%)	0.0	0.0	-0.1	0.0	-0.1	-0.1	-0.2	0.1	0.1	0.8	0.4	0.1	0.1
Scenario 6	51	54	52	51	47	49	53	53	53	52	53	53	52
Diff (°F)	0.0	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	0.1	0.4	0.2	0.0	0.0
Diff (%)	0.0	-0.1	-0.2	0.0	-0.1	-0.1	-0.2	0.2	0.1	0.8	0.4	0.1	0.1
Scenario 7	51	54	52	51	47	49	53	53	53	52	53	53	52
Diff (°F)	-0.1	-0.1	-0.2	-0.1	-0.1	0.0	-0.1	0.1	0.0	0.4	0.4	-0.1	0.0
Diff (%)	-0.2	-0.1	-0.3	-0.2	-0.2	-0.1	-0.1	0.1	0.1	0.8	0.7	-0.1	0.0

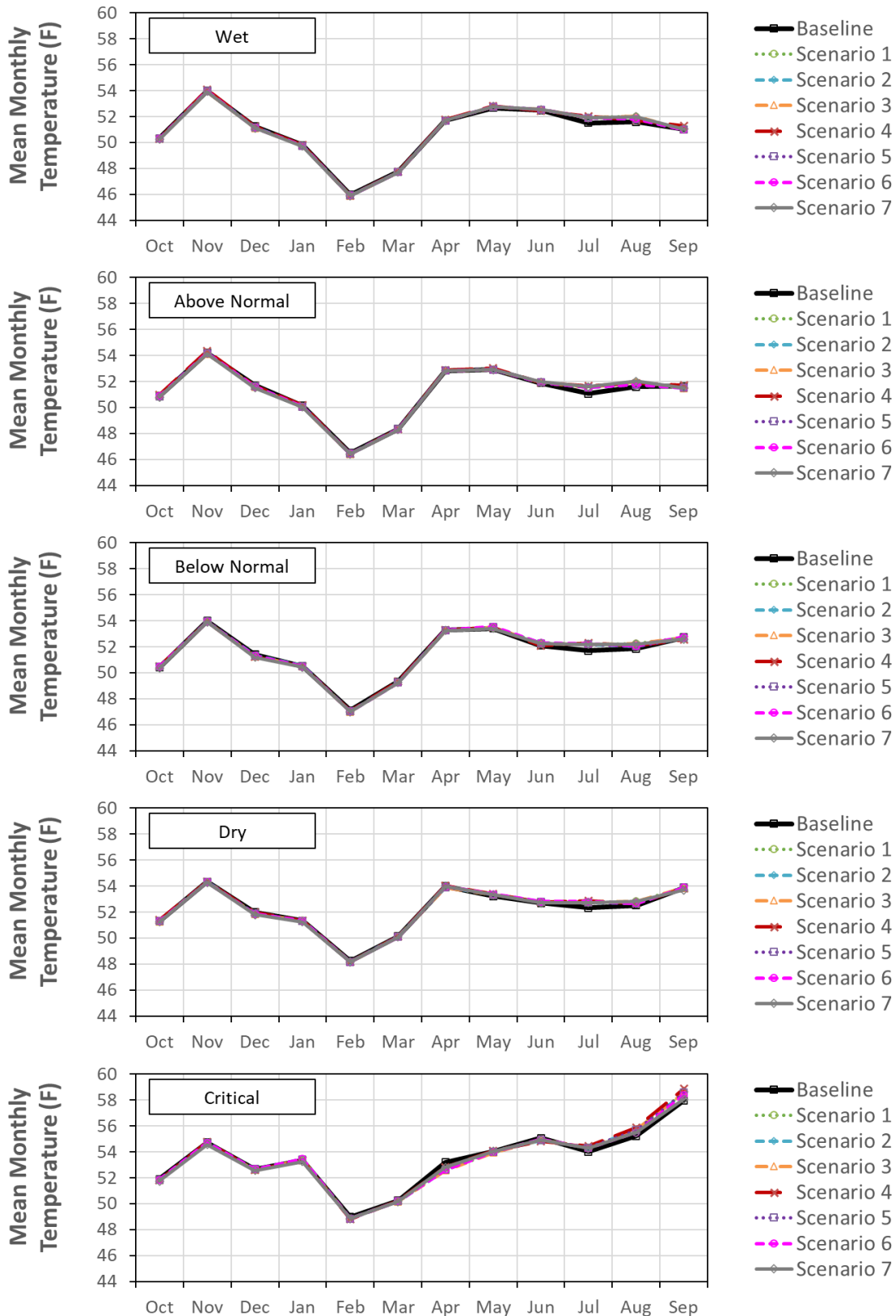


Figure 5-47. Sacramento River below Clear Creek Mean Monthly Water Temperature in Degrees Fahrenheit for All Scenarios by Sacramento Valley Water Year Type.

5.7 Non-Modeled Factors

The seven modeled scenarios each cite one or more objectives that were expected to positively benefit Chinook Salmon and other aquatic species in the Trinity River. Table 4-1 and Table 4-5 highlight beneficial factors which were expected under each release scenario and indicate which were captured quantitatively by the suite of models used in this project, and which were not modeled. The non-modeled factors and the expected benefits or potential impacts of each are described below.

- **All Scenarios: Increased spawning and rearing habitat and distribution of Coho, steelhead, and lamprey.** The effects of increased habitat in the Micro-Habitat Model and S3 are only quantified for natural Chinook Salmon and not for other species that spawn and rear in the Trinity River and lower Klamath River, including Coho Salmon, steelhead, and lamprey. The effects of Contract Water releases on these species were not assessed, though workshop participants hypothesized releases that benefitted Chinook Salmon would also benefit these species. In addition, the interactions between Chinook Salmon and these other species are not represented. Biologic pulse flows (Scenarios 2, 3(B), 4, 5) are expected to redistribute or disperse these other species, which should provide a benefit to rearing Chinook Salmon by decreasing local competition for resources. However, increased spawning and rearing habitat for Coho Salmon and steelhead provided by Scenarios 1 and 6 could negatively affect Chinook Salmon by increasing their competition with these other species.
- **Scenarios 2, 4, 5: Recruitment/entrainment of organic matter (leaf litter, insects, benthic invertebrates).** Biologic pulses are expected to distribute leaf litter for masticating insects, recruit organic matter into the river to support invertebrates and primary producers that utilize detritus as a food resource, entrain terrestrial insects into the river as a food source, and suspend benthic macroinvertebrates into the water column for food. All of these factors would be expected to increase food supply and nutrients for rearing fish, enhancing juvenile survival and increasing fish size.
- **Scenarios 3 and 4: Resetting the macroinvertebrate community.** Geomorphic pulses reach magnitudes ($\geq 6,000$ cfs) known to be sufficient to transport gravel and disturb biofilm. This process would create clean surfaces for microorganisms to colonize, which could recruit macroinvertebrate species at higher densities, increasing benthic productivity and food availability for rearing salmonids. All of these factors would be expected to increase food supply and nutrients for rearing fish, enhancing juvenile survival and increasing fish size.
- **Scenarios 3 and 4: Scouring and geomorphic changes.** SRH-2D and the Micro-Habitat Model assume a static topography using the 2018 survey data. Geomorphic pulses reach magnitudes ($\geq 6,000$ cfs) known to be sufficient to provide significant scour, geomorphic changes to the morphological structure including transporting large woody debris, sediment load, and sediment composition in Trinity River. Maintaining dynamic processes are closer to the natural river environment created by the pre-dam hydrograph and would be expected to provide habitat and ecological services conducive to all life stages of salmonids.
- **Scenarios 2, 3, 4, 5: Biologic pulses in fall (Scenarios 2, 4, 5) or spring (Scenario 3) timed with hatchery operations.** In the fall (October), yearling hatchery Chinook Salmon are released. In spring (March-April), hatchery Coho Salmon, hatchery steelhead smolt, and additional hatchery Chinook Salmon are released. Fall and spring pulses could aid with disbursement of juveniles released from the hatchery, alleviating competition

between natural and hatchery fish. This would be expected to enhance juvenile survival. Fall pulses could improve attraction flows for adult salmonids to the hatchery, increasing the amount of salmonids and steelhead trapped for spawning and increase the intermixing of natural and hatchery fish, which improves genetic diversity.

- **Scenario 6: Risk of redd dewatering when baseflow releases are reduced in January.** A drop in flows during the spawning, egg incubation, or fry emergence life stage could result in a drop in water surface elevation, which could dewater redds, eggs, and larvae, or have other detrimental effects such as changes in pressure, interstitial flow, and dissolved oxygen concentrations. This would be expected to negatively impact the benefits to Chinook Salmon by reducing egg survival.

6 SUMMARY

A set of modeling tools including CalSim II, HEC-5Q, RBM10, sediment models, Chinook Salmon habitat models, and S3, were applied to evaluate the effects of releasing at least 50 TAF of additional flow annually down the Trinity River. The tools simulated a baseline condition and seven different release scenarios. For each scenario, primary model outputs included Trinity Reservoir and CVP system operations, water temperature in Trinity Reservoir, Lewiston Reservoir, and Lake Shasta, Lewiston Reservoir releases, flow and water temperature in the Trinity River and Sacramento River, and the resulting effects on sediment transport, Chinook Salmon habitat, and Chinook Salmon abundance, survival, and growth in the Trinity River.

Modeling results are summarized below, quantitatively in Table 6-1 and also narratively in the following subsections, based on effects of Contract Water releases, relative to the baseline, on Trinity Reservoir, Trinity River juvenile Chinook Salmon, and the CVP system.

Effects on Trinity Reservoir

All Contract Water scenarios that released at least 50 TAF annually from Trinity Reservoir had similar effects on Trinity Reservoir storage. In general, these scenarios reduced mean annual Trinity Reservoir storage by 30 to 50 TAF, with smaller storage reductions of 0 to 10 TAF in wetter years and greater storage reductions of 50 to 100 TAF in drier years. The storage reduction was a result of increased annual releases to the Trinity River, and decreased exports to the CVP. In wetter years, the storage volume reduction, relative to the baseline, created by releasing Contract Water could be refilled with natural inflow that otherwise would have been passed downstream through a safety-of-dams release. In consecutive drier years, natural inflow could not increase the storage volume reduction, and the effects of Contract Water began to accumulate, resulting in greater storage differences. When Contract Water was held as carryover and not released, the opposite effect was observed in drier years. An additional 50 TAF was allowed to accumulate, and storage increased by up to 350 TAF when a safety-of-dams release did not occur for multiple years.

Changes in Trinity Reservoir storage resulted in relatively small changes to Trinity Reservoir release temperature. Contract Water scenarios that released at least 50 TAF annually had similar effects – small increases in release temperature of up to 0.2°F from June through January. Scenario 4 released up to 170 TAF of Contract Water annually, which led to lower Trinity Reservoir summer storage levels and an increase in release temperature of up to 0.4°F in summer months. For Scenario 7 (carryover), release temperature decreased up to 0.4°F in summer months. These trends in release temperature changes were generally preserved through Lewiston Reservoir and into the Trinity River, but scenarios that released more water in March and April generally reduced water temperatures by up to 1.7°F, the result of higher magnitude cold water releases being routed through Lewiston Reservoir.

Table 6-1. Mean Annual Percent Changes Between the Scenario Metric and the Baseline Metric for the Seven Modeled Contract Water Release Scenarios in the Restoration Reach of the Trinity River.

	Modeling Tool	CalSim II		Sediment Transport		Habitat Model			Stream Salmonid Simulator (S3)				
	Primary Analysis Metric	Mean annual Lewiston releases	Mean annual CVP Contract deliveries	Total sediment mobilized	Stream bed mobilization	Redd habitat area	Fry capacity	Parr capacity	Egg survival	Juvenile survival	Abundance	Biomass	Fish mass
Scenario #	Scenario Description	Thousand acre-feet	Thousand acre-feet	Tons/year	% bed mobilized	Mean ha (Oct-Dec)	Mean n per m ² (Mar-May)	Mean n per m ² (Mar-May)	Mean annual %	Mean annual %	Mean annual n of fish	Mean annual metric tons	Mean annual grams/n
1	Building baseflow	5%	-0.2%	-0.3%	0.0%	0.5%	-1.6%	2.3%	-0.4%	0.5%	0.2%	-4.0%	-1.6%
2	Fall pulses	5%	-0.2%	-1.6%	-0.1%	0.4%	-0.8%	0.0%	1.3%	-0.9%	0.4%	0.9%	3.1%
3	Geomorphic pulse or spring pulses	5%	-0.2%	7.5%	6.4%	0.0%	0.0%	2.3%	-0.3%	-0.5%	-0.7%	-2.4%	2.3%
4	Combine scenarios 1-3	22%	-4.6%	15.0%	7.0%	0.2%	3.2%	10.5%	0.9%	1.4%	2.6%	-2.8%	-1.6%
5	Fall pulses with storage-based delay	5%	-0.2%	-1.4%	-0.1%	0.2%	-0.7%	-1.0%	1.2%	-0.9%	0.3%	0.8%	0.6%
6	Fall baseflow	5%	-0.7%	-1.5%	0.0%	5.1%	-0.7%	-1.0%	2.6%	0.2%	2.9%	2.8%	-0.1%
7	Carryover	5%	-1.2%	7.9%	0.3%	0.0%	4.6%	4.0%	0%	-0.1%	-0.1%	0.3%	0.4%

Notes:

The first row lists the modeling tool used, the second row lists the primary evaluation metric, and the third row lists the units below each primary evaluation metric.

Metrics with greater than a positive 2% change relative to the baseline are presented in bold and highlighted gray.

Metrics with less than a negative 2% change relative to the baseline are presented in bold and highlighted orange.

Key: TAF = thousand acre-feet, ha = hectares, % = percent, m = meters, n = number of fish

Effects on Trinity River Physical Parameters

The effects of Contract Water releases on Trinity River flow and temperature were evaluated at Pear Tree, which is typically where fish production and migration rates are measured and a location that receives inflow from additional tributaries between Lewiston Reservoir and North Fork Trinity River. For all scenarios, mean daily Trinity River water temperature differences relative to the baseline were generally less than 2°F, and less than 4°F for short duration periods (peak day of pulse or safety-of-dams release). Daily water temperatures were generally reduced the most in the fall due to baseflow releases (Scenario 6) and in the spring due to baseflow and pulse flow releases (Scenarios 1, 3, and 4). The largest decreases in mean daily water temperature of -8°F in some years were in the spring. In most years, water temperatures in January through March were either equivalent to the baseline, or slightly higher due to lower Trinity Reservoir storage and lower magnitude cold water safety-of-dams releases. Trinity River water temperatures in April through June were generally similar to the baseline. July through September Trinity River water temperatures were generally increased by 0°F to 4°F for most scenarios except Scenario 7, which decreased water temperatures in some drier years.

Planned geomorphic pulses (Scenarios 3 and 4) or large relative magnitude safety-of-dams releases (Scenario 7) were required to initiate materially quantifiable bedload transport and streambed mobilization relative to the baseline. Scenarios 1, 2, 5, and 6 did not significantly affect bedload transport or partial bed mobilization. Sediment transport exhibited a high degree of interannual variability, as only 42% of modeled years exhibited coarse bedload transport >10,000 tons above the baseline in scenarios 3, 4, and 7 and only 33% of modeled years increased the fraction of bed mobilized >10% above the baseline in scenarios 3 and 4. The greatest effect on sediment and geomorphic work relative to the baseline was observed when a safety-of-dams release was timed with a Contract Water pulse release (Scenarios 3 and 4), or when Contract Water carryover increased the safety-of-dams release magnitude (Scenario 7). Most of the transport and mobilization of sediment occurred in the downstream reaches of the Restoration Reach between Weaver Creek and North Fork Trinity River; however, because the majority of redds are established directly below Lewiston, relatively small increases in sediment mobilized in the upper reaches may create a larger impact on fish spawning habitat.

Effects on Trinity River Juvenile Chinook Salmon

The effects of Contract Water releases on spawning and rearing habitat were primarily a function of the timing, duration, and magnitude of flow changes relative to the baseline. Fall flows released as pulses (Scenarios 2, 4, and 5) increased redd habitat area on the ascending and receding limbs of the pulse, and decreased habitat during the peak of the pulse. These scenarios produced higher egg survival relative to the baseline, indicating an overall net positive effect on spawning habitat suitability. Fall flow released as a baseflow had a longer duration and more frequent positive effect on redd habitat area, which translated to the highest egg survival of all scenarios relative to the baseline. Note the model did not account for the potential effects of redd dewatering following a reduction in baseflows on January 1. All other scenarios did not explicitly target fall releases, and had minor effects on redd habitat area. Spring releases generally increased fry and parr capacity regardless of whether those releases were a pulse or a baseflow. For scenarios that released water primarily in the fall, Trinity Reservoir storage was generally lower in the winter months, which allowed storage to stay below flood pool elevations for longer, resulting in lower average magnitude safety-of-dams releases relative to the baseline. This indirect effect of Contract Water releases resulted in reductions in spring habitat capacity in some years.

Contract Water release scenarios had different effects on juvenile Chinook Salmon egg survival, survival from emergence to Pear Tree, abundance, size, and biomass based on scenario specific combinations of flow and temperature. Contract Water released in the fall had the greatest beneficial effects on egg survival, with flow released as a baseflow increasing survival more than flows released as a pulse flow. Juvenile fish survival increased for scenarios with higher magnitude releases in March and April (Scenarios 1 and 4), when juveniles are rearing, and also for Scenario 6, which had the highest egg survival rate. The largest increases in annual juvenile abundance were for Scenario 4, which released the largest volume of Contract Water, and Scenario 6, which had the highest egg survival rate. Scenario 6 released 50 TAF annually and produced higher abundance than Scenario 4, which released 170 TAF annually, highlighting the effect of Contract Water release timing, rather than magnitude, as a key parameter influencing modeled population dynamics. Contract Water scenarios that released higher magnitude, cooler (1 to 2°F) water in the spring – Scenarios 1, 3, and 4 – had the largest reductions in mean annual fish mass, while all other scenarios produced fish mass relatively similar to the baseline. Mean annual juvenile biomass changes reflect differences in both abundance and fish size. Consequently, Scenario 6 produced the largest biomass increase relative to the baseline. Scenarios that reduced fish size also had a reduction in annual biomass relative to the baseline.

Effects on CVP System

Two methods of CVP re-operation to balance TRD export reductions were modeled for each scenario that assumed 50 TAF of annual Contract Water use. The first increased releases from Lake Shasta and maintained similar CVP contract delivery amounts NOD and SOD. Under this method, mean annual CVP deliveries NOD and SOD were reduced about 10 TAF (-0.2%), and mean annual Lake Shasta storage was reduced 20 TAF (-0.5%) relative to the baseline. The second method reduced CVP deliveries and maintained similar Lake Shasta storage and releases. Under this method, CVP delivery reductions ranged from 34 TAF (-0.7%) to 57 TAF (-1.2%) relative to the baseline, and Lake Shasta storage was reduced 6 TAF (-0.2%) relative to the baseline. Sacramento River water temperatures below Clear Creek were generally similar to the baseline for each method, with increases of around 0.4°F in July and August.

It is concluded that Contract Water scenarios that release at least 50 TAF annually from Trinity Reservoir have similar effects on the CVP system. The magnitude of effects on Lake Shasta storage and CVP deliveries would differ whether the first or second method described above was used to adjust CVP operations, but the magnitude of effects would not vary across the type of Contract Water release made from Trinity Reservoir. Whether releases were made annually as a fall baseflow, fall pulse flow, spring pulse flow, or spring baseflow, they all resulted in similar storage patterns in Trinity Reservoir – an annual reduction in storage relative to the baseline that was relatively small in wetter years and larger in drier years. This lower storage pattern created a similar reduction in TRD exports to the CVP. Because the timing of exports is similar each year, the reduction to exports occurred at the same time each year, independent of Contract Water release timing, resulting in similar storage, CVP delivery, and water temperature effects in the Sacramento River basin portion of the CVP. The water temperature effects on the Sacramento River were primarily attributed to changes in storage, release magnitude, and release temperature from Lake Shasta, and not due explicitly to inflows from the TRD.

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